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Digital Writing Technologies in Higher Education

Theory, Research, and Practice

OPEN ACCESS

Springer

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ISBN 978-3-031-36032-9 ISBN 978-3-031-36033-6 (eBook)
https://doi.org/10.1007/978-3-031-36033-6

This book is based upon work generously supported by the Swiss National Science Foundation (Scientific Exchanges, grant number IZSEZ0 198960). The Swiss National Science Foundation funded a workshop for authors in Winterthur, Switzerland (30.11.2021–4.12.2021) and covered the open access fee for the publication of this book.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

Aught of Woe or Wonder

> **Horatio**. What is it you will see?
>
> If aught of woe or wonder, cease your search.
>
> —Shakespeare, Hamlet V, ii, ll. 362-363

Homo scribens were cyborgs from the first time we extended our linguistic reach through inscription tools, inscribed media, and written signs. During the first five millennia of literacy, we invented writing tools (e.g., styluses, brushes, pens, ink, printing presses, pencils, typewriters), surfaces to write on (e.g., leaves and bark, stone, clay, wax, papyrus, paper), and sign systems (iconographic, rebus, syllabic, alphabetic). These technologies changed the physical skills human needed to learn and the sign systems to become familiar with, but the affective and cognitive task, the composing work, changed only gradually in relation to the changing socio-literate arrangements and expectations, calling for different kinds of messages for different situations. The composing work had always been to find the words to realize communicative impulses and needs in ways recognizable and effective for audiences.

In a sense, digitization has only changed the surface on which we write. Input through keyboards and styluses has been around for a while. For most end users, the alphabets, numbers, languages, and formats are familiar, though information travels within and between devices in ways intelligible only to programmers. You might think the surface is perhaps the least radical component of the cyborgian amalgam of writing, but the surface has become dynamic, animated, no longer the quiet, stable receptacle for our words. The surface has transformed the resources we have at hand, the support we have during production, the flexibility with which we write, and the people we work with. It has transformed how we compose, how we think, and maybe even how we feel. It has changed what we write. It has also changed what humans need to learn in order to write well and how they go about learning to write. As the Apple advertising of a few years ago went, writers are learning to "think different."

Most of this book documents the history and current set of tools and affordances that have come to form the medium on which we inscribe: the computers, the word processers, the internet, the tools of collaboration and feedback, the tools for inspecting and commenting on what appear on the screen, the tools for assessment, the tools to assemble and elaborate our messages, the tools we as researchers can use to analyze the material, and even the tools we use to create the communicative structure of virtual classes. Each of these changes on the surface we write, however, has impact on how we think as writers, as coordinators and designers of writing environments, and as teachers of writing. Which categories of tools we choose and which specific software we choose for ourselves, our workplaces, and our classrooms are consequential not only for what we, our workplace colleagues, and our students wind up writing and how we go about doing that, but how we all think using those tools, and even more how we come to learn to think using those tools.

The most obvious use of the first three parts of this book, twenty-five of the thirty chapters, is as a kind of department store; each of the chapters offers a department of technological products that have come into being in recent decades, and within each are displayed all the items currently on the shelf. These products are described with all their affordances for writers, teachers, and researchers of writing. Some of the chapters caution about the limitations of the class of software (at least in current versions), and how institutions may use the software and thereby constrain what students and teachers may do. At times, the implications of these affordances for thinking and learning are considered. Where research on these different technologies exist, the chapters review what research has found about their usefulness and classroom success, but because the technologies proliferate and evolve so rapidly, the research is limited and lags behind. Ultimately, we are left with our personal assessment as to what works for us and what will be beneficial for our colleagues and students—which is why the detailed descriptions of the technologies and their affordances are so useful.

In a larger way, though, together the chapters provide us an opportunity to think about what writing and writers are becoming and may become in the future. As teachers, we are prompted to consider what kind of writers we are fostering in our classrooms and whether this is what is most needed. The last part of five chapters makes explicit this larger purpose of the volume, as a tool for thinking about the future of writing, writers, and the teaching of writing. These final chapters also use the potentials of these new tools to contest long-standing assumptions about writers, the kind of thinking associated with writing, and what good writing might be. We are left with fundamental questions about how we might be conducting our writing classes, with what goals, with what tools, and what critical skills to foster in our students so they can make effective choices within their ever-more-intensely-cyborgian composing world. The human side of the cyborg needs to become as smart about controlling the cyborg as the mechanical side is clever in extending the cyborg's reach.

While much of the volume is framed by our field's rightful attention to the classroom, a few of the chapters note that many of the tools being adopted in the classroom had their origins and continuing life in industry, social life, and civic participation. This may mean these tools don't necessarily match all the values and needs of the classroom. It also reminds us that students will soon be leaving the classroom and the university to participate in the broad landscape of life, which itself is becoming reorganized through the use of the same tools. Some of these tools in fact allow students already to share their work beyond their classmates and teachers—in creative writing journals and undergraduate writing journals, in Wikipedia articles, on blogs and internet webpages, as part of activist campaigns or social media influencing. Our task may not be so much to help students learn the tools as to learn the roles, but the tools shape those roles and how one can present oneself in those roles. People are generally good about learning those tools they need, but they may be challenged to think about how those tools shape the writing choices they make and who they will become for which communities by using such tools. By entraining writers into using technologies, the technologies themselves in a sense become the continuing education of all writers, shaping values and roles of writers.

In the past, we used to think (probably wrongly) that the artifice of school activities directed at individual development prepared students with the baseline of skills they would need in the writing world (though we started to recognize that practices of professions, disciplines, and social domains would add specific requirements and environments). Now, however, perhaps it is the technologies that will school people throughout their lives and form the environment for their learning. Nonetheless, our classes can help students think critically and wisely, to make choices about the technologies they will engage with beyond the class. If we do not help students navigate their choices and think about the affordances and limitations of technologies, they will become unreflectively limited by the encompassing directiveness of technologies they fall into or that are mandated by their organizations. Since technologies most assuredly will continue to evolve rapidly along with the social arrangements they will be mediating, students will have rough and changing seas to navigate. Those who cling tightly to the life rafts they may be provided in their high school or undergraduate writing courses are not likely to fare well. Is the way we go about teaching writing restricting students as individuals or making them smarter about the communicative world they will be facing? An even larger question is whether we are creating a smarter society, better able to use the amazing technologies we will have at hand to be able to identify and address new problems, to communicate creatively and affectively. Or will we be narrowing the roles that people take in this brave new world? The recent advances of AI and its potentials for displacing much of the work writers currently do make this an especially sensitive issue. What will be left for humans, and will that be the most significant or the most trivial of decisions? What effect will those choices have on human and social development? And is there something we, as teachers, can do to affect that outcome?

This volume itself raises the kinds of critical questions this volume hopes to foster about the opportunities and challenges of digitization. Even to begin writing, I had to make uncomfortable choices about questions of the economics and social distribution of knowledge posed by the volume's publication arrangements. Historically, publishers were able to locate themselves at the center of the distribution of knowledge, because printing presses were expensive and printing houses required substantial paid labor and capital. As editing, preparing manuscripts for production, binding and distribution were combined with printing, publishers became compulsory passage points for selecting and organizing works, producing them, publicizing them, making them available, and setting prices. For many years the values of moderately sized publishers remained sufficiently aligned with those of authors and readers, grounded in the love of books and book culture. In the latter half of the twentieth century, however, corporatization and digitization changed the economics and values of the business. Maximization of short-term profits changed priorities for selecting and pricing publications and more of the preparation and editing could be shifted to authors with desktop technology. Printing presses, paper, ink, shipping and book returns were no longer required. Publishers, however, worked to maintain their gatekeeping role and prestige, while retaining some copyediting, book design, and publicizing tasks.

At the same time, digitization has created the opportunity for authors and readers to gain more control over the production and distribution of knowledge and culture, using many of the tools described in this book as well as other desktop publishing systems. Corporate publishers are seeking ways to address competition from author-produced open-access publications. The arrangements for this volume with a major traditional publisher offer free electronic distribution for readers, providing wider access for niche-market material that might otherwise have been expensive and of limited distribution. There is also no cost to the authors. So knowledge seems to flow as freely as it might in a fully open-access world that works on the basis of authors and academic sweat equity. This seems good for the growth of knowledge and the increasing intelligence of all educational institutions in all regions and all of society, as long as they have access to the internet. Given my own commitment to open-access, this has given me sufficient warrant to participate in this project. I have, however, tried in recent years to avoid large corporate publishers when I could, and I remain uncomfortable with the compromise of this volume. The corporate publication of this work (a necessary condition for some of the authors' participation—an indication of how publishers have been able to leverage their legacy prestige) is dependent on an institutional subvention from the Swiss Government to the publisher. In the long run, if this model prevails, it means that only those who have sufficient grant support from institutions with deep pockets will be able to contribute to the growth of knowledge, giving them prestige and publicity advantages. Those who do not have access to those institutional resources will be pushed to less visible corners of the internet, or not published at all. That is, the rich will continue to get richer, by seeming to share THEIR wealth, myself included.

So, this is just one case in point about how digitization has great promise, but is fraught with perils. This volume offers us important tools for reflection about the future of writing, writing instruction, and writing in society. How should we use these tools in the classroom to make our students and our society smarter, more flexible, more observant about our world, able to frame and solve more fundamental problems? Or will these tools make us more hierarchically rigid, controlled by previous decisions, leaving fundamental choices in the interests of the few that design the technologies?

By laying out the options and implications of each category of tool, this volume can make us a bit smarter as teachers of future generations. This information might even make faculty committees and administrators smarter as they ponder curricula, purchases, assessments, and other campus policies. Now wouldn't that be something?

Santa Barbara, CA, USA Charles Bazerman

Introduction

Digital writing, in simple terms, is writing using a digital environment or tool. As with literacy more broadly, for many of us digital environments and tools are increasingly prevalent in our writing endeavors. And yet in the field of digital writing, we have no comprehensive overview of which technologies are used in writing, how, when, and where they are used, and what their impact is on writers and their writing processes. This book aims to fill that gap. This introduction sets the stage for the book starting from the inception of digital writing and proceeding through three phases of transformation leading up to the present. We point out the challenges for research and practice in the field of digital writing targeted in this book. We preview how each chapter contributes to a systematic account of digital writing technologies, which builds on past scholarship and sets the research agenda for the future.

By "digital writing," we colloquially mean the use of electronic computing hardware and software to write, typically involving personal computers in the form of desktop machines or laptops with programs designed for composing and editing text. More narrowly, digital writing uses an electronic medium to record, store, and display text. Letters and words are inputted through an interface that translates analogue continuous signals into discrete digital ones, removing noise and allowing for retrieval, reproduction, and modification. In a broader semiotic sense, all writing can be called digital because every true writing system makes use of a finite set of discrete and arbitrary elements, the characters or graphemes of the script (see also Goodman, 1968). This book deals only with digital writing in the narrower sense.

The Advent of Digital Writing

Even for those of us who lived through the digital transformation that has taken place over the last 40 years, it is difficult to recall how writing happened in the world before personal computers (PCs) and-smartphones. To understand how digital writing came into our lives, it is worth going back to one of the most illustrative documents of its onset: William Zinsser's book *Writing with a Word Processor*, published in

1983. Zinsser (1983) provides a compelling and entertaining retrospection of how he replaced his trusty typewriter with an IBM Computer named “Display Writer.” A self-confessed complete technical novice, Zinsser recounts his struggles not only with a new and demanding technology, but also with new terminology, which he translated for himself (and for us) into ordinary English.

From his recollection, we learn just how floppy floppy disks were at the time, how slow printers could be, what the limitation of 20-line displays meant, and how meager the Display Writer’s working memory was. Before each use of his Display Writer, he had to upload the program and the content diskettes separately. The screen was dark green with light script, and Zinsser’s eyes burned from unaccustomed exposure. He drew us into the various failures of the system that resulted in the loss of a day’s work. Reading his book, we can imagine how it felt to see a cursor for the first time, or a “delete” button, or an error code, or the automatic pagination of a paper. Yet despite the many challenges, his undampened enthusiasm anticipated the future triumph of digital technology:

> I could hardly believe how quickly and easily and silently I typed as my writing gathered momentum. The physical labor of pounding on a typewriter was gone; the weight of a lifetime was lifted from my fingers and shoulders. My words leaped instantly onto the screen – and instantly off again when I changed or erased them. . . . Nirvana! Technology was my buddy after all. (Zinsser, 1983, p. 39)

Zinsser’s encounter with this new technology is representative of how writing was entering the digital age. His fear and hesitancy are reminiscent of the anti-technological affectation of that time as well as the complete digital innocence of his generation. He makes us feel what basic computer literacy (and the lack thereof) meant and illustrates what an extraordinary effort it was to catch up with the digitalization of his own profession as a writer. Yet as immature as the technology may have been, Zinsser arrived at the point where he dropped his manual Underwood for good and felt comfortable with his new electronic writing companion. He made the transition from a digital novice to a pioneering computer user. As through a magnifying glass, Zinsser shows us what was to come, both reduced to the very core of digital writing and beautifully enlarged by his extraordinary sense of humor and self-honesty.

Forty years later, where do we stand? Today, word processors provide highly professional working environments for all kinds of text production. Word processors are not only connected to the internet but also integrated into voluminous business platforms like Microsoft Teams, Google’s Workspace, or Apple’s iWork apps, where the writing device is only one icon away from the phone, video call, chat, e-mail, learning platform, calendar, planner, search engine, statistic package, and more. Each of them is there to communicate and each of them has functionality to insert text, thus competing in some way with the word processor. The number of genres, registers, writing occasions, and exchange channels has grown exponentially and has become intertwined with sound and visuals. Writing has both increased its range of activities and lost its privileged superiority over oral communication.

Today, we are approaching or have already reached a stage that matches Licklider’s (1960, reprinted in Norman, 2005) prophecy of a (hu)man-machine symbiosis in which we do not simply use technology but are enmeshed with technology in "socio-cyborgian activity systems," as Bazerman (2018, p. 188) has claimed. Human skills depend on machine skills and vice versa. The reliance on technology for almost any academic kind of work shapes the new landscapes of literacy that we inhabit today.

As we see from Zinsser's careful explorations of his own experience with his first word processor, understanding technology also means understanding users' learning and thinking processes. Making sense of technology means knowing its features and affordances, its potential uses, the adaptations users make in response to the task at hand and their own thinking, and their digitally mediated social context. This book aims to explore these relationships to develop a shared understanding of what it means to write in the digital age.

The Long Farewell from Gutenberg: Evolution and Revolution of Writing Technologies

Writing has always required tools and symbols and, as such, technology has always been an integral part of the writing process. Understanding writing therefore entails understanding writing technologies. Technology is not an add-on to writing, but something that constitutes its core (Haas, 1996). As Baron (1999, 2012) has documented, written literacy was influenced by several stages of technological innovation before the advent of computers. In the pre-digital era, however, technology did not matter too much for the study of writing because it developed very slowly. It could be treated as a constant that influenced all kinds of writing in the same way. With digitalization, the pace of technological development accelerated, and its influence on writing processes increased. Technology became a highly influential factor in writing studies, as each change in technology had the likely potential to also change the nature of writing. Today, three revolutionary or disruptive developments must be taken into account to understand digital writing.

The introduction of word processors in the 1980s, which made computer-assisted writing accessible to a mass audience, silently initiated a first writing revolution akin to the invention of Gutenberg's printing press. It turned out to be the Big Bang of digital writing, the starting point of a flood of technical innovations that continues to expand in many directions, revolutionizing all areas of the production, design, dissemination, and use of texts. Within a decade, the PC had become widely accepted as a writing instrument, and a decade later, when laptops and notebooks became available, typewriters were largely relegated to the status of museum pieces. Unlike the printing press, the word processor is not a publication medium, but a writing tool that replaced the inscription of traditional writing materials with standardized and universally usable digital codes.

With the development of the Internet, a second radical innovation followed, revolutionizing not only the production but also the communication and publication of writing. This second revolution created the basis for the universal accessibility of writings. It also led to the emergence of platforms and cloud computing as transactional media, offering a fundamental alternative to the printing press and creating the dynamics for further development of writing technologies.

The third innovation was the onset of Natural Language Processing and Artificial Intelligence, corpus and computational linguistics, and writing analytics. At first, this revolution did not appear as impactful as that of the personal computer and the internet, but with the recent advent of ChatGPT and similar AI-based text generation software, its potential as a cultural game changer has become clear. We follow this line of technologies back to its beginnings to show how human language has been technologized.

Today, these technologies also provide automated feedback along many textual dimensions and enable real-time support to writers in areas such as spelling, grammar, word selection, sentence completion, translation, and more recently, advanced thinking and content creation. They now have the capability to write text themselves, drawing on large language models and providing methods of knowledge extraction, automatic summarization, and natural language generation. Given the advanced capabilities of these models, writing with the machine, and perhaps even co-authoring with it, will likely become mainstream in the future, as we see increasing research in this area (Lee at al., 2022). How the continually progressive technologies may enhance writing or undermine foundational skills for a learner is yet to be determined through empirical inquiry (initial findings on desirable writer behaviors are emerging; see Shibani, et al., 2023).

Digital transformations of writing are happening at a rapidly increasing pace. The technology of the Gutenberg age was relatively static. For hundreds of years, change happened at a snail's pace. The goose quill was the dominant writing tool for many centuries, before it was succeeded in the nineteenth century by the iron pen, which lasted half a century until it was replaced by the fountain pen and then again, almost a century later, by the ballpoint pen (see Baron, 2012). The typewriter, invented in the late nineteenth century, kept its basic form for almost a century, evolving to the digital typewriter until being overtaken by the personal computer in the 1980s. Today, technological change does not allow such time for adaptation. Change has become the norm, and permanence the exception.

With these considerations in mind, this book is designed to take this moment in time to explore the changes in writing since the onset of digitalization. It focuses on all three technological innovations and the impact of these innovations on writing and writers. We provide a comprehensive map of the current technological landscape and consider what this implies and entails for current conceptualizations of writing. While we acknowledge the need for critical appraisal of these changes (e.g., Peters, 2013), this is not our primary focus. In this book, we take stock of what has happened and where we are in the digitalization of writing, and then initiate the process of critical evaluation for writing theory, research, teaching, and future development of digital writing tools in Part IV. Our hope is to engage all relevant communities beyond the technological sphere of computer science and industry (writing researchers and practitioners, linguists, tool developers, educators, etc.) in a substantive discussion about the writing technologies we use and their impacts.

Challenges Addressed in This Book

This book provides a consistent and systematic examination of writing technologies pertaining and adjacent to the field of academic writing studies. However, we acknowledge that digitalization of writing presents various challenges to both scholarship and practice. We build on former reflections of these issues such as those addressed in the first edition of the journal *Computers and Composition* in 1983, or in the works of Haas (1996), Haas and Neuwirth (1994), Hawisher (1986, 1988), McKee and DeVoss (2007), Moran (2003), Porter (2002), Selfe and Hawisher (2002), and Williams and Beam (2019), all of which contributed to our thinking about writing, technology, and research. In continuing these discussions, we are able to look back at a series of technological innovations, allowing us not only to pursue a more complete account of technology development but also to formulate specific meta-technological statements to accompany current and future research. These also refer to the basic challenges that technology research in writing will have to meet.

First, the term "technology" itself is hard to define and has multiple facets. From its Aristotelian roots, technology refers to both the skilled or systematic activity of humans and the tools they use for this. Gudanowska (2016) lists the following components of technological systems in digital contexts: tools and artifacts, skills and talents, specifications and regulations, flows and procedures, and virtual environments. It is essential not to separate the technology from its developers or from its users. With this book, we hope to provide a framework for technology studies within writing research that is inclusive without reducing the focus to pure technology, to technology use, or to attitudes toward technology.

Second, scholarship on technology is a moving target. It is difficult to isolate and characterize existing and developing technologies. Since technology is not static, we cannot assume that a technology we study today will be the same when we apply it tomorrow. The S-shaped developmental curve for technology (Branson, 1987), which starts with a slow initial development, then rapidly improves in the middle phase of its lifetime, and finally flattens again when it reaches its upper limit, means that the performance, use, and study of a technology are heavily influenced by its degree of maturity. This severely limits the application of intervention studies or of comparative designs in technology research (Honebein & Reigeluth, 2021). It is difficult to come to conclusive judgments on writing technologies unless a view is adopted that accounts for the progressive, disruptive, and iterative development of technology. Interpretations of the current state of technology and hypotheses about its future are both essential for technology research and may differ depending on the lenses we may see them through. However, given the varying life-time phases in which technologies discussed in this volume find themselves, it has been sometimes difficult to present a consistent and balanced identification of challenges and opportunities for each. To compensate for a lack of sufficient empirical evidence or hindsight, we would be lending ourselves to speculation. This book, thus, provides examples for research approaches suitable for the writing sciences rather than to foresee or prescribe uses of technology for writing.

Third, the range of technologies in use is vast and not restricted to writing alone. Technologies easily transgress borders between intellectual activities established in former media generations, for instance, communicating, publishing, learning, designing, and searching. Borders between these activities have become porous or have vanished altogether (Bazerman, 2018) and led to the creation of many new writing spaces connecting and combining different intellectual activities with each other. In consideration, we include many examples of technologies bridging different activity fields.

Fourth, complexity is a continuous issue in digital writing research that threatens our ability to understand even the most common writing tools such as word processors. Listing and explaining all the functions of word processors is a task that not even Microsoft is attempting any longer. Currently, there is no handbook for Microsoft Word or any other systematic description of it. There are simply too many functions, tools, and add-ons that such platforms host. And these functions are no longer limited to the tools or platforms themselves. They are additionally extended by operating systems with their connections to memory functions, mouse and keyboard controls, internet connections, screen set-up, and the like. Similarly, word processors are subordinated to large business platforms that connect them with many other functions of the web. It is necessary to address such complexity directly, instead of ignoring it with research methods that were designed for much simpler writing tools.

Fifth, new technologies generate new terminologies. Speaking about digital writing makes it necessary to apply such terminologies which, by and large, originate in the computer and information sciences. Integrating these into writing sciences discourse is not a simple task. We were confronted with this challenge throughout this book and in response, added a consolidated glossary with the terms that seem most relevant for writing studies or may be unfamiliar to those not coming from the domains of computer or information sciences.

Sixth, how and to what end writing research should engage in tool development is an open question. Tool development is not only a way to push the boundaries for future technologies but also a way of learning about technology and understanding its basic principles. Tool development has also been instrumental in allowing researchers to study writing in new ways. In a rapidly developing field such as writing, this may become a core competence not only for developers but also for researchers. Cooperation with other disciplines is inevitable in such emerging projects. Our book covers a broad span of relevant disciplines and modes of collaboration between them.

Seventh, the digital writing research community does not have clear-cut boundaries. Digital writing research is inherently interdisciplinary or even transdisciplinary and is therefore faced with disparate discourses and knowledge repositories across different disciplines, including computer sciences, computational and corpus linguistics, applied linguistics, psychology, second-language studies, media and information sciences, cognitive sciences, education, e-learning, and more. We believe that not only there is a place for all these disciplines in the field of digital writing, but also that research and theory-building have to cross borders more often than not (Anson, 2021). Hence, a major aim of this book is to explore the positioning and stance of varied strands of writing research in this domain.

This book tackles related challenges directly. First, it provides a systematic mapping of technologies for writing, locating their current position within the rapidly moving state of technology. By "systematic" we mean a coherent and comprehensive account of digital writing technologies, both historically and technologically. Second, it creates a unifying discourse (including terminology) so that technologists and writing specialists have a shared language and framework within which to explore the field. With this, we hope to contribute to a theoretical framework for theory building, teaching, and research on digital writing technologies. And third, it helps to delineate research fields for writing sciences and highlights areas for future studies and developments.

Further Considerations

As editors of this collection, we have been preoccupied with one ultimate issue: to get a grip on the enormous complexity, rapid development, and confusing ramifications of digital writing technologies. We are convinced that not only we personally but also our disciplines are at the edge of being overwhelmed by the current flood of developments. In order not to lose track and control of them, we adopt a hard focus on technology, which does not result from ignoring other aspects, but prioritizes the aims of mapping, describing, and analyzing technology. One of the main claims in our overall argument is that an all-encompassing technological view has to be an integral part of the study of writing and must not be left to the technical disciplines. If technology does have a major role in determining what writing is, we have to keep our hands on it.

By providing a systematic and comprehensive inventory of digital writing technologies, we hope to pave the way for the systematic investigation and treatment of some connecting social, cultural, and socioeconomic topics such as access to and distribution of new technologies. We see the need to expand technology discourses on issues of inclusivity, diversity, and social justice that have accompanied the dispersion of digital technology from its very beginning. We are aware that writing technologies shape not only the work of our institutions but also the lives, identities, and social relations of our students. Such changes are considered only marginally in this collection, not because we see them as negligible but because they demand a different perspective on technology and would deserve comparable in-depth attention. Similarly, the study of ethical issues arising, for instance, from the use of automated text generation, which is currently shaking educational institutions worldwide, may profit from our approach to understanding current technologies and their affordances.

We recognize that the issues of access and inequities discussed in the context of educational technology and artificial intelligence also apply to writing technologies. With the digital divide and reduced access to writing platforms, educational inequities in the society can be further amplified because the users who have access to advanced writing technologies can become more prolific writers compared to those who do not. However, it may also work the other way because technology can sometimes act as a tool to help bridge existing social divides by its widespread deployment in schools for students who would normally be unable to access them in their home environments (Warschauer & Matuchniak, 2010). In addition, digital literacy and competency, and feedback seeking—the skills needed by a learner to effectively engage with tools and content—are also becoming increasingly important, particularly in the era of ChatGPT where any question on writing can effectively be answered in seconds by the technology. Here, the key is recognizing which part to use (if helpful at all), what needs to be verified (and how), and if it can positively augment learners' thinking rather than undermine it (Shibani et al., 2022). These issues, while referenced in the chapters on analytics and automated writing tools, warrant a much deeper discussion, which is beyond the scope of the current collection.

We also hope to provide material and motivation for systematic studies of the roles that the tech giants such as Microsoft, Google, and Apple play in the advancement of writing technologies, as well as the roles of smaller companies and open developer communities, to determine how these may be shaping writing technologies. Such an approach might similarly be applied to the study of the great publishing houses dominating the distribution and exploitation of the products of academic writing. Approaching digital writing concerns from these angles, however, demands a decidedly economic and sociological perspective. This would be a valuable contribution for a future volume.

It is also important to acknowledge here that innovations in writing technology are part of an even broader media revolution that not only affects reading, writing, sound, and image processing, but also intervenes deeply in the organization of professional fields in science, business, commerce, culture, and entertainment. It is difficult to isolate writing from these broader domains, especially since this revolution is changing not only the way we communicate, think, and use language, but also the way we perceive reality and gain orientation in the world (Carr, 2010). Within this context, it is also necessary to set clear limits for what this book does and does not address. While we recognize the transformative potential of multimedia communication, this book focuses exclusively on writing and more specifically on writing as it is used within the academic context of higher education by students, researchers, and educators for knowledge creation and for fostering learning through academic papers, essays, theses, reflective writing, and e-portfolios. We cover some of the changes resulting from the transition to more informal, personal kinds of writing such as blogs, wikis, portfolios, and learning management systems within academic contexts, but do not consistently include writing on mobile devices, e-mail communication, and social media. We also had to draw the line at discourses on e-learning, distance learning, and blended learning—all of which involve writing in some way but as a subset in the pursuit of a different aim. These decisions were necessary to keep the focus tight and to avoid becoming lost in the countless strands and details of digitalization.

Overview of the Book

To be coherent and comprehensive within a dynamic field such as digital writing, we take a mapping approach. We build on the work of Schcolnik (2018) to provide a classification of tools in academic writing. For precision, we define a tool as a standardized technical solution that enables users to carry out a specific task in writing. Tools usually have a defined aim but may have several functions that contribute to solving the tasks they afford. Tools may be specified by the technology they are based on and by the kind of writing at which they are directed. Some tools have primarily a pedagogical function in learning to write while others are used by writers across all levels of proficiency. For each tool type in our classification, we delve into its development over time, its primary purpose in the writing domain, and its affordances in the practice of writing. We also provide exemplars of the most common or paradigmatic tools within each classification.

Finally, we explore the research evidence base for each tool type in the field of writing and, where appropriate, in other relevant fields. This state-of-the-art synthesis captures 40 years of development in digital writing and grounds it firmly within contemporary theories of writing process and practice. It provides the foundation for a deeper analysis of what has changed in the processes of written communication and what conceptual re-orientations the new technologies invoke. This foundation, in turn, establishes the basis for a cohesive, consistent theoretical view of the new realities of digital writing.

The volume is organized into five parts. Parts I–III provide an extensive synthesis of the key technological innovations in academic writing, sequenced in terms of the three transformations in writing of the last 40 years: the introduction of the word processor, the emergence of the internet and networked platforms, and the natural language processing revolution. Within these parts, each chapter includes the following elements:

- Overview of the purpose and development of the writing technology
- Core idea of the technology
- Functional specifications for the technology
- Main products (most common or paradigmatic products)
- Research evidence base
- List of tools referenced

Part I "Word Processing Software", edited by Christian Rapp, covers the development of word processors. With three separate contributions, this development is covered from its first stages to the current mega-platforms, where writing is just one among many options for communication, organization, learning, and designing. The first chapter traces the progression from early computer applications to the rise of word processors and the struggle for usability, hardware, and market share. The second contribution is devoted to Microsoft Word as the prototype of word processors, which dominated the market for about two decades. The chapter focuses on basic properties of word processors and their impact on the practice of writing. The third contribution covers the developments since the invention of collaborative online word processing by Google, which opened many new doors for innovative technologies. Critical evaluations of MS Word are also offered in this chapter.

Part II "Web Applications and Platform Technology", edited by Kalliopi Benetos and Ann Devitt, addresses writing technologies within a web-based digital environment. Where word processors are primarily concerned with the generation and revision of text, web-based digital environments integrate a wide scope of functions to support factors and activities that surround and define the writing activity (actors, contexts, domains, interactions, etc.). The social affordances and the transformations of writing processes incurred by web-based environments are addressed in the chapters on social annotation, collaborative writing, next-generation wikis, and chats for writing. Cognitive scaffolding and self-regulation afforded by semantic connectivity and conceptual mapping tools are considered in the chapters on creativity software, tools for argumentation development, e-portfolios, and hypertexts. The contributions of technologies supporting dialogic feedback are discussed in the chapters on teacher and peer feedback tools. Finally, the uses of tools that extend external memory and facilitate information management and organization are explored in the chapters on digital notetaking, plagiarism detection, learning management, and reference management systems.

Part III "Writing Analytics and Language Technologies", edited by Elena Cotos, is devoted to language technologies and writing analytics and contains a span of descriptions of different tools and technologies and their applications in academic writing contexts. Language technologies that automatically summarize, find and extract knowledge, and generate texts are discussed in the first two chapters. The third chapter provides an overview of different analytical approaches to automated writing analysis. The following three chapters center on tools for automated scoring, automated feedback, and intelligent tutoring for writing, which have gained popularity in learning and assessment contexts. The next chapter follows on the same focal point on learning by discussing the applicability of corpora in support of writing development. The last chapter takes a turn to the research technologies needed for the study of writing development and production, zooming on keystroke logging for investigating writing processes.

Part IV "Implications", edited by Otto Kruse, contains five chapters with implications for the theory and teaching of writing. These chapters draw on the systematic overviews in Parts I - III to critically analyze the impact of technologies on core dimensions of writing. They offer interpretations of the meaning and significance of technological developments for writing theory, scholarship, and pedagogy. The topics include writing processes, writing and thinking, writing and learning, language support for writers, and writing quality. Within this last part, each of the implication chapters provides a synthesis from existing theory and current technological affordances to future possibilities, being structured as follows:

- Introduction—serves as the focus of the chapter

- Existing theoretical assumptions (the past) - frames the chapter discussion with relevant research and theory
- Current transformations of writing brought about by technology (the present) - presents transformational processes and current technological solutions
- Conclusions—looks to the future for research and technology trajectories.

In addition to the thematic parts, the book offers a consolidated glossary, edited by Antonette Shibani, that defines key terms referenced in the chapters and provides a terminological baseline for future studies on writing technology.

Taken together, the book provides the first comprehensive and systematic account to the digitalization of academic writing and sets the agenda for future research and development.

Otto Kruse
Christian Rapp
Chris M. Anson
Kalliopi Benetos
Elena Cotos
Ann Devitt
Antonette Shibani

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Contents

Word Processing Software

The Beginnings of Word Processing: A Historical Account

Till A. Heilmann

Abstract Word processing software evolved from rudimentary yet highly specialized tools for programmers in the early 1960s into very sophisticated but user-friendly PC applications for the general public in the 1980s and early 1990s. The history of word processing—from debugging code on teleprinter terminals in computer labs to authoring everyday documents on personal computers with graphical user interfaces—is therefore also the story of how computing technology came to the masses and how it transformed our concepts, instruments, and practices of writing. This is the first of three chapters on word processing covering the initial stage of the development. It gives a summary of the early ideas and technologies that would eventually lead to the ubiquitous writing tools available for PCs, laptops and other mobile devices today. The beginnings of word processing, however, were not as smooth as modern applications may suggest. A large set of technological innovations in both hardware and software, conceptual shifts concerning writing and novel business strategies for the computing business were needed to finally realize today's paradigm of digital writing. The chapter's historical account ends around 1990 with the emergence of Microsoft Word for Windows as the *de facto* industry standard for word processing.

Keywords Word processing · Personal computer · Text editor · Text formatting · Desktop publishing

1 Overview

Today, word processing means using a standard application for desktop or mobile computers in order to (a) write and revise any kind of text, and to (b) apply formatting to a text for its output in printed or other form. Hence, word processing software serves as a technology that combines two distinct modes of text production: the composition

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_1

of a manuscript (from first draft to final version) and the typographic preparation of a document (for publication and distribution in printed or electronic form). By merging the typewriter with the printing shop, word processors have fundamentally changed the process of writing and publishing and have blended the role of the author with those of the typesetter and the graphic designer.

Daniel Eisenberg (1992), Tim Bergin (2006a, b) and Thomas Haigh (2006) have given concise historical accounts of word processing with a strong emphasis on specific PC applications like WordStar, WordPerfect and Microsoft Word. More recently, Matthew Kirschenbaum (2016) has devoted an extensive study to the "Literary History of Word Processing". More research on word processing will be presented in the next chapter (Kruse & Rapp, "Word Processing Software: The Rise of MS Word").

While it originated from a very different technological and economic environment, word processing is closely tied to personal computers and their spectacular commercial success since the late 1970s. The widespread adoption of word processors became possible only with the advent of microcomputers and with the rise of the IBM PC platform in the 1980s (Haigh & Ceruzzi, 2021, pp. 227–242). Before that, text editing and formatting tools were confined to time-shared mainframe installations, minicomputers, and dedicated office computers, they addressed narrow, highly trained user groups with specific demands, and they were not open the public. PC word processors, on the other hand, were—and still are—designed for the wider audience and a broad range of purposes. The two domains are historically demarcated by the emergence of a software industry for business and private use of PCs in the late 1970s (Campbell-Kelly, 2003, pp. 201–228). Whereas the first users of early text editors had to program their own custom tools (and many committed hackers and software engineers would continue to do so for a long time), office clerks and PC owners since the late 1970s have been doing their word processing with off-the-shelf, commercially—or freely—available applications.

Conceptually as well as technologically, one of the decisive moments in the evolution of word processing software was the inclusion of the video screen. As electronic displays were uncommon up until the 1970s, early digital text editing usually happened character for character and line by line on hard-copy terminals like teleprinters and customized electric typewriters (Haigh, 2006, pp. 13–15). By putting characters on a real-time video screen, computers turned written text into a 'malleable' visual object and opened a new kind of "writing space" (Bolter, 1991) in which individual letters and words, whole sentences or larger textual units could be easily and instantly manipulated. Equally important, bitmapped video screens allowed for WYSIWYG or "What you see is what you get", i.e., a mode of display that shows all the formatting of a text (with different typefaces, sizes and so on) and its page layout just as it would appear when printed on paper.

Long before video screens for word processing were actually implemented, a few visionaries had already pondered the possibilities and potentials of modern media technology for writing. One of the first authors to do so, and a recurring point of reference in future discussions, was Vannevar Bush. His article "As We May Think" from 1945 established the idea of a mechanized database of documents projected onto ‘translucent screens’ (Bush, 1945, p. 107). Bush’s text exerted a strong influence on two other visionaries, Douglas Engelbart and Ted Nelson. Engelbart expanded on Bush’s ideas during the 1960s with his own concept of “Augmenting Human Intellect”. Displaying text on a computer screen, Engelbart argued, would allow for completely “new methods of manipulating symbols” (Engelbart, 1962, p. 75).

Nelson also continued on Bush’s work. In his treatise on “A File Structure for the Complex, the Changing and the Indeterminate” from 1965, Nelson hypothesized about a computerized ‘dream file’: an electronic text environment that would assist the author with “manuscripts in progress” through all stages of the writing process, and particularly “during the early periods of muddled confusion, when his [or her] ideas are scraps, fragments, phrases, and contradictory overall designs. And it must help him [or her] through to the final draft with every feasible mechanical aid—making the fragments easy to find, and making easier the tentative sequencing and juxtaposing and comparing” (Nelson, 1965, p. 88). Digital computers, in short, would foster the creativity of writers by making written text easily modifiable and re-arrangeable on the screen.

The screen was also instrumental for another decisive shift in writing. For computer displays can act as more than just intermediaries in the digital production of paper documents. Bush, Engelbart, and Nelson all thought about and worked on the possibility of linking together individual documents and fragments of text through mechanical and electronic means—an idea for which Nelson coined the term ‘hypertext’. The concept of strictly digital documents that were not to be printed on paper but would be written and read exclusively on video screens began to take shape with early hypertext systems in the 1960s (Barnet, 2013). From the 1980s on, networked computers with services like bulletin board systems (BBS), Usenet, and, finally, the World Wide Web (WWW), turned this idea into reality. Today, the screen has supplanted paper for many purposes and has become a primary medium for displaying text in its own right. While common word processors are not geared towards creating hypertexts and webpages, they are routinely used to write documents that are meant first and foremost for the screen.

After word processing on PCs had become wide-spread and with the revolution of the Internet and the WWW looming at the beginning of the 1990s, writers like Jay D. Bolter (1991) and George P. Landow (1992) again discussed the new electronic ‘writing space’ and hypertextuality from a historical and philosophical perspective. Other notable voices in the debate include Michael Heim (1987), Vilém Flusser (2011) and Jacques Derrida (2005). The consensus of such theoretical analyses seemed to be that word processing had changed writing from the task of producing a fixed, stable, ‘bookish’ text by a single identifiable author to a continual process of creating and revising ever-changing digital documents that constitute a highly dynamic hypertext of multiple and shifting authorial agents.

Notwithstanding the substantial changes brought about by digital hard- and software, our concept of text and even our basic methods of generating letters, words, and sentences have proven remarkably resilient. Most digital texts still largely follow the traditional visual architecture of the “bookish text” that goes back to medieval scholasticism (Illich, 1993, p. 115). And most digital writing is still done by pressing keys on typewriter-like keyboards whose layouts were invented and perfected at the end of the nineteenth century. It is no wonder, then, that the most successful word processing applications still adhere to the model of the printed page.

2 Core Idea of the Technology

The core ideas of technology that led to word processing as we know it today are (roughly in chronological order):

1. The interactive use of computers.
2. Entering and editing text on computers.
3. Using interactive editing tools for "regular" texts (not computer programs).
4. Formatting digital text according to traditional typographic conventions.
5. Putting text on a computer screen.
6. Printing digital text to paper.
7. Computer systems usable by non-professionals.
8. Simulating paper documents on computer screens.
9. Automating clerical work with computers.
10. Computers available to and affordable for everybody.
11. A market for standard word processing software solutions.

The technological foundation of digital word processing is the interactive use of a computer while it is running, i.e. the possibility of a rapid back and forth information exchange between user and system through suitable input/output devices. Interactive computing started around 1960 with the first time-shared installations and minicomputers (Haigh & Ceruzzi, 2021, pp. 109–138). In the beginning, teleprinters were the preferred interface for this new kind of 'dialogue' between man and machine. They were well-known from telegraphy, relatively cheap, reliable in operation, and, most importantly, easy to adapt for use with computers: Employing telegraphic character encodings like the Baudot or Murray code, teleprinters already processed writing in digital form. As an additional benefit, they could often read and write texts from and to paper tape, a popular storage medium of early computers.

One of the very first uses of interactive computing was the inspection and debugging of programs. Doing this online was much easier and faster than poring over paper printouts of faulty code and failed runs (van Dam & Rice, 1971, p. 97). It was soon realized that computers could also help with the preparation of program tapes. At the time, computer code was developed using pen and paper, written by hand (sometimes on special coding sheets), then mechanically transferred to paper tape or punched cards, and finally fed to the computer. While faulty cards could be easily swapped, a tape containing an error had to be punched again from scratch. Harnessing the computer for debugging programs and producing corrected tapes would considerably speed up the software development process.

Colossal Typewriter, created in 1960 at Massachusetts Institute of Technology (MIT) for the Programmed Data Processor 1 (PDP-1), the world's first commercial minicomputer, is arguably the oldest known digital text editor. As the name says, it turned the 120,000 US dollar computer installation into a giant typewriter for the purpose of "tape preparation and tape editing" (McCarthy & Silver, 1960, p. 1). By today's standards, Colossal Typewriter was extremely rudimentary and cumbersome to use. But it made life much easier for programmers and kicked off a slew of subsequent text editors with ever more advanced capabilities and features. The most important of these is probably TECO from 1962, also initially for the PDP-1 (Murphy, 2009). TECO is the direct ancestor of the Emacs editor which was developed by Richard Stallman in the 1970s and is still used by many programmers and some non-programmers on PCs even today. Again, the name of the program is revealing: While it was later renamed Text Editor & Corrector, the acronym TECO originally stood for *Tape* Editor & Corrector, pointing to the primary medium of early computing and text editing.

As Colossal Typewriter, TECO and their successors spread throughout computer labs and facilities in parallel to the rise of time-sharing systems and minicomputers during the 1960s, programmers realized that these tools could be used to write not just code but regular texts in prose as well. Soon they also created technical documents, office memos, lab reports, and other pieces with the same programs they used for editing code (Brock, 2018, p. 9). In the process, text editors were gradually extended and enhanced for the new tasks. And because regular texts were read by humans from pages of paper (not by computers from paper tapes), they needed to be organized accordingly for printouts with proper line, paragraph, and page breaks, headers and footers, page numbers etc. Consequently, the first methods and instruments for digital text-formatting were invented.

The common way to do this was, and still is, for the user to put special control characters or commands like .BR or .CENTER into the text at the right places (what is called "markup" today). When a text was printed, the control characters or commands in the text were processed by the formatting program and effected the desired typographic results like page breaks, centered lines, indented paragraphs etc. One of the earliest tools, Type Justifying Program 2 (TJ-2), again developed for the PDP-1 at MIT in 1963, already made use of the computer's electronic display and light pen for hyphenating words (Massachusetts Institute of Technology, 1963). More influential would become the RUNOFF program, also created at MIT in 1964 for the time-sharing system CTSS (Saltzer, 1964). Not only did its control commands allow for more complex formatting of texts and page layouts than before, RUNOFF also served as the main inspiration for most other formatting programs and languages to follow and is the direct precursor to the basic text processing tools at work in every Unix operating system (including macOS computers) even today.

At the same time as text editors and formatting tools were developed and refined in university labs, a few visionaries and outsiders of the computer industry began to build "free form text editors" (van Dam & Rice, 1971, p. 105) that were meant to enable wholly new ways of thinking and writing. Chief among them was the aforementioned Douglas Engelbart at Stanford Research Institute (SRI) who sought to "augment human intellect" through computer-aided symbol manipulation on electronic displays (Engelbart, 1962), a project that was funded by the US Air Force, NASA, and ARPA (Advanced Research Projects Agency). Together with his team, Engelbart created the oNline-System (NLS), a time-shared computer installation for collaborative work which he famously demonstrated to the public at the Fall Joint Computer Conference in San Francisco in 1968—an event that has become known as 'The Mother of all Demos'. While NLS boasted many 'firsts' (including the computer mouse, linked hypermedia and document version control), it was essentially a screen-based word processor technologically and conceptually far ahead of its time (Bardini, 2000). The NLS, though never successfully commercialized, had a profound impact on computer culture. Probably the most important contribution to digital writing was that it showed to the world what were the possibilities for working with text when it was displayed on a computer screen.

The failure of NLS was its enormous technological and structural complexity and the resulting steep learning curve. Non-specialists found the system nearly impossible to work with (Ittersum, 2008, pp. 156–157). Making computers useable for ordinary people was a big challenge that the industry had to confront in the 1970s. Some of the most important contributions in this regard were made at the Palo Alto Research Center (PARC), founded in 1970 by photocopier giant Xerox in order to invent the 'office of the future' (Hiltzik, 1999).

One of the major conceptual breakthroughs at PARC was the enforcement of modeless editing. Simply put, this means that pressing a key on the keyboard when editing a text should always result in the corresponding letter being inserted, never in something else (like, say, the current line being deleted or two paragraphs being transposed). This was obvious to a secretary at PARC who was asked by the software engineers how she imagined editing text on the screen was supposed to work (Perry, 2005, pp. 50–51). But it was news to the programmers who had invented digital writing tools and were accustomed to operate within multiple modes (the aforementioned TECO, for example was actually more of a programming language than a text editor). The insight gained from this ethnographic study was, in short: For word processing, the computer keyboard should serve just a like regular typewriter, not like the control console of a computer.

Probably the biggest of PARC's contributions to computing was its advancement of the mouse-driven graphical user interface (GUI). With their experimental Alto computer, developed from 1972 on, PARC pioneered high-resolution bitmapped graphics that turned the screen into a digital canvas able to display all kinds of visual information: pictures, tables, drawings, diagrams, and, of course, letters (Haigh & Ceruzzi, 2021, pp. 245–250). Not incidentally, one of the first major applications that made good use of the Alto's GUI capabilities was a word processor called Bravo, created in 1974. Not only did Bravo show all the details of a text's graphic formatting on the screen, i.e. the various looks of typefaces, styles, sizes, and so on. It was also the earliest WYSIWYG application—a text editor that let the users see what they were writing on the screen just as it would appear in printed form (Kirschenbaum, 2016, pp. 125–126). With Bravo, the text on the computer screen visually matched the text on the page produced by a laser printer—which was another one of PARC's ground-breaking inventions.

A later version of Bravo that combined the GUI/WYSIWYG display with modeless editing arguably counts as the world's first word processing software in the modern sense. Its ease of use and graphic text editing capabilities made it an instant hit—not only with PARC engineers and employees but also with their families and friends who would come in to create personal documents like newsletters, resumes, and school reports on the Xerox Alto machine. And although Xerox failed to capitalize on the many conceptual and technological innovations concerning personal computing at PARC (Hiltzik, 1999, pp. 389–398), the Alto computer and Bravo program would exert a lasting influence on the further evolution of the personal computer and word processing. In 1979, a team of Apple's engineers were given tours of PARC and demonstrations of the Alto. Their subsequent work on the Macintosh, the first commercially successful GUI computer released in 1984, was heavily inspired by what they had seen. And in 1981, Charles Simonyi, the lead programmer of Bravo, left PARC to join Microsoft where he would oversee the development of productivity applications and become the chief architect of Microsoft Word (Lohr, 2002, pp. 135–136).

The beginnings of commercial word processing outside of research labs like SRI and PARC in the 1970s were much more modest than what Engelbart's NLS or the Xerox Alto had to offer. Thanks to advances in semiconductor technology and falling prices for memory chips, video terminals as computer interfaces were becoming more common. But they were mostly meant for input of and access to structured data in large companies and public offices, not the editing of regular texts. At the beginning of the 1970s, computers were still too costly and too difficult to operate for untrained clerks and secretaries. Paperwork in offices (and in private homes) was still done almost exclusively on mechanic or electric typewriters. Fittingly, IBM began to use the term "word processing"—an invention by one of its German typewriter division managers (Heilmann, 2012, pp. 141–155)—to promote all of their office products, typewriters, copiers, and dictating machines alike.

Computer-based word processing for the office was championed by other, much smaller companies than IBM like Wang Laboratories. Although it is mostly forgotten today (as are other competitors in the business like Lexitron, Vydec, and Linolex), Wang Labs actually dominated the market for office word processing systems during the second half of the 1970s (Haigh, 2006, p. 22). Their dedicated word processors were, essentially, 'micros' like the first PCs released by MITS, Apple, or Commodore at the time, i.e. computers based on 8-bit microprocessors by Intel, MOS Technology, or Zilog. Unlike PCs, however, they were marketed to businesses, came with all the necessary peripherals (keyboard, screen, printer), and were not freely programmable but designed to do one thing, and one thing only: text editing for clerks and secretaries. In fact, Wang Laboratories were very careful not to advertise their word processors as 'computers'. Instead, they pointed out the similarities to familiar office equipment: "Just type as on a normal typewriter" (quoted in Heilmann, 2012, p. 172). Wang word processors could in no way match the GUI and WYSIWYG capabilities of the Xerox Alto and Bravo. But they were actual products available on the market and quickly garnered a reputation for being easy to use and speeding up paperwork. History has it that the architects of Wang's initial word processing system wrote the user manual first and only then set about to design the required hardware and software (Haigh, 2006, p. 18).

Despite their early and spectacular success in the word processing market for businesses, Wang would ultimately not survive the vast expansion and consolidation of the microcomputer landscape through the dominance of the IBM PC platform in offices and homes in the 1980s. With personal computers, word processing solutions were transformed into off-the-shelf applications for everybody. In the face of an ever-growing market for PC hardware and software, expensive single-task workstations like Wang's dedicated word processors had no future.

The story of the PC has been told many times (Bergin, 2006a, b; Campbell-Kelly et al., 2014, pp. 229–251; Ceruzzi, 1999) and need not be recounted here. A few short remarks on the relation of personal computers to word processing have to suffice.

Word processing for PCs was not a revolution—neither in technological nor in conceptual regard. Rather, the problem was one of re-implementing known concepts and techniques as a commercial software product for a novel hardware platform, the ready-assembled microcomputer for home and business users. It is not surprising, then, that the development of PC word processing applications reiterated seminal moments in the larger evolution of digital writing since the 1960s in fast-forward.

PC word processors grew out of homemade editors to program the new machines for which no software existed at first—beginning with Michael Shrayer's Electric Pencil from 1976 (Freiberger, 1982; see also Bergin, 2006a, pp. 33–35 for Word-Master from 1978 and EasyWriter from 1979). They spread on the back of mass-marketed micros and in turn served as one of the 'killer applications' that helped introduce the new hardware paradigm to the general public (together with games and spreadsheets). They quickly differentiated into a myriad of competing solutions on the growing range of personal and home computer systems, most of which are forgotten today (Bergin, 2006a, b, p. 44). Due to the limited resources of early PCs, the programs were text-based at first—like the popular WordStar (1978) and Word-Perfect (1979) applications; but as computing powers increased, they gained the GUIs and WYSIWYG capabilities demonstrated by the Xerox Alto—most notably with Word for Mac (1985) and Word for Windows (1989). And although there were some experiments towards a 'purely' digital writing on and for the screen with systems like Storyspace and HyperCard (Bolter & Joyce, 1987; Williams, 1987), the imperative of printed paper would dominate word processing (along with desktop publishing pioneered by Aldus PageMaker from 1985 and Adobe's PostScript and PDF technology) even after PCs had become networked through the WWW in the mid-1990s.

According to Bergin (2006a, b), the history of word processing for PCs unfolded in three overlapping stages: an initial phase of 'origins', beginning in the mid-1970s with early microcomputers like the MITS Altair 8800 and the very first rudimentary PC applications like Michael Shrayer's Electric Pencil and John Draper's Easy Writer; a second phase of 'proliferation', beginning at the start of the 1980s with the introduction of the IBM Personal Computer and more sophisticated word processors, most notably MicroPro's WordStar and SSI's WordPerfect; and a third phase of 'consolidation', beginning around 1990 with the rise of Microsoft Windows and the eventual monopoly of Microsoft Word for Windows.

The three phases of PC word processing described by Bergin coincide with major shifts in the ecology of microcomputer hardware and software: the first phase (ca. 1975–1980) was characterized by the initial diversity and mutual incompatibility of machines, reconciled only by the popularity of the CP/M operating system; the second phase (ca. 1981–1989) brought a massive standardization of technology through the homogenizing forces of the IBM PC hardware platform and the MS-DOS software environment; finally, the third phase (since ca. 1990) saw the breakthrough of the GUI paradigm for PCs and completed their standardization through the hegemony of Microsoft Windows. Thus, the evolution of word processing software followed the trend of the PC platform as a whole: from a variety of competing but incompatible products to a single, 'universal' solution; and from simpler, text-based products to an elaborate graphical system within a common GUI framework. From this perspective, the success of Microsoft Word can been seen not only as the result of Microsoft's ruthless business practices but also as the culmination of a larger technological and commercial process of increasing standardization and integration in personal computing. While most essential word processing features had already been implemented by other programs in the mid-1980s, the addition of true WYSIWYG capability and the seamless interaction with the Windows framework was the unique factor that helped Microsoft Word conquer the market at the beginning of the 1990s. (On the Apple Macintosh, Word possessed WYSIWYG capability since 1985; Microsoft's main competitor WordPerfect only got it more than a year after Word for Windows and never really played well with Windows).

In total, PC word processing differs from the earlier digital writing tools and systems from the 1960s and 1970s discussed above by four main facts:

1. It consists almost exclusively of commercial off-the-shelf products (with a few exceptions like OpenOffice or LibreOffice Writer).
2. While there was a very lively and diverse market for word processing applications in the beginning, the field has been monopolized by the *de facto* standard of Microsoft Word for Windows since the early 1990s.
3. Since the mid-1990s, word processing has stretched beyond narrow user groups and reached the general population (at least in so-called developed countries) where it has mostly replaced the typewriter.
4. Today, the scope of word processing covers almost any field of writing, from personal notetaking to the preparation of legal documents.

3 Functional Specifications

Word processing applications for PCs typically offer the following four sets of essential functions:

1. Editing of text (entering and deleting text, copy-pasting and search-replacing strings etc.).

2. Handling of documents (creating, saving, deleting files).
3. Formatting of text and documents (choosing different fonts, text sizes, paragraph alignments, page layouts etc.).
4. Displaying and printing of documents (with video screens and laser or inkjet printers, especially in WYSIWYG mode).

As shown in the previous section, the first and second set of functions are historically derived from the text editors used by computer programmers since the 1960s. The third set stems from the text formatting and document processing tools invented for time-sharing and minicomputer installations in the 1960s. Finally, the fourth set goes back to experimental computer systems like NLS and the Xerox Alto from the 1960s and 1970s.

While word processing applications are most commonly used by authors for composing their own texts, the four sets of functions actually address them in different roles: The first set treats the author as editor, the second set as secretary and the third and fourth set as typesetter and graphic designer. Addressing the author as a creative and a collaborative writer was not an integral part of word processing until the 1990s. More information on the corresponding technological functionality will be offered in the following chapter (Kruse & Rapp, "Word Processing Software: The Rise of MS Word").

Acknowledgements The author wishes to acknowledge Christian Rapp and Otto Kruse for their kind assistance and unending patience in helping to bring this chapter about.

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Word Processing Software: The Rise of MS Word

Otto Kruse and Christian Rapp

Abstract In the mid-1980s, more than 300 different versions of word processing software existed (Bergin, 2006a, b), but within a decade, Microsoft Word emerged from the pack and became the standard writing tool. MS Word convinced the public to exchange their typewriters for microcomputers with writing software. It gave writing an (inter)face to become familiar with. A new era of literacy had begun and started to shape writing, thinking, design, and communication in its own way. First, we provide an overview of the developments that made MS Word successful and describe in broad terms the core issues of word processing before we look at the functionalities that MS Word offers. Next, we reflect on the importance of research on word processors and show that it has dwindled since the initial wave of studies. Research ceased since the 2000s, even though new technological opportunities to study word processors arrived, such as key logging and screen recording. The report ends at the time when the internet had developed sufficiently to change literacy once more and when word processing had to adapt to the tasks, technologies, and demands of writing for the web or in the web.

Keywords Word processors · Microsoft Word · Inscription · Writing research

1 Overview

This chapter covers the stage in the history of word processing that Bergin (2006a) called the "consolidation phase" (see also Heilmann, "The Beginnings of Word Processing: A Historical Account"). It began with the implementation of Microsoft Word in MAC OS in 1986 and three years later in Microsoft Windows. Both offered

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_2

comfortable window-like operating systems and were tailored to affordable PCs such as the one IBM launched in 1981 (Haigh & Ceruzzi, 2021) or, at the same time, Apple with its II, SE, or Macintosh. The consolidation phase ended around 2006 when Google Docs was launched and a new chapter in word processing as a platform-based technology started (see Rapp et al., "Beyond MS Word: Alternatives and Developments", and Castelló et al., "Synchronous and Asynchronous Collaborative Writing").

Even though word processing for PCs was not a technical or conceptual revolution, as Heilmann ("The Beginnings of Word Processing: A Historical Account") noted, it was a media revolution—at least when its impact on literacy development and writing cultures is considered. The revolutionary act was the rapid and almost complete adoption of word processing as the dominant means of writing in education, sciences, business, and more. Word processing, along with desktop publishing software, marked the end of the age of the letterpress and heralded a new era of literacy (Baron, 2009; Bolter, 1989; Haas, 1989, 1996; Harris, 1985; Heim, 1987; Mahlow & Dale, 2014, Porter, 2002; Reinking et al., 1998).

In this chapter, we look at MS Word as the dominant software in the 1990s and 2000s that, for a long time, has set the agenda for digital writing. Its significance could be compared to that of Henry Ford's "Tin Lizzy" in the 1910s, which is said to have put America on wheels. Similarly, MS Word, along with the Mac and Windows operating systems, put America on screen and made it go digital. The rest of the world followed suit when MS Word internationalized writing by first adapting itself to different languages and then also to other script systems.

After 40 years of development, it is increasingly difficult to characterize or describe MS Word as it covers more changes, additions, and technical adaptations than can be listed or described here. One attempt can be found on Wikipedia at https://en.wikipedia.org/wiki/History_of_Microsoft_Word. In this chapter, in contrast, we restrict ourselves to the downloaded, offline version of MS Word and leave browser-based versions for the following chapter, even if for some questions we had to extend the focus to a longer period of time. Alternatives to MS Word will be covered in Rapp et al. ("Beyond MS Word: Alternatives and Developments").

This contribution also brings up the question of how much we need to know about word processing and exactly what kind of research writing science can and should deliver about it. The technical development of word processors has been addressed in various publications (for example, Baron, 2009; Bergin, 2006a, 2006b; Haigh & Ceruzzi, 2021; Heilmann, 2012), but we know much less about what word processors actually do and how writers use them. Word processors are the white elephant in the living room of the writing sciences. They have continuously changed and integrated many functions without anyone in our disciplines keeping track of it and commenting on its transformations. Today, MS Word and similar processors are virtual hubs for writing technology and keep expanding their functional portfolios in many directions.

For the writing sciences, the word processor is the critical technological element determining what writing is and how literacy develops, particularly in academic domains. Even if "digital writing" is a broader term encompassing many kinds of software for various mobile devices and internet applications (McKee & DeVoss, 2007), the word processor still forms the core element from which all digital writing evolved. We refer to MS Word as the prototype of word processing in spite of the many existing alternatives (see Rapp et al., "Beyond MS Word: Alternatives and Developments"). In this chapter, we will look at word processors from three different angles: (i) from the technological principles of word processing and their meaning for the nature of writing, (ii) from the perspective of technological functionalities and their meaning for the practice of writing, and (iii) from the viewpoint of research and the various attempts to understand digital writing technology.

2 Core Idea of the Technology

2.1 Inscription

In all its versions, writing technology consists of fixing letters, words or symbols on a writing surface, be it a temple wall, papyrus roll, or sheet of paper, with some form of paint or ink (Ong, 1982). This procedure is generally referred to as "inscription" (Bazerman, 2018; Kruse & Rapp, 2023). For alphabetical writing systems, this may be seen as a notation procedure for sounds which allows to reproduce oral language. Lindgren et al. (2019, p. 347) define: "The point of inscription is always the location where the writer is currently producing or deleting text."

If a script was to endure, it had to be fixed permanently; otherwise, like with slates, blackboards, or wax pads, it could be erased and would lose its permanence. Durability and changeability were exclusive attributes of all pre-digital writing technologies. Digital writing did not alter the fact that inscription is a notation procedure for sounds in letters, but it did change the way to make script permanent by storing letters as digital codes which can be flexibly arranged and rearranged on screen as a two-dimensional document. This altered the relation of durability to changeability of script allowing for an easy inscription, deletion, relocation, and recombination of letters and words.

To insert letters, computer designers relied on keyboards similar to those used with teleprinters and type writers. Keys were connected to letters or other symbols which, in turn, had been assigned digital signatures by the ASCII code (American Standard Code for Information Interchange) developed in the early 1960 and revised several times. The original code provided a number and a digital signature to 128 letters and symbols, making them processible by a machine in a standardized way (see: https://en.wikipedia.org/wiki/ASCII). Later standardizations, known as "Unicode," overcame the limitations of its 7-bit design (allowing for up to 128 characters) by extending it to 16 bits and later 32 bits. This made it possible to encode more than 65,000 signs, among them 21,000 Chinese symbols. With the latest 32-bit version, more than four million positions are available, each of which can be defined by a particular symbol (Lobin, 2014). What is essential for writing is that these codes connect the keyboard to a universe of signs ready to be accessed and used in writing.

Any restriction to the Latin alphabet of the early ASCII code was overcome, and all major script systems are now available for word processing.

2.2 Linearization and Formulation

Unlike a picture, where content can be presented simultaneously, language enforces linearity where only one sound can be produced at a time and only one word can be placed in a line of words—never two or more (Kruse & Rapp, 2023). Notably, this is a matter of language, not technology. Writing technology has to model the sequentiality of language and support it. A text can be read in one direction only, and there is a dependency between what is said later from what has been said earlier. Additionally, transitions from one topic to the next must be managed—a task that de Beaugrande (1984) called the creation of a "moving focus." Such a moving focus can be described at the level of idea development (which linguists call "coherence") and at the level of the linguistic connectors and transitional phrases (called "cohesion"). Word processors must support the creation of language and support writers in transforming whatever they want to say into a coherent line of words that others can decode. For this, the string of words must follow a defined order, usually governed by grammar.

Lindgren et al. (2019) distinguish the point of inscription from the "leading edge" of text production as "the point in writing where new meaning is being created." While inscription can be devoted to marginal corrections or revisions, writing at the leading edge relates to the creation of meaning. The activity involved in creating text (oral or written) is traditionally called "formulation" (Kruse & Rapp, 2023; Levelt, 2013; Wrobel, 1997). In writing, formulation is a way of thinking that happens in interaction with the writing tool along the leading edge. Different from speakers, writers can see what they think on the writing surface and can modify, extend, delete, and restructure their thoughts as desired. Formulation is not simply the translation of cognitively generated content into language but the creation and modification of content using a writing tool (Wrobel, 1997, 2002). Word processors, today, support formulation processes through functionalities such as grammar, style and spell checkers, synonym finders, sentence completion apps, and more. They are currently at the edge of creating content, conducting literature searches, proposing formulations, and translating. As Lobin (2014, p. 95) suggested, formulation has become a hybrid activity in which the word processor acts as a co-author.

2.3 Formatting

Writing has always been a graphic venture; not only did the letters need to be designed, but so did the pages that framed the writing. It has always been tied to a two-dimensional way of displaying script, and so has reading as the eye follows the text (see Heilmann, "The Beginnings of Word Processing: A Historical Account"). However, word processor technology reduces text to a one-dimensional line of digital code. Hence, one of the tasks facing developers of word processors was to invent ways of making the stored line of code visible. The formatting instructions are also part of these lines of code, as are all graphic elements and the commands they follow. Two inventions were necessary to provide MS Word with user-friendly ways to make code visible: The first were graphic user interfaces (GUIs) which were programs such as Mac OS or MS Windows, transforming code into a graphic content to be displayed on a screen. The second was the "WYSIWYG" principle, which ensures that the image on the screen matches the image on paper when the line of code is printed out. The WYSIWYG principle mimics the former writing technologies by making the graphic appearance of a text as fixed as inscriptions on paper once were.

2.4 Revision

The relation of fixity and changeability of written text determines the options for revision. In digital writing, text revision has been greatly simplified, where the "delete" button and the "cut" function stand for an unlimited replaceability of any inscribed sign. Even if technically insertion and deletion are basic elements of text production, the boundary between inscription and revision has been blurred by them to such a degree that it is questionable whether this distinction is still meaningful. They are both practiced at the same time and have become inseparable in text production.

Opportunities for revision exist not only at the level of inscription but also at the macro-level of structure and outline. The outline function allows users to shift text blocks or recycle text that has been temporarily removed. Outlines may be adjusted, and hierarchical orders can be altered or adapted easily.

2.5 Networking and Interaction Among Writers

Writers relate to other writers in several ways. Traditionally, quoting other authors was the primary means of interaction and community building among researchers (Hyland, 2000). Also, co-authoring publications was a common way of connecting researchers. Since digital code can be read by all computers with similar operating systems and editor functions, writing in a digital context means not only that the users can interact with their computers, but that computers can communicate with other computers and, in turn, their users. Word processors successively support and enable networking between authors, leading to several forms of collaborative writing. In addition, texts are interconnected in new ways by hyperlinks and web-based publications. Even though intertextuality has always been a principle of academic texts, hyperlinks have simplified these connections and offered new opportunities for intertextuality (see Castelló et al., "Synchronous and Asynchronous Collaborative Writing").

3 Functional Specifications

The following compilation of functionalities contained in MS Word makes no attempt to be complete, nor does it say anything new to readers familiar with word processors. Instead, we seek to demonstrate what difficulties arise when verbalizing what writers can do more or less intuitively with MS Word. MS Word is a universal writing tool designed to suit all purposes of text production in all contexts and domains, and we focus here on what is essential for the writing sciences rather than what is technically possible. Furthermore, we make no distinction between when the respective functionalities were added to MS Word or how they have evolved over time.

3.1 Entering, Editing, and Revising Text

Entering and modifying character strings: The core function of word processors is to produce chains of characters and words. Characters (and other symbols such as numbers, connective signs "&", "+", and punctuation marks) are entered into the system and then graphically displayed on the screen. Each keystroke generates (or better, selects) a letter (for upper cases or special symbols, two or more keys must be pressed simultaneously, as with a traditional typewriter).

Characters, symbols, and signs: An almost unlimited number of signs and script systems are available. Character sizes can vary, and dozens of fonts can be selected. In addition, a wide palette of colours can be used for fonts, graphics, and backgrounds.

Cut, copy, paste, shift, and delete: These are the basic commands that writers have at their disposal to insert, modify, remove, or dislocate letters or words. Letters and words can be marked and then deleted, copied, cut out, and shifted to another part of the text. Also, text from other sources can be imported or vice versa, and existing text can be exported to another document.

Emphasizing, highlighting, and marking: Several modes of highlighting are available, such as bold, underlining, italic, and crossed out. Other textual effects such as shadowed, mirrored, or shining characters can be chosen.

Search and replace: The search and replace function is both a tool for navigation and revision when words need to be exchanged, deleted, or altered.

3.2 Handling and Formatting Documents

Creating files: As letters are not fixed on paper, it was necessary to create "files" as containers for digital code that a computer could transform into visible text. Files were not stored within the word processing program but in the operating system, which also provides the file register and directory. Today's cloud solutions have expanded the memory capacity of computers almost infinitely.

Save, retrieve, and import text files: Any text produced in the computer's working memory can and must be saved as a document if it is to be retrievable. For this purpose, the operating system enables the creation of directories in which a file name can identify the document. Files can be opened and edited at any time. Electronic storage takes a fraction of the space it would take in an analogue environment, with writing and storage taking place on the same device.

Organizing file structures and personal libraries: Even though file structures are not a part of word processors but of the operating system, the creation of consistent file structures is an important part of the digital writing, learning, and working environment.

Document design: MS Word is not only a text creation program but also a layout program, which can assume many functions of formatting text—and there is a wide range to choose from. Automatic word wrapping was one of the first tasks word processors had to solve to arrive at a consistent layout. The typing area can be determined by specifying line spacing, indents, margin sizes, headers and footers, page numbers, etc. The text can be arranged either right-aligned, left-aligned, centred, or arranged in block space. Line spacing and indentations can be generated automatically.

Styles: To make formatting choices in designing a document easier, the function "styles" has been included from which a large number of integrated designs can be selected. A visually represented "styles gallery" of pre-designed formatting choices can be used or different styles can be customized by the user and then included in the gallery.

3.3 Text and Idea Organization

Enumerations, lists, sequences: MS Word offers many ways to organize the linear arrangement of texts that on paper were difficult to implement, such as bullet points, numbered lists including indentation and modified line spacing and tables. Furthermore, genre-specific text templates are available, e.g., for applications, letters, CVs, certificates, reports, invitations, and so on, which, in addition to a sample structure, also offer a plausible layout for the respective task.

Non-linguistic text elements: MS Word provides writers with many graphic elements and symbols that can be placed into the document or used to create visualizations, such as SmartArt in MS Word and PowerPoint. Videos or audio files can also be included in the text and hyperlinks can be inserted. The sole connection between the writing system and printed paper is thus removed in favour of multimedia technology.

3.4 Language and Formulation Support

Language interface: Several language preferences can be chosen at the Windows level. One is the language of the User Interface determining the language of all commands and instructions. A second is the choice of the authoring language which refers to the language that is used for writing and connects to the proofreading services. Over hundred languages and dialects are available for this.

Grammar, spelling, hyphenation, and punctuation: Grammar and spelling services inform the writer by a wave-like underscoring about errors in a defined part of the text. Alternative formulations may be displayed by mouse click. Grammar checkers rely less on grammatical rules but on lists of common linguistic errors. Punctuation, spelling, and hyphenation support is usually included in the grammar checkers. Automatic checking of spelling is done by comparing the input with lists of correctly spelled words and their morphologies. Hyphenation is similarly done with lists of words where the division points are marked and applied when the text approaches the margin.

Support at the word level: Synonyms can be displayed with a mouse click when a word is, and a thesaurus provides directories of common words and expressions.

Sentence completion: Autocompletion and word prediction are mainly used in mobile phones and small or restricted input devices but are now increasingly found in word processors as optional features. They operate based on word frequencies or collocation lists but can also be adapted to individual linguistic preferences.

3.5 Internal and External References

Automatically created tables: Lists of figures or tables can be generated and numbered; page numbers are adjusted automatically.

Footnotes and endnotes: Both can be selected with a mouse click and graphically inserted precisely at the bottom of the page or the end of the text.

Tables of content: Marked chapter headings can be assembled to a table of content with several graphical options for its design.

Hyperlinks: Both, within a document and across documents (provided it owns an URL address) hyperlinks can be arranged.

3.6 Reviewing Features

Tracking changes: Changes can be tracked and marked so that different text versions remain visible.

C*omment function:* The comment function can insert suggestions for improvement and corrections by others remain visible; these can be accepted or rejected individually. Comments can be inserted, answered, accepted, or rejected.

Version control: Different document versions can be compared, and deviations will be highlighted. In earlier versions of MS Word, this could be done when a text was exchanged by e-mail; in online versions, Share Point is used to compare the texts (see Rapp et al., "Beyond MS Word: Alternatives and Developments").

Understanding word processing as a technology needs to refer to the many kinds of actions users can perform. Writing processes are mediated by these technological functions and by the actions they allow or request. Even if many of these activities may concern lower-order processes, enough of them interact with the conceptual, structural, and rhetorical issues of writing or with the social contexts in which it occurs that it seems legitimate to speak of the work processor as a co-author (Lobin, 2014).

4 Research on MS Word and Word Processors

4.1 Technological Research: General Considerations

MS Word and similar word processors determine to a large extent what writing means and how it is done. Accordingly, this should motivate research that includes the technological aspects of word processors. But MS Word is, as we have shown, a complex tool with hundreds of specifications, which makes it a somewhat daunting research prospect. Indeed, there seems to be considerable uneasiness about technological research in writing and how such research should be done.

Although there is a great demand for this research, there are only a few specified methods that would particularly suit a study of word processors. Some basic and obvious questions are: (i) What do writers do in MS Word? (ii) Which functions do they use and which don't they use? (iii) How do they organize the interaction of text input and revision? (iv) What kind of language support are they using? (v) How do writers shuttle between word processors and other tools for translation, literature searches, note taking, feedback, collaboration, etc.? and (vi) How do writers choose their preferred word processors, and what do they think of them?

Such research questions aim to study the quality of word processors as a writing medium that enables writing and sets the limits. It would, at the same time, include the writers as actors relying on and responding to the medium. When the mediating force changes, the writing changes too, has been expressed by Haas (1989). But how can research react to a constant change? The comparability and generalizability of studies referring to technologies at different developmental stadiums must be questioned (Honebein & Reigeluth, 2021). Along with the generalizability, the integration of knowledge in the writing sciences is also in question.

4.2 Comparative Research and Intervention Studies

Historically, the first reaction to the new writing technology was to test it against the traditional one to see whether it led to better papers, made writing more enjoyable, and enriched writing processes in terms, for instance, of more planning or revision. Several reviews of this early research (Bangert-Drowns, 1993; Goldberg et al., 2003; Hawisher, 1986, 1988; Hawisher et al., 1996; Moran, 2003; Selfe, 1999; Susser, 1998) looked at studies comparing the new technology with previous ones. Most of them came from the K-12 context and sought answers to whether schools should switch from handwriting to computers (Bangert-Drowns, 1993). Expressed in terms of impact factors, the results of the meta-analyses were mixed. The impact factors, for instance, of computer writing on the text quality reported from the individual studies ranged from −0.75 to +1.75 (Bangert-Drowns, 1993), which gave a slight edge to positive impact even if reports on negative effects appeared repeatedly. Similarly, Goldberg et al. (2003) found in their meta-analysis that computer writing led to longer and slightly better texts. All in all, a small advantage of word processing over conventional writing can be derived from the comparative literature. From their meta-meta-analysis of writing studies, Graham, Harris & Chambers (2016) even made a substantial recommendation for "evidence-based practice" out of the "use of word processing as a stylus for writing" for students in grades 1 to 12.

Among the studies comparing the digital writing of college students with previous writing technologies, the work of Haas (1989) is instructive, including its programmatic title: "How the writing medium shapes the writing process." Haas restricted her study to the effects of word processor use on planning and compared three conditions of writing: One with paper and pencil, another using a computer only, and finally, a hybrid of the two. All test subjects were equally familiar with the word processor used—Carnegie Mellons's EZ word processor from the user interface "Andrew" which the university had developed in cooperation with IBM. Evaluating think-aloud protocols, her study was able to distinguish between several kinds of planning activities at several stages of the writing process. Protocols were transcribed and then analysed for statements referring to planning activities.

The results of Haas' studies showed a significant difference between the handwriting and the computer condition, but not between any of these two or the hybrid condition. When using word processors, writers planned significantly less before beginning to write, and did significantly less conceptual planning but more local or sequential planning. This effect was the same for experienced and novice writers. This tendency towards less conceptual planning surprised the author, and she speculated about the possible adverse effects of word processing. However, she did not (and certainly could not) consider back then that word processors would develop powerful tools for conceptual and structural planning such as outline functions or other text organizers to make up for the tendency of a shallower way of planning. The study also brings up the question whether planning in digital writing still is the same as in handwriting. Can we assume that Hayes and Flower's (1980) cognitive process theory, on which she relied, still applies to digital writing?

4.3 *Widening the Focus to Include Developments and Contexts*

During the 2000s, comparative research and intervention studies ceased. Writers now had up to 20 years of experience with computer-based writing, which had changed their attitudes, social practices, writing habits, and more. Qualitative studies, including the writers' personalities and biographies, seemed a more promising way to react to the new technology (Selfe & Hawisher, 2002). One consequence was the choice of single or small case studies to document the individual gain from digital writing (for example, Selfe & Hawisher, 2002).

Hartley (2007) proposed to focus on the *changes* in writing rather than on the writing itself. Treating writing as a fluid activity might bring back the generalizability of the results and account for one of the most salient aspects of today's technologies—its rapid development. In a small-case study, Hartley compared the texts which authors had written over a period of thirty years and showed that despite of considerable changes in working modes, some personal preferences and styles of the professional writers remained stable over time and different technologies.

Additionally, teaching contexts had also changed. Writing courses would move into the computer lab, laptops appeared in the classrooms, LAN and WLAN allowed for networked writing and learning management systems enabled an exchange of papers with more ease than before (see, for instance, Selfe & Hilligoss, 1994). Accordingly, the focus of research started to shift. Digital literacy became a new focus providing access to cultural change in writing and connecting it better with reading. Later in the 2000s, the internet made writing global, and word processors lost ground to browsers, which were the entrance gate to large social networks, new professional environments, sales platforms, digital library services, and search tools (see, for instance, Hawisher & Selfe, 2000).

It became clear that word processors were framed socially, economically, politically, and environmentally and had become part of a more extensive scenery that expanded the boundaries of digital writing. Consequently, evaluative research chose a broader focus for studying the effects of digital writing technologies. Purcell et al. (2013), for instance, surveyed more than 2,400 teachers about their evaluation of digital writing, from which 96% agreed that digital technologies "allow students to share their work with a wider and more varied audience"; 79% agreed that these tools "encourage greater collaboration among students" and 78% agreed that they "encourage student creativity and personal expression." As for disadvantages, 68% noted that digital tools made students more likely "to take shortcuts and not put effort into their writing"; 46% said that "these tools make students more likely to write too fast and be careless," and 40% said that they made students "more likely to use poor spelling and grammar" (although another 38% said they made students less likely to do this). The study of Purcell et al. (2013) suggested that research approaches should not only look at the interior complexity and sophistication of word processors but also at the complex digital and social environments they are part of.

Current research on digital writing similarly has expanded its focus to a broader view on technology, including “technology-based writing instruction” (Limpo et al., 2020; Little et al., 2018), “digital support for academic writing” (Strobl et al., 2019), Writing and digital media (Van Waes et al., 2006), “Digital tools in academic writing” (Schcolnik, 2018), or simply “digital writing” (DeVoss et al., 2010). Word processing has become part of a larger complex of communicative, enabling and educational technologies where it is difficult to single out its influences on writing and the writers.

4.4 *Keystroke Logging Studies*

New lines of research emerged when technologies for the registration and recording of digital writing processes became available—one was keystroke logging (or “key-logging” in short), and the other was screen capture or screen recording. Both provide insights into what happens during writing, although in different ways.

Eklundh (1994) developed a registry for keylogging activities, which recorded every input by the keyboard and the mouse along with a time stamp in milliseconds. Key logging is perhaps the most direct way of studying writing processes as it records all the commands given to the computer via the keyboard (and mouse) in a separate table. These tables can be processed and evaluated by statistical tools in various ways. Research summaries have been provided by the edited collections of Sullivan and Lindgren (2006) and Lindgren and Sullivan (2019). A profound account of keylogging technology is given by Wengelin & Johansson (“Investigating Writing Processes with Keystroke Logging”).

Keylogging led to various tools for writing research, such as “progression analysis” (Perrin, 2003, 2019), ScriptLog (Strömqvist et al., 2006) or “InputLog” (Leijten & Van Waes, 2013; Van Waes & Leijten, 2006). Keylogging research focused mainly on text progress (fluency), pauses, and revision activities as these variables are what the data reveal most easily. However, it can be connected to many other aspects of writing, provided respective data recording or evaluation measures are included (Wengelin et al., 2019).

Although keylogging produces valuable data to study writing processes, it has some restrictions. Logging data can register mouse clicks but does not cover the functionalities that the mouse addresses, such as changes in format, the opening of tables, creating footnotes, graphical insertions, use of outline generator, or literature management. Since none of these can be represented by keylogging recordings, logging studies were comparatively unsuccessful in assessing the technology of word processors and their various functionalities unless combined with other technologies such as screen recording (for example, Knospe et al., 2019), self-report measures, or eye tracking (Wengelin et al., 2019). Keylogging studies make it possible to assess the following variables:

- *Linearity*: Eklundh (1994), one of the pioneers of keylogging technology, used this technology initially to study the linearity of writing. She referred to any deviation of the generation of text from the final order in which the words appear as "non-linear writing." Even though she recognized non-linear writing as part of the recursivity of text production, she hypothesized that digital writing leads to new ways of non-linear writing. She built on studies by Lutz (1987) and van Waes (1992), who had observed that revision in digital writing was somewhat local in nature, while in her small group research ($n = 5$; four writing tasks), three of the participants were linear writers but changed their style to a more non-linear way of revising with more recursive changes.

- *Pauses*: The idea of studying pauses as an access point to thinking activities during writing has a long tradition (for example, Matsuhashi, 1981; Pianko, 1979). Flower and Hayes (1981) called them "pregnant pauses" to indicate that they are not simply time wasted but used to prepare the next part of the text or revise something already written. In cognitive models of writing, this is called "planning." Wengelin (2006) described a pause as any interruption that takes longer than the time needed to find the next letter. Accordingly, pauses can be classified along their lengths, their frequency, their consequences (resulting in a revision or new text), or their position in the micro context of text production ("within word," "between words," or "between letter and punctuation mark").
- *Revision*: The study of text revision is the most common use of keylogging research, as Eklundh (1994) demonstrated in a study on linearity. In this context, revision means to alter, delete, or replace any letter or word in a text. Revisions can be classified with respect to the time relative to the primary inscription (immediate, delayed, retrospective) or with respect to size (minor or major revisions).
- *Fluency*: Words in speaking and writing do not flow at a constant rate but rather as chunks of words which Chenoweth and Hayes (2001) called "bursts." The bursts of experienced writers are longer than those of inexperienced ones, and those of L1 writers are longer than those of L2 writers. Van Waes and Leijten (2015) showed that by adopting a process perspective fluency should preferably be approached as a multi-faceted concept. They identified four dimensions to describe fluency: (i) production (e.g., characters per minute), (ii) process variance (e.g., the standard deviation in character production during the process), (iii) revision (e.g., product/process ratio), and (iv) pause behaviour (Leijten et al., 2019, p. 72). Fluency can either be captured as a product-related measure (how many words result from writing in a particular time unit) or as a process-related measure (how many words are written down and eventually deleted again) in a specific unit of time.

Keylogging research opens the door to the study of writing processes as they happen in word processors and provides valuable indicators for relevant process parameters of writing, such as linearity, pauses, revision, planning, and fluency, which seem to apply to all forms of writing. If we see inscription as the defining element of writing, then keylogging provides access to the most salient aspect of writing. From there, inferences on the formulation processes and cognitive activities of the writers can be drawn.

4.5 Screen Recording and Screen Capture Technology

Screen recording or screen capture technology is a method that records what can be seen on the screen of the computer used. It runs in the background of the operating system and can record data from word processors or browsers (Geisler & Slattery, 2007; Seror, 2013). The data provided covers everything visible on the screen, such as inscription activities, the use of word processor support functionalities, all windows opened during observed session, all contacts to internal files, web-based sources, and use of tools other than the word processor. Screen recording is a technology applied most often in settings conducting usability research, along with eye-tracking and think-aloud or stimulated-recall assessments (for example, Menges et al., 2018). The primary difference between screen recording and keylogging is that the former does not automatically provide a database but must be evaluated manually by examining the recordings and applying additional analytic methods. The advantage of screen recording is the larger scope of relevant user data beyond the keystrokes, including shuttling between different texts, tools, websites, and services.

Screen recording research offers a powerful way to study what writers do with or in their word processors. Bailey and Withers (2018) used screen-capture methodology with 20 university students writing a summary and evaluated the screencasts in respect of the functions of MS Word they used. They found that the synonym finder was the most frequently used tool (23%), followed by spell checkers, grammar checkers, and external resources. Frequent use, however, did not necessarily mean improved writing. In 62% of cases where the synonym finder was used, the writers changed their text, but 29% of the chosen synonyms were unsuitable. Good technology can also result in a worse outcome; unfortunately, only eight of the 20 participants in the study were L1 English speakers, so conclusive generalizations about synonym finder use by either L1 or L2 students were not possible. Still, this research shows what can be done with screed recording.

A similar, small case study was conducted by Hort (2020) to examine how student writers manage their workflow in essay writing. As a result, she pleaded for more investigation into word processing, especially by studies considering the type of "navigation" through a text that can be seen in screen capture recordings.

Acknowledgements The research of Christian Rapp was financially supported by the ZHAW DIZH Fellowship Call 2020.

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Beyond MS Word: Alternatives and Developments

Christian Rapp, Till Heilmann, and Otto Kruse

Abstract Microsoft Word, the word processing software developed by Microsoft in 1983, established itself as the market leader in the 1990s and 2000s and remained the gold standard for many years. Despite its obvious benefits, it always faced criticism from various quarters. We address the persistent criticism that MS Word is overloaded with features and distracts from writing rather than facilitating it. Alternatives, mainly distraction-free editors and text editors for use with a markup language, are briefly reviewed and compared to MS Word. A serious challenger emerged in 2006 with Google Docs, a cloud-based writing software that has moved text production into the platform era, enabling files to be shared and creating collaborative writing spaces. Even though Google Docs failed to break the dominance of MS Word, it became the trend-setter in online writing. Microsoft and Apple soon followed by designing complex web environments for institutions and companies rather than individual writers. We give an overview of technologies that have evolved to challenge the supremacy of MS Word or compete for market share. By this, we hope to provide clues as to the future development of word processing.

Keywords Alternative word processors · Beyond MS-Word · Distraction-free writing

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_3

1 Overview

While, for a certain time, MS Word appeared to be the ideal writing tool and was the unchallenged market leader (Bergin, 2006), it had several shortcomings (see Bray, 2013; Johannsen & Sun, 2017; Sharples & Pemberton, 1990; Wilson, 2012), which motivated the search for viable alternatives.

- MS Word is tied to the paper world in several ways. It relies on pages as physical units of text and on the WYSIWYG (what you see is what you get) principle linking the text editor to the paper format. The programme mimics the format of a paper page and enables writers to create layouts and produce text. This direct connection is not inherently necessary as digital word processors can do without pages and, unlike a typewriter, can create the page design in a second step.
- For a long time, MS Word was limited in its capacity to present the mathematical equations and formulae needed in writing about science. Other software, for example, LaTeX, is more flexible in this regard. Similar specializations were created to accommodate specific domains or genres.
- Many writers have found MS Word to be too overloaded with functions for their purposes. Their needs led to the idea of plain-text tools allowing users to fully concentrate on content production while suppressing or masking all other functions.
- Synchronous collaboration of different authors in the same text was impossible in the desktop version of MS Word. This situation only changed when it became accessible as a web service with Office 365.

In the next section, we map the alternatives to MS Word and analyse how the word processing field has developed. We identify drivers for future developments and discuss their meaning for writing practice and the teaching of (academic) writing.

2 Core Idea, Functional Specifications, and Main Products

Several alternatives to MS Word are briefly described below, including the basic idea they follow and their main features.

(1) Office suites such as OpenOffice/LibreOffice include a word processor with similar features to those of MS Word. They are usually free of charge and open source.
(2) Google Docs is also part of an office package. It breaks new ground with a new way of software delivery accessed via a browser and running on a server rather than locally.
(3) Other word processors try to surpass MS Word in certain features, such as right-to-left writing support. MS Word usually incorporates these features over time.

(4) Distraction-free writing software does away with unnecessary functions claiming to help writers focus on the writing process itself.
(5) Markup editors separate text production from formatting and layout to give the user better control of both functions.
(6) Desktop publishing (DTP) programmes supplement rather than replace MS Word but may have a pivotal role in printing.

In this chapter, rather than adding a separate chapter on research, we integrated information on the literature, where available, into the description of the technology. Google Docs is covered in a separate chapter by Castelló et al. ("Synchronous and Asynchronous Collaborative Writing"), and research on word processors is reviewed by Kruse and Rapp ("Word Processing Software: The Rise of MS Word").

2.1 Parallel Solutions to MS Word

One of the word processors developed more or less at the same time as MS Word was StarOffice, which later became OpenOffice (now Apache OpenOffice) with the fork LibreOffice (for a comparison of OpenOffice and LibreOffice see Möhring, 2020). While this Microsoft competitor did not do as well as a business model, it was technically on par with the Microsoft Office Suite (cf. https://wiki.documentfoundation.org/Feature_Comparison:_LibreOffice_-_Microsoft_Office).

The precursor to StarOffice was StarWriter, which was released in 1985 and developed on the OS of Schneider/Amstrad CPC, after which it was exported to DOS. In 1993, it became available in Windows. The programme was developed by the Germany-based company Star Division, which added a complete office suite in 1992 called "office pack 2.0" (see StarOffice, 1998). The suite was expanded several times, and more than 20 million copies were sold. In 1999, Sun Microsystems bought StarOffice and released Version 6 of the suite under an open-source license as free software in 2000. This version can still be downloaded today from the openoffice.org website.

While StarOffice is no longer maintained, OpenOffice and LibreOffice were continuously advanced by a large community of developers. They are available for various operating systems such as Windows, MacOS, Linux, FreeBSD, NetBSD, OpenBSD, and Haiku. Both have no significant shortcomings compared to Microsoft Office. Like Microsoft's products, desktop, mobile, and online versions are available. Neither could, however, ever really compete with Microsoft Office financially, even if Open-/LibreOffice was, for a long time, one of the few office suites running on Linux. Incidentally, Open-/LibreOffice was and still is a feasible choice for public administrations, educational institutions, and companies looking for a free, open-source alternative to Microsoft Office.

2.2 *Writing in the Cloud: Google Docs*

The invention of, and advances in, cloud computing laid the foundations for a new wave of alternatives to MS Word, of which Google Docs is the best known and most used. As these solutions are discussed in depth by Castelló et al. ("Synchronous and Asynchronous Collaborative Writing") in the chapter on collaborative software, only key points are addressed here.

The technology for Google Docs was developed by Tom Schillace, who had co-programmed a word processor called Writely (Hamburger, 2013). Writely was not run locally on a conventional operating system such as Windows or Linux but on a web server; it was implemented to be used remotely via a web browser. It was acquired and adapted by Google in 2005 (McHugh-Johnson, 2021). Within less than a year, Google developed a version it called Docs, along with its online spreadsheet "Sheets". The beta versions of Google Docs and Sheets had many shortcomings compared to the sophisticated, convenient MS Office solutions. However, Google established a collaborative writing feature that allowed synchronous writing as an integral part of a freely available word processor. More importantly, this development opened a door to platform technology that all other providers of writing software had to take: Microsoft did so with Office Online in 2010, and Apple with its iWork apps in 2013 (see Ingraham, 2021). The announcement of Google Docs read as follows:

> With Google Docs & Spreadsheets, Google is taking a set of important tasks and offering an online solution to completing them individually or with a broader group. With a Google Account, a compatible web browser, and an Internet connection, users will now easily be able to:
>
> - Create documents and spreadsheets, and then manage and access them in a single, secure location
> - Easily collaborate with others, online and in real time
> - Export to and import from a wide variety of file formats
> - Share them with others as view-only
> - Publish them to a blog or as an HTML page
>
> Simply put, Google Docs & Spreadsheets is focused on providing users with an innovative and efficient way to create and share information on the Web. (Googlepress, 2006)

It is instructive to see Schillace's perspective on this from an interview with Oliver Burkeman:

> Word processors today were invented 20 years ago, when the endpoint of the document was usually print, so they were very focused in that direction,' Schillace says. 'But nowadays the endpoint of a document is usually communicating [online]: you're posting to a blog or a website, or you're emailing a document around. (Burkeman, 2006)

With the new browser-based word processors, software no longer had to be installed and continuously updated on a local computer but could be executed on a server and accessed through the internet (i.e., software as a service, SaaS). Saving documents was no longer necessary as the cloud-based software stored every input immediately.

In addition, by preserving the text's history, any former version could be restored. However, it became necessary for Google to create an offline function to make writing possible when an internet connection was unavailable or had broken down.

Another implication of platform-based software is that the documents, too, are stored on the server rather than locally. Along with online editors, cloud-based document structures were needed. Dropbox, Google Drive, and One Drive offered such a service with a vast storage capacity. These solutions became the basis for a large-scale file-sharing ability, a prerequisite for collaboration across larger teams or companies.

It is instructive to see what it took for Google to develop its software package beyond its beta status and integrate it into the emerging platform structures of communication, messaging, and networking. This process did not run smoothly but had severe drawbacks. One of the problems Google encountered was the need for synchronization of the online text with the locally stored text, a topic that is all but trivial technologically. In 2007, Google Gears was introduced, a browser extension for Mac, Windows, and Linux. It proved unstable and was dropped again in 2009 in favour of HTML 5 (Ingraham, 2021). Another failure was the introduction of Google Wave in 2009, a web-based platform meant to merge computational, communicative (email, instant messaging, wikis, social networking), collaborative, and writing software. Additional software such as automatic translation, spelling, and grammar checking was added or planned (see Google Wave, 2009). After only two years, it was abandoned, however, and sold to the Apache Software Foundation. Ingraham (2021) suspected that it happened "because it felt like even less of a finished product than most of Google's 'beta' launches."

Still, Google Wave anticipated developments that, ten years later, resulted in Google's "Workspace" (May 2021), previously called "G Suite" and "Google Apps" (a free version for private use with limited features exists as Google Docs Editors, 2022). Microsoft issued MS Teams in 2017 (followed by a free but limited version in 2018). On its part, Apple launched a version of iWork Apps in 2013, with a fully collaborative version to follow only in 2016. All three new platforms are not primarily aimed at individual users but at corporations and institutions that want to help their staff collaborate across the organization. It includes phone, video, messaging, email, text collaboration, translation, and more. For a short time, Google was the market leader in offering these platforms. With a market share of roughly 48 percent, the Microsoft Office package (Office 365) won back the pole position from Google Apps (46,44%) in February 2022 (Vailshery, 2022).

When it adopted cloud computing as the new technology, Google changed word processing forever by enabling truly synchronous writing and, even more, by turning the internet into the place where writing happens. Writing spaces shifted from local computers to the internet and the cloud accessed via the webbrowser, rather than a word processing software. The impact on writing in different contexts and the related research is discussed in depth in the respective chapter by Castelló et al. ("Synchronous and Asynchronous Collaborative Writing").

2.3 Outdoing MS Word

There are only a few applications on the PC word processing market that try to beat MS Word at its own game by offering a better word processor with regard to text editing or formatting capabilities. From the dozens—if not hundreds—of competitors in the 1980s and 1990s, no more than a handful remain today, the most popular one being WordPerfect. WordPerfect was created by Satellite Software International (SSI) and is today developed and distributed by Corel (see https://www.wordperfect.com). WordPerfect is a true WYSYWIG processor which was popular when DOS was the dominating operating system and it lost ground when Windows was introduced (see Bergin, 2006). For a long time, it was operated by key strokes only before it optionally integrated a menu band with key commands. Different from MS Word, control characters were visible within the text indicating what would be a headline or what would be printed in bold. The decline of WordPerfect, which for a period of time in the 1980s was the markt leader, seems to be owed to the increasing unpopularity of DOS, not to the unpopularity of the word processor itself.

Other programmes typically offer features that are—or were, at least—missing or more basic in MS Word and are geared towards audiences with particular needs. A good example of such a feature is support for right-to-left (RTL) writing in scripts like Arabic, Hebrew, or Sindhi. During the 1980s and 1990s, only a handful of PC word processors could handle RTL scripts and text. Even today, a lot of software from the western world still struggles to process non-Roman writing systems correctly (see Stanton, 2021).

By addressing otherwise neglected aspects of writing, competitors to MS Word have highlighted important characteristics and differences between various techniques and practices of writing across cultural, geographical, and linguistic boundaries. Catering to specific requirements and tasks, these programmes question the idea of a universal model for digital writing, a general-purpose word processor, or a one-size-fits-all technological solution to writers' wants and needs. It has to be said, however, that MS Word has always caught up with its competitors by incorporating features such as RTL and reference management.

In addition to the aforementioned WordPerfect, the most notable WYSIWYG alternatives to MS Word are probably Nisus Writer Pro, Mellel, Scrivener, and Storyist. Tellingly, perhaps, all of these, except for Scrivener, are macOS/iOS applications. While the programmes look and feel very much like MS Word and mostly implement near-identical GUI menus and commands for editing and formatting text, they nevertheless seek to differentiate themselves through distinctive functionality.

Nisus Writer Pro, for example, claims superior multilingual text support for writing in nearly any language and script. Similarly, Mellel provides multilingual support and commends itself for academic writing with its advanced bibliography and outlining tools. Storyist, on the other hand, is made explicitly for novelists, playwrights, and screenwriters with templates and formatting tools tailored to the respective literary genres.

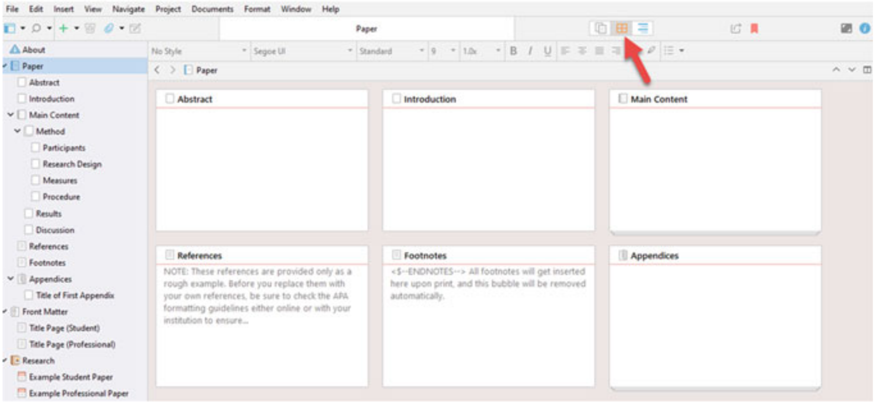

Fig. 1 GUI of Scrivener, storyboard view

Scrivener offers unique modes and features for planning, outlining, and organizing large writing projects in a modular structure. According to Bray (2013), it can be seen as a combination of a distraction-free tool (as discussed in more depth in the next section), creative writing software, and document management. Figure 1 shows one example of an unconventional view provided by Scrivener, in comparison to other word processors like MS Word or Google Docs, the story board view. Three alternative views (text, outline, storyboard) are easily provided by one click (red arrow). Bray (2013, p. 205) pointed out that

> These three types of alternative writing software have inspired Scrivener's key features: its support of nonlinear and distraction-free composing processes, the ability to view one's document in several modes, and the means to manage research and writing documents in one file. Indeed, it was the failure of standard software like Microsoft Word to support nonlinear composing processes and document management strategies that led Keith Blount to develop Scrivener.

Quite another idea is pursued by Thesis Writer (Rapp & Kruse, 2016, 2020; Rapp et al., 2015), a writing platform tailored to dissertation writing. At any level, dissertations and theses are writing situations or writing assignments with similar needs and demands. Thesis Writer uses an editor that is less elaborate than MS Word but adds specific functions such as tutorials, a proposal wizard, outline structures, sample phrases, corpus search tools, a project management tool, and more. At current (2023), Thesis Writer is available at the authors' Swiss university only.

2.4 *Distraction-Free Tools*

As alternatives to full-featured word processor systems, so-called "distraction-free" writing apps were created. Two examples of this type of software, which has gained some prominence in recent years, are iA Writer and Ulysses. Rather than adding more features or specializing in particular domains of writing, distraction-free tools emphasize ease of use. As such, they are the antithesis of the GUI and WYSIWYG models of writing embodied by MS Word.

Distraction-free word processors downplay the visual appearance of text on the screen and the possibilities for changing that appearance in favour of a much-simplified presentation and interface. They reject the logic of the printed page and conventional typography. Instead, they use the computer screen as a writing space "abstracted" from specific dimensions and materialities of paper and particular typographic realizations of text. Following the terminology of Bolter and Grusin (1999), distraction-free writing tools seek to replace the (simulated) immediacy of the printed page and the hypermediacy of the modern GUI with the immediacy of disembodied, "purely" digital writing.

Consequently, the options for formatting text are few and, typically—except for italics and boldface—restricted to semantic styles (i.e., section headings, block quotes, lists, etc.). Changing a text's physical aspects (e.g., font and size, indentation of individual paragraphs, and exact line-spacing) is usually impossible. Text is presented and processed as a construct of logical pieces rather than a primarily visual phenomenon laid out on the page.

As the name suggests, distraction-free tools promise to divert an author's attention as little as possible from the actual process of writing and the written text. To this effect, some programmes employ special features. iA Writer's "focus mode", for instance, keeps the sentence under the cursor always centred on the screen and dims all other visible text.

Of course, most regular word processors allow their interfaces to be customized by the user and thus can be made less intrusive or cluttered. Many programmes (MS Word among them) also offer a "distraction-free" modus. And some applications (e.g., Scrivener) could even be considered distraction-free out of the box as their graphical interface is relatively minimal.

However, actual distraction-free writing tools like iA Writer are built on the philosophy of decreasing functionality—and, by consequence, minimizing distraction—by giving authors only a restricted set of word processing options. Writing happens only at the level of entering and editing text in 'plain text' characters. This is achieved by replacing WYSIWYG processing capabilities with lightweight markup languages like Markdown, which is discussed in the following subsection.

2.5 Text Editors and Markup Languages

At the opposite end of the scale to graphical word processing with WYSIWYG is a return to the beginnings of digital writing. Using a markup language and a processor like Markdown (see Fig. 2 for an example), one can restrict oneself to a simple editor like Windows Notepad. Documents can be written and formatted as 'plain-text' files from which the processor generates 'output' files for printing or distribution, typically

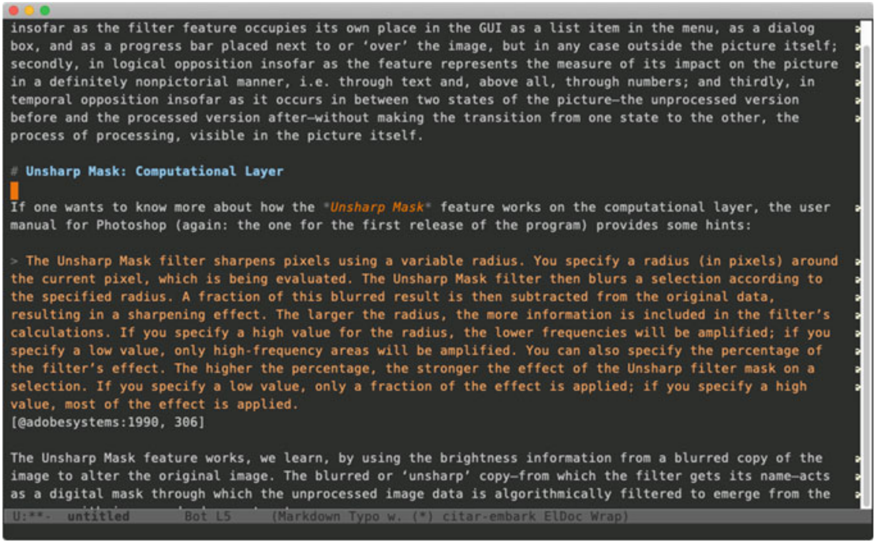

Fig. 2 Example of text formatted with Markdown language in Emacs editor

as PDFs. In theory, any WYSIWYG word processor application can be used like a simple text editor to write documents in markup languages.

Since RUNOFF, the first implementation of a digital markup language in the early 1960s, text markup technology has developed considerably. Today, there are almost as many different languages and processors for markup as there are editors. However, the idea has remained unchanged: Formatting and structuring text is achieved not by manipulating it on the visual level of WYSIWYG but by 'marking it up' with control characters and words that are constructed from ordinary characters and signs. In Markdown, for example, text can be *enclosed in asterisks* to emphasize it, or a # sign can be added to a line of text to denote it as a section heading. Only in the resulting output file produced by the markup processor will the corresponding text be italicized (for emphasis) or rendered in a larger font and possibly with automatic numbering (for a section heading). In addition to basic text formatting and structuring, modern markup languages also support procedures and practices necessary for academic writing, such as the handling of notes, tables, and figures, automatic citation, and reference lists.

The separation of content and style enforced by markup languages helps authors concentrate on the text without having to deal with matters of appearance and graphic design while writing and editing. Therefore, as in distraction-free writing tools, markup should be as minimal and unobtrusive as possible. More complex markup, such as in LaTeX, a user-friendly derivative of the typesetting language TeX, can easily get in the way of writing and make text files look cluttered and more like computer code than ordinary prose. This is the reason why distraction-free writing tools rely almost exclusively on the lightweight solution Markdown or one of its many variants. Other popular languages include BBCode, Textile, and reStructured-Text. (La)TeX, arguably the most versatile and powerful digital markup system, is used primarily in the sciences to produce documents with complex mathematical expressions and graphics.

Once early markup languages like roff and (La)TeX had been relegated to special domains and niche audiences by the success of WYSIWYG word processors in the 1980s, the advent of the World Wide Web with its HyperText Markup Language (HTML), along with blogging in the 1990s, led to a flowering of new languages and processors. It is no coincidence that Markdown, probably the most popular markup language today, was explicitly developed “to make writing simple web pages, and especially weblog entries, as easy as writing an email” (Swartz, 2004). Yet, the separation of content from style in Markdown makes it possible to produce output in multiple document formats from one and the same ‘plain text’ source file. With a processor like pandoc, text written in Markdown (or a comparable markup language) can be converted not only to HTML, but also to EPUB, PDF, RTF, or even MS Word docx.

A not insignificant benefit of using a markup language to write and format text is that authors are free to choose whatever editor they consider best. Even the most rudimentary text editor application will do. More powerful programmes such as Notepad++, Sublime Text, Atom, vi(m), and Emacs offer advanced text editing capabilities and can often be customized to a user’s needs and preferences.

2.6 Desktop Publishing

A final alternative to MS Word must be mentioned briefly: desktop publishing (DTP) programmes. Although not designed for writing and editing text, applications like Adobe InDesign nevertheless play a pivotal role in the digital production of printed text. DTP programmes are used to generate digital files for professional print publications.

While there is considerable overlap between the functionality of digital word processing and DTP, DTP applications are more robust in handling page layouts and offer more typographical control. And although editing text in DTP programmes is possible, this is not what the programmes are meant for. Typically, documents are written and edited by authors with standard word processing software first, then imported into DTP by the publisher and prepared for printing by typographers and graphic designers. As an author writing a text on your computer (even if the text is to be published professionally later on), you will probably never use a DTP programme yourself. Of course, word processors also do page layouts and typography. And some publishers will even demand camera-ready PDFs generated from the original MS Word manuscript (or comparable word processing programmes). Additionally, some markup languages and processors like DocBook and (La)TeX can produce high-quality output files suitable for professional printing.

Adobe InDesign has been the de facto standard for DTP since the early 2000s, taking over from Quark XPress. The commercial software Affinity Publisher and the free open-source programme Scribus are noteworthy competitors.

3 Conclusions

The monopoly position of MS Word as the dominating writing software has been dissolved mainly since Google Docs moved word processing into the cloud and forced all competitors to follow. Google Docs has been the gamechanger. Therefore, it is no longer the writing software itself at the centre, but the platform into which it is integrated. The new platforms host far more functionalities than the former Office solutions to act as working environments for companies or institutions. They are extendible, it seems, ad libitum. The creation of mega-platforms bundling a whole range of office software appears to be the current developmental trend. It is unclear whether this downgrades writing, but it certainly changes its position in social contexts and organizations.

Writing in word processors has lost some of its exclusiveness since writing has become part of almost all communication and learning media (learning platforms, blogs, email, chat, social media, calendars, mobile phones, etc.). The question arises as to what the role of the word processor in this orchestra might be or, to use another metaphor, how the role of word processors in a literate landscape hosting such a media ensemble should be specified.

The professional contexts of word processing have to be monitored more closely as the interconnectedness with domain-specific communication and design media is pushing writing into new directions. This generates activities for which the term "text work" (Bazerman, 2018) might be more apt than simply "writing". Also, new working spaces are being created that "invade" word processors, reducing their spatiality to a subsection of, for instance, MS Teams.

In addition to the greater variability of writing tools, the ability of word processors (and most tools contained in the Office packages) to enable collaboration reconnects writing and communication in new ways. Although synchronous collaboration seems widely accepted and is used routinely, there is little reflection on the changes this imposes on writing (see Castelló et al., "Synchronous and Asynchronous Collaborative Writing", for a deeper analysis).

With the arrival of alternatives to MS Word, a discussion has started about the most useful and most appropriate technology for writing. It seems that the one-fits-all era is over and that writing will have to be (or will be able to be) selective. Writers will soon be faced with the challenge of choosing the right tool for the right task. We have discussed a range of alternatives to MS Word that occupy different niches and serve specific writers' needs. Bray (2013) showed in her study about Scrivener how writing support for nonlinear composition can be connected with better options for outlining and synthesizing materials. In academic writing, we have very little knowledge about how students or researchers use their word processors and how linear or nonlinear their writing is (see Kruse & Rapp, "Beyond MS Word: Alternatives and Developments").

Other questions to address in this context include: Who supports students in their choice of writing tools? And can we assume that they can find the best tools by themselves? The more specialized the writing tools and the more numerous the solutions on offer, the less likely it is that students will make appropriate choices. The same goes for decisions such as whether to use online or offline processors and whether a large platform is preferable to self-organisation of the writing software.

The future of writing is hard to predict. Still, for the writing sciences, it will be important to understand and keep close track of developments which are too important to leave up to computer scientists and programmer communities. As we have seen, writing software will increasingly assume the role of a co-author, not only by supporting and guiding writers but also by co-producing and co-evaluating the texts that are written.

4 List of Tools

Name (alphabetically)	Category	URL
Adobe InDesign	Desktop publishing	https://www.adobe.com/products/indesign.html
Affinity Publisher	Desktop publishing	https://affinity.serif.com/
Apache OpenOffice	Parallel offers to MS Word	https://www.openoffice.org/
Atom	Text editors and markup languages	https://atom.io/
BBCode	Text editors and markup languages	https://www.phpbb.com/community/help/bbcode
DocBook	Text editors and markup languages	https://docbook.org/
Emacs	Text editors and markup languages	https://www.gnu.org/software/emacs/ https://emacsdocs.org/
Google Docs	Writing in the cloud	https://docs.google.com/
iA Writer	Distraction-free Tools	https://ia.net/
iWork	Writing in the cloud	https://www.apple.com/iwork/
LaTeX	Text editors and markup languages	https://www.latex-project.org/
LibreOffice	Parallel offers to MS Word	https://www.libreoffice.org/
Mellel	Outplaying MS Word	https://www.mellel.com/
Microsoft 365	Writing in the cloud	https://www.microsoft.com/en/microsoft-365?rtc=1
Nisus Writer Pro	Outplaying MS Word	https://www.nisus.com/pro/
Notepad++	Text editors and markup languages	https://notepad-plus-plus.org/
pandoc	Text editors and markup languages	https://pandoc.org/
Quark XPress	Desktop publishing	https://www.quark.com/

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Name (alphabetically)	Category	URL
reStructuredText	Text editors and markup languages	https://docutils.sourceforge.io/rst.html
Scribus	Desktop publishing	https://www.scribus.net/
Scrivener	Outplaying MS Word	https://www.literatureandlatte.com/scrivener/overview
Storyist	Outplaying MS Word	https://storyist.com/
Textile	Text editors and markup languages	https://textile-lang.com/
Ulysses	Distraction-free Tools	https://ulysses.app/
Vi(m)	Text editors and markup languages	https://www.vim.org/

Acknowledgements The research of Christian Rapp was financially supported by the ZHAW DIZH Fellowship Call 2020.

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Web Applications and Platform Technology

Hypertext, Hyperlinks, and the World Wide Web

Susan Lang and Craig Baehr

Abstract Hypertext, defined at the most essential level as "linked text," and the hyperlink (shortened to simply "link") serves as the foundation of much writing in digitally native spaces, impacting print-based writing. The World Wide Web has stood for nearly three decades as the primary implementation space for hypertextual writing. The characteristics of hyperlinking, intertextuality, multi-pathed organization, hypermedia, content forms, and collaborative authoring practices have come to replace print-based writing conventions as the dominant features of electronic-based ones. Research has been conducted on hypertext and the World Wide Web since their inception by computer scientists and writing specialists, among others, to better understand technological needs, writing pedagogies and practices, as writers work from an increasingly diverse input base—from computers to tablets to mobile devices.

Keywords Hypertext · World Wide Web · Hyperlinks

1 Overview

Hypertext was touted in the 1980's and 1990's as a revolutionary concept that was capable of instantiating much of contemporary critical theory, yet one whose definition proved difficult. It has been labelled as "non-sequential writing" (Nelson, 1993, p. 17), a "system of linked presences" (Kolb, 1994, p. 335), and as catalyst for discontinuities in a primary narrative. But with the advent of Berners-Lee's World Wide Web (WWW), hypertext became a (some might claim "the") primary method of conveying content to users—content developed to take advantage of the brief attention span of a user seeking information and content developed to be consumed

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_4

in a way more analogous to print media. Given the span of possibility, hypertext and the WWW have and continue to be explored as places to create and revisit conceptions of what it means to construct and experience information. This chapter will explore some of the main trends in hypertext/WWW research in the last several years, building on such work as Lang & Baehr (2012 & 2019), particularly as they apply to writing and writing instruction.

Foundationally, the idea of what would become known as hypertext was developed in the 1930s and published in 1945 by Vannevar Bush, a science advisor to U.S. President Franklin Roosevelt. Bush was concerned about the growing volume of scientific information and the difficulties that sorting through and indexing such information would pose for scientists. The Memex (MEMory Extender) would enable a user to keep their own library of texts in which the user could create associative links (the first hyperlink!) between ideas across documents. Although the Memex itself was never built, Bush's ideas were taken up by others in the 1960s. In 1965, Theodor (Ted) Nelson created the terms hypertext and hypermedia and began work on a hypertext system known as Xanadu (https://www.xanadu.com.au/projects.html), work that continues even today. As personal computers became more available, a variety of iterations of hypertext and hypermedia systems were constructed, including Symbolics Document Examiner, Guide, and HyperCard. While all contained the ability to link topics and paths throughout individual hypertexts, they did not do so at the scale envisioned by Bush, Nelson, or other early hypertext developers.

The World Wide Web project, developed from 1989 at CERN by Tim Berners-Lee, dramatically changed the landscape of hypertext. One of the original project summaries, from an email by TBL from 1991, https://www.w3.org/People/Berners-Lee/1991/08/art-6487.txt describes the role of hypertext in its genesis: "[the project] merges the techniques of information retrieval and hypertext to make an easy but powerful global information system [and] is based on the philosophy that much academic information should be freely available to anyone." In 1994, Berners-Lee left CERN for M.I.T. and founded the World Wide Web Consortium (W3C), which continues to define standards for web technologies and recommendations for use (https://www.w3.org/Consortium/mission).

Since its conceptual inception, hypertext has been closely connected to academic writing in scientific and technical disciplines. For a period of about 20 years, from the 1980s through the early 2000s, the study of hypertext and its potential connections to modernist and postmodernist literature and literary theory sparked interest in areas of literature and creative writing, as well. *StorySpace*, developed by Jay David Bolter, John Brown, and Michael Joyce, became the platform in which much hypertext fiction was composed during hypertext's peak as a literary genre; it is still marketed by Eastgate Systems (http://www.eastgate.com/). Although the literary shelf life of hypertext was fairly brief, the implementation of a key feature, the hyperlink has become a ubiquitous feature of digital writing. Further extensions have become fully realized as both commercial and personal products, including Berners-Lee's World Wide Web, individual Web sites, wikis, blogs, content management systems, learning management systems, social media applications, and many others.

2 Core Ideas of Technology

Hypertext is built upon the singular premise inherent in its basic definition, linked text, including all its possibilities both structurally and semantically. Baehr and Lang (2019) identify the key tenets of hypertext as an information technology, which summarizes its features and potential, which include hyperlinks, intertextuality, multi-pathed organization, hypermedia, content focus, and collaborative authoring capabilities, derived from both hypertext scholarship and the many applications that have followed. Hyperlinking includes the basic feature that any section of content, whether visual, spatial, or textual, can be associatively linked to others based on a discrete semantic relationship. Intertextuality describes the relationships between different linked content chunks or sections, suggesting that they also share semantics in terms of their meaning, use, or relationship. Multi-pathed describes the wide variety of organizational and navigational choices and possibilities within a hypertext. When at its full potential, hypertext offers users different navigational options, which they can employ based on need or interest, and not necessarily following a set linear content experience or path when interacting and reading. *Hypermedia* describes the range of multimodality possible with hypertext, in that content can be static or dynamic, asynchronous or synchronous, audio or video, passive or interactive in nature. In fact, hypermediated content is unrestricted and fluid, in all of these aspects, allowing for hybridity in content presentation and form. As such, within a hypertext, content creates the experience and is the primary element around which all other aspects are built upon, whether visual, spatial, or interactive. Because, in theory, hypertext cane be modified by anyone with write/edit privileges to a particular text or site, hypertext displaces the notion of a singular author or creator of content, in most cases, fostering the possibility for collaborative authoring of content. Hypertext's use of semantic hyperlinking allows multiple content sources, and information products, to be interconnected in different ways, which essentially encourages this collaborative aspect. Whether multiple hypertexts are connected through hyperlinks, networking, or other techniques, these references enable the inclusion of content from other sources, into the primary one, suggesting the many different applications that hypertext affords.

Hypertext's prescribed use has been primarily as a model for electronic, interactive, networked content, which is prevalent throughout virtually all information technologies today, including the World Wide Web and social media applications. A wide range of open-source markup and scripting languages have been developed with capabilities that allow hypertexts to realize their full potential as electronic information products. The core languages widely used include Hypertext Markup Language (HTML) and Extensible Markup Language (XML) for content markup, Cascading Style Sheets (CSS) for design styling and presentation, and JavaScript (JS) and Hypertext Pre-Processor (PHP) for adding interactive features both client and server-side. These languages are imbued with many of the core tenets, or characteristics, of hypertext, including the abilities to hyperlink, create intertextual semantics, present complex information structures and hierarchies, and integrate interactive and multimodal content experiences. In a sense, these languages also comprise part of the actual literacy of electronic writing. A wide range of development tools can also be used, which assist developers in the actual coding and implementation of these languages in creating hypertext systems.

Hypertext, as a technological innovation, describes emergent features of writing in both hybrid and electronic environments. While it was conceived in an era when print-based communication products were dominant, many of its characteristics were simply not possible Because in a print-based environment due to inherent limitations of printed methods and materials. While printed books could reference other sections using textual references, they lacked the ability to create complex interactive features, which hypertext affords. But electronic environments, many of which were designed specifically for hypertext, could imbue the aforementioned characteristics of hyperlinking, intertextuality, multi-pathed organization, hypermedia, content forms, and collaborative authoring practices. In essence, these key characteristics of hypertext have come to replace print-based writing conventions as the dominant features of electronic-based ones and even, to some extent, in the production of print supporting materials (Baehr & Lang, 2019).

3 Functional Specifications

Hypertext provides the fundamental framework upon which virtually all electronic information products and documents are built and has changed writing at both authoring and reading levels, Hypertext has changed how information products and documents are composed and created, creating possibilities for dynamic and interactive content that were not possible under print-based constraints. Hypertext authoring supports a rich, complex environment in which information products have improved structural, semantic, and presentational aspects. Hypertext encourages collaborative and multimodal authoring practices, as well as new ways to network and share information resources. It has also changed the ways in which readers approach many texts. In a pre-hypertextual era, readers approached most texts as something to be read from a starting point to a finishing point. Only reference texts (encyclopaedias, dictionaries, manuals) were not assumed to be read end to end, though even manuals were constructed with a particular (hypothetical) sequence of tasks in mind.

Additionally, the World Wide Web Consortium (W3C) provides functional specifications for the markup languages and supporting scripting and programming languages that support hypertext development. Its core mission is to serve as an international community that develops standards and specifications that support a thriving World Wide Web (http://www.w3c.org). The specifications provided span the entire range of markup and scripting languages, which support the Web and hypertext development, including HTML, CSS, JavaScript, XML, PHP, and many others. Additionally, the W3C provides supplementary Web Content Accessibility Guidelines, which can be used to help hypertexts improve access to users with specific limitations or disabilities when accessing content.

A robust user community and wide breadth of informational resources are available, which support hypertext, its core markup and scripting languages, and development platforms and supporting tools. User communities often have their own resource libraries and Web sites that allow users to freely comment, troubleshoot, and share content across a broad user base. Some examples of useful resources include graphic and media libraries, markup and scripting libraries, automated validation tools, design templates, site map generators, analytics tools, and many others. While these communities and resources do not represent formal specifications, they provide valuable informational resources that support both hypertext development and its community, as functional assistive tools for developers and users. Many hypertext's capabilities have been realized over time and through the development of various specifications, communities, and resources. However, the tool demands and relies upon continual development of supporting technologies.

4 Main Products

The main products of hypertext include the World Wide Web, content management systems, and the use of embedded hyperlinks throughout electronic documents and products. While many early iterations of hypertext had their own proprietary software-based environments, the Web and supporting browser tools have helped advance more standardized methods for hypertexts, particularly those available on the Internet. Web browsers are perhaps the most useful tools when it comes to interacting with hypertexts that are essentially Web-based, whether present on an internal network (intranet) or on the Internet. Web browsers serve as tools, which interpret markup and scripting languages used in hypertexts, making them accessible through local files as well as through Universal Resource Locator (URL) address.

Content management systems, and their various extended applications including blogs, learning management systems, wikis, etc., serve as useful hypertext development tools to help developers with the tasks of designing, organizing, and presenting hypertexts as fully-developed, data-driven Web sites. Other hypertext development tools include a wide range of text editing and Web development software programs, which can be used as authoring environments to create hypertexts. Many development tools include supporting content libraries to assist developers with more complex authoring tasks, including interactive forms, built-in applications, media libraries, and wizard tools that help users drag-and-drop content and make selections as they develop various hypertext features. Many tools also include robust editing and validation tools, which assist developers with quality assurance tasks, to ensure both content and markup conform to project and standardized specifications.

Hypertext continues to evolve as a technology, so its development can be considered to be actively progressing. Standardized solutions for developing and presenting hypertexts capabilities have arrived, however, as new technologies and capabilities are integrated into the markup and scripting languages and development and presentational tools, these will continue to evolve and realize additional features and capabilities. An example of this is with the core HTML markup language specification, which for nearly two decades, was used without revision. In the mid-2010s, version 5 of the HTML specification was released, which integrated expanded support for structural and semantic markup, as well as graphic and media presentation capabilities, while depreciating older features, such as frames and stylistic presentation attributes. Similarly, over the course of the Web's development, other languages have undergone similar progressive transformations. Subsequently, these and other technological advancements in computer hardware and software have influenced the changes and capabilities of hypertext and its primary product, the Web, and its various applications.

5 Research

Research on hypertext and the World Wide Web as academic writing tools has been conducted since the 1980s on hypertext, and since shortly after the inception of the web. Nearly 100,000 publications on hypertext have been published since the 1980s and generally fall into one of the following categories: hypertext systems and specifications; hypertext and critical theory; hypertext and reading; hypertext and hyper/interactive fiction; hypertext and the materiality of writing; and hypertext and writing pedagogy. If one adds in publications on hypermedia/digital media/ multimodal composing, as well as publications examining writing for/with the world wide web, the number of publications may well reach into the hundreds of thousands.

The most sustained source of research into hypertext, the Association for Computing Machines Hypertext and Hypermedia conference (ACM HT), has published proceedings of these conferences since 1987 and remains the most complete source to understand the evolution of hypertext research. The 32nd HT conference, completed virtually in September 2021, provides insight into current key issues in hypertext/hypermedia research. Atzenbech and Cheong (2021) explain that only a few of the "original" hypertext topics, such as system infrastructures and hypertext in electronic literature, have been sustained throughout conference history and that actions must be taken to ensure that hypertext community does not fragment and vanish. They propose the *International Teaching and Research in Hypertext (INTR/HT)* project as a way to rebuild a teaching and research community focused on hypertext.

The thread of hypertext scholarship most dominant in the 1980s and 1990s was that which claimed hypertext as the instantiation of postmodern critical theory; George Landow (1991), perhaps the most prolific author in this thread, establishes the link: "critical theory promises to theorize hypertext and hypertext promises to embody and thereby test aspects of theory" (p. 3). Landow creates links between Barthes, Derrida, Foucault, and Ong, among others. Bolter (1991, 2001) explains that readers are experiencing the "late age of print" and similarly connects hypertext to postmodern theory as well as reader-response theory as it recreates and reconfigures writing spaces. While this line of scholarship continues to inform discussion of hypertext in some areas, McEneaney (1997) posed a challenge to this perspective, arguing that the break between print and hypertext was not nearly as neat or as simple as Landow, Bolter, and others had posited.

Two peer-reviewed journals, *Computers and Composition (C&C)* and *Kairos: A Journal of Rhetoric, Technology, and Pedagogy*, have focused since their inception on digital technologies and (primarily) academic writing. Authors publishing in these venues explored implications and applications of hypertext and web technology for students in a variety of post-secondary writing courses. Research focusing primarily on hypertext flourished in *C&C* from 1990–2005, although authors continue to discuss multimodal and web-based writing to the present day. *Kairos* has published all works as "webtexts" since its first issue in 1996 and in doing so, mandated that authors engage in composing hypertextually as they write about digital composing pedagogies and practice. In Technical Communication, flagship journals, including *Technical Communication, Journal of Technical Writing and Communication, IEEE Transactions on Professional Communication,* and *Technical Communication Quarterly*, have published numerous articles concerning hypertext and its applications. As well, hypertext and related topics regularly appear on programs of major conferences in the field, such as Association for Teachers of Technical Writing (ATTW) and the Conference on Programs of Technical and Scientific Communication (CPTSC).

Usability in regard to hypertext and webtexts has focused on both the functionality of the construct and the user experience (U/X) while acknowledging the shortcomings of conventional usability measures. Since the early days of hypertext, usability and U/X researchers have developed a robust research agenda which examines and tests various features of hypertext's applications. Many of these are highly situated studies. Following, a few representative studies. Nielsen (1989) examined 30 usability studies of hypertext and concluded the development of a single hypertext UI design that worked for the majority of users was unlikely. (Note that this work pre-dated Berners-Lee's WWW). Smith (1996) noted that the exploratory nature of hypertext made typical usability measures difficult; Smith called for measuring time to find information and charting routes taken through the text to do so. Chen and Rada (1996) extend Nielsen's work as they echo his primary finding—that the complexity and dynamic processes that underlie users' experience with hypertext makes evaluating its usability difficult. Naji (2021) provides usability guidelines for hypertext links, but no testing protocol.

6 Implications for Writing Theory/practice

Prior to the development of the World Wide Web, those interested in writing hypertextually designed and/or developed platforms, including Ted Nelson's *Xanadu*, Brown University's *Intermedia*, Eastgate Systems' *StorySpace*, and Apple Computer's *HyperCard* to test the tenets of hypertext theory. These systems ultimately were dwarfed by the the unveiling and explosive growth of the World Wide Web which refocused the trajectory of hypertext writing and research, as well as in many ways redefined the distribution of formerly print-restricted academic texts. Print textbooks have been supplemented by online, hypertextual resources or replaced by curated open-source material either available freely on the web, developed locally by instructors, or curated from university libraries. Many academic journals no longer publish print copies; increasingly, the entire submission, review, and publication process occurs online. Even in manuscripts published in pdf format to enable printing often include hypertext links to sources and supplemental material—this material would not have been easily accessed in a pre-hypertext age. And in the teaching of academic writing at all levels, students work with genres and concepts of writing informed by hypertext, especially if they are creating multimodal work. Hypertext thus represents one of the foundational theoretical subjects for digital writing and literacy as we approach the end of the first quarter of the twenty-first century.

7 List of Tools

HTML (Hypertext Markup Language)	a standardized system for tagging text files that enables them to be viewed in a web browser	https://www.w3schools.com/html/
CSS (Cascading Style Sheets)	describes how web pages are to be displayed on screen, on paper, and other media and can be used to format multiple web pages at once	https://www.w3schools.com/css/
JavaScript	An advanced programming language used to make web pages more dynamic and interactive	https://www.javascript.com/
XML (Extensible Markup Language)	a fully customizable system for creating tag sets and markup languages, of which HTML is one example	https://www.w3.org/XML/

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Creativity Software and Idea Mapping Technology

Otto Kruse, Christian Rapp, and Kalliopi Benetos

Abstract This contribution focusses on technologies connected with the graphical representation of knowledge and text content through the generation, creation and organization of important concepts, thoughts or ideas into visual diagrams. Although they already existed in the pre-digital era, with digitalization, mind maps and concept maps have been scrutinized methodologically and the scope of their use has been expanded with respect to function and applicability. For writing, mapping technologies serve both a creative function to develop a pool of interconnected ideas from where to begin writing and a selective and structuring function to organize content during writing. Both kinds of mapping have been developed primarily as learning and thinking tools but can also be used as valuable means of connecting thinking and learning with writing. The contribution shows important developments as well as methodological differentiations and suggests the integration of idea mapping technologies into writing courses at the early undergraduate level, particularly in connection with the teaching of reading, summarizing and synthesizing sources.

Keywords Creativity software · Mind mapping · Concept mapping · Idea mapping

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_5

1 Introduction and Background

Creativity techniques in writing had been fairly well established at the time when digitalization set in. Basic concepts for such techniques came from stage models of writing which always suggested brainstorming and idea-collecting activities as a pre-writing phase (Anson, 2014; Murray, 1985; Rohman, 1965). Differing from the demanding formulation activities, where ideas have to be linearized into a coherent succession of words, the preparatory activities were assumed to undercut the grammatical and linguistic constraints of formulation activities and focus on thought and concepts instead.

Creative thinking was thought of as an uncensored, associative, and "left-hemispheric" activity producing more ideas than necessary for a text so that writers could select the most relevant ones. The most prominent philosophy of idea development as a preparation for writing came from Elbow (1981, 2000) who established free writing and automatic writing as modes of idea generation. To him, there were four main benefits of free writing (summarized and quoted from Elbow, 2000, pp. 86–88):

- It gets writers going and makes it much easier to begin
- It does not only lead to words on paper but also initiates thinking
- It "puts life into our writing: voice, energy, presence"
- it makes writers experience themselves as writers when enjoying the surprising results of spontaneous text production.

Cognitive process models of writing, such as that of Hayes and Flower (1980), de-emphasized the role of brainstorming activities in favour of a rather rational activity of planning, thus accounting for idea selection more as a problem-solving activity than as a creative one.

A decidedly creativity-enhancing approach was offered by Rico (1983) who connected idea development with a graphical arrangement of thoughts which were placed in circles around a core word. Here too, idea development was enhanced by abstaining from formulation activity and consisted in jotting down just single words or expressions and encircle them. Similarly, as in Elbow's free writing, writers were instructed to reduce rational control of word production and let the unconscious guide the pen. Every word can lead to new, associated ideas which are then also encircled and connected to the first one with a line. When enough associations have come up, a tentative network of ideas is available to start writing. Rico's main idea of creativity involved making use of graphical arrangements to arrive at a bi-hemispherical engagement of the brain and avoid early rational filtering of the ideas. Only when the associative process has dried out, a conscious selection and connection of the ideas should take place. To our knowledge, there is no digital version of clustering directly based on Rico's approach, but some versions of the mind map technology come close to it (for instance, Scapple, see below).

A group of techniques appealing more to the rational side of the mind compared to Rico's clustering are mind maps and concept maps (Novak, 2010), here summarized as idea mapping technologies. Other terms for them are "knowledge maps"

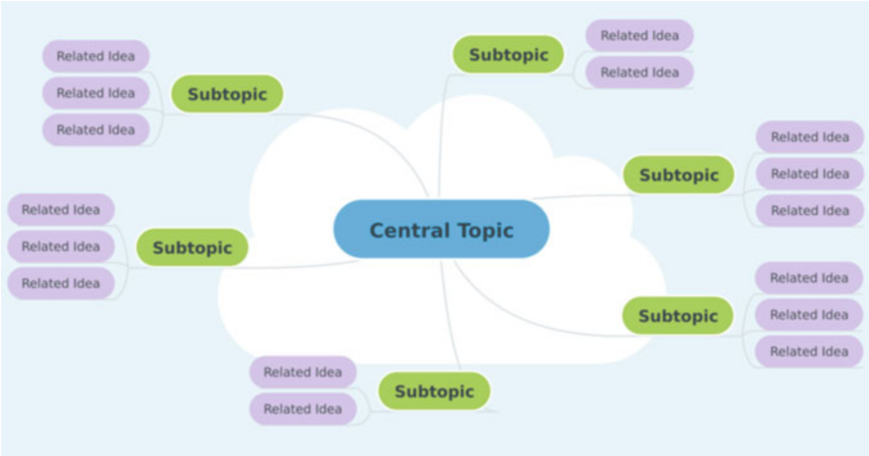

Fig. 1 Mind map schema. From: https://www.mindmeister.com/blog/wp-content/uploads/2019/09/Mind-Map-Example-796x417.png

(O'Donnell et al., 2002) or "graphic organizers" (Alvermann, 1981; Ives & Hoy, 2003), knowledge maps or node-link diagrams (Nesbit & Adesope, 2006), or mind tools (Jonassen & Marra, 1994). Both forms make use of graphical arrangements to create and organize thought. They also aim to make accessible for inspection what a thinker has in mind. They see their techniques as multi-purpose tools that can be used for various activities, such as idea-generation, note taking, summarizing, memorizing content, organizing ideas, understanding complex matters, or preparing to write a paper. This last function, as it pertains specifically to academic writing, is what we focus on in this chapter. Other graphical organizers such as flow charts, Venn diagrams, Vee diagrams or conceptual diagrams are not considered here as they are preferably used as a visual communication media, not as part of writing activities (Fig. 1).

Buzan (2006) designed the mind map technique primarily as a thinking device. The technique consists of writing a topic or core issue in the middle of the paper and then add branches to other concepts (nodes), each of which represents a relevant aspect of the topic. The branches receive names and smaller branches are attached on them, each of them representing a separate, subordinate aspect. Mind maps feature what are referred to as spoke, radial or hierarchical tree-like structures. Michalko (2006, p. 67) described the five common features of all mind maps. They

- organize topics
- work out core aspects of topics
- illustrate relations between the aspects on the map
- form thematic clusters
- focus thoughts around the topic (involvement).

Concept maps follow an idea similar to mind maps but are justified more as a way of representing knowledge than as a tool for thinking (see Fig. 2), even though thinking and knowledge seem to belong to two sides of a single coin. Developed by Novak (2010) in the 1960s, concept maps were initially considered a pedagogical means of representing the knowledge students have acquired but soon the concept was expanded to a tool for a wider range of tasks and users. Novak and Cañas (2006) describe the basic structure of concept maps: Concept maps are graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts. Words on the line, referred to as linking words or linking phrases, specify the relationship between the two concepts. We define *concept* as *a perceived regularity in events or objects, or records of events or objects, designated by a label.* The label for most concepts is a word, although sometimes we use symbols such as + or %, and sometimes more than one word is used. (See Fig. 2 as an example)

Hay and Kinchin (2006) identified three predominant concept map structures though there may be some deviation or crossover with a single concept map. In predominantly *chain* structures, concepts are linked sequentially. In *radial* structures, a central concept branches out into subordinate concepts, resulting in a root or tree-like structure. *Network* structures can have multiple links to and from concepts and do not adhere to a top-down hierarchy. For Hay and Kinchin, concept maps are a representation of conceptual knowledge to be used to assess learning, where the richness of the conceptual understanding is characterized by the number of concepts and crosslinks between them.

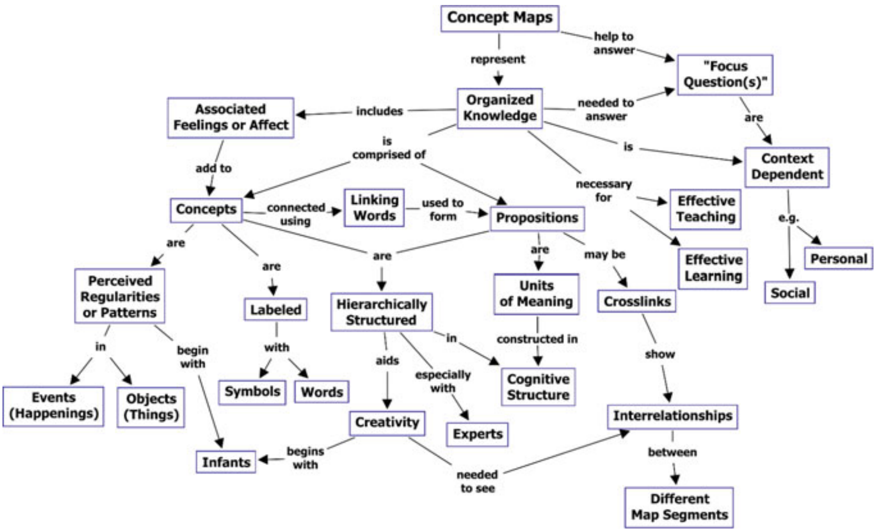

Fig. 2 Example of a concept map that represents concept mapping (Novak & Cañas, 2006)

A meta-analysis of Nesbit and Adesope (2006) from 55 studies on the effects of concept and knowledge maps in secondary and higher education showed constant learning gains in various tasks and in comparisons with other forms of knowledge representations from readings such as lists or notes. Unfortunately, information on the support used for mapping (digital or paper) and when digital, on the type of tool used, was not provided. The study was also primarily interested in learning and retention effects after reading, rather than in the effects on writing practice.

Eppler (2006) notes that concept mapping techniques are difficult to apply, particularly for non-academic users:

– they have relatively strict formal rules that have to be followed
– the emphasis on identifying concepts and relations is time consuming
– the general top-down structure of concept maps (from concepts to examples) may not always be adequate to represent sequential content (processes, timelines)
– the boxes-and-arrow format makes it difficult to efficiently represent a great number of items.

These difficulties seem greater for concept maps than for the less-demanding mind maps.

Both techniques, mind maps and concept maps, were theoretically framed as tools for self-directed learning and intellectual empowerment. As writing in education, similarly, fulfils both functions, they do connect well. What makes concept maps differ from mind maps is that the connecting lines between the elements may be named, thus allowing writers to specify the kind of relationships between the concepts. Labels may be pre-given (like "is" and "has") or may be created by the user, thus connecting two elements by labels such as "results in", "contains", "means", "is necessary for", "is part of", and so on. The connecting lines usually are arrows to indicate that the relations specified are unidirectional. Mind maps in contrast, only specify higher-order and same-order aspects: mainly indicating different levels of abstraction organised in sets and subsets. While mind maps simply name elements (or thoughts) and order them, concept maps create more complex structures by connecting two ideas with a connecting element such as "Creativity - > needed to see - > Interrelationships." Each of these triplets forms a concept of its own. As each element may be connected to several other elements, a network of ideas arises.

2 Core Idea of the Technology

The opportunities which a transfer of idea mapping technology into digital environments would offer were obvious. Instead of drawing circles and squares around the text on a separate sheet of paper, it could be done in the same environment and be connected to the emerging text in various ways. As multimedia opportunities were one of the most remarkable features of early digital writing software, the graphical approaches of mind mapping and concept mapping inspired many developers to create digital supports for these activities. Both are part of a larger class of visualization software, which also includes such graphic elements as Gantt diagrams and flow chart diagrams which are not discussed here as they are not used to enhance writing. Software such as MindManager, Cacoo, Diagram.net and Lucidchart include various types of premade “nodes” for specific types of diagrams, such as Gantt and flow charts, as well as node palettes and chart templates for modelling domain specific activities (business, engineering, software development, etc.).

Although faithful to their paper-based ancestors both, digital mind maps and concept maps changed in many ways and were enriched with additional functions and an extended list of applications in different fields. Digitalization primarily added an easy-to-handle graphical design with flexibly arrangeable boxes, branches and connecting lines along with optimized modes of inserting content. In the last decade, these have moved from locally installed software to online application services. This has added the possibility to collaborate on single maps and co-construct knowledge representations offering artefacts for socio-constructivist learning scenarios and collaborative writing (Kurniawan et al., 2020; Mammen, 2016).

Using idea mapping technologies is part of several activity fields which overlap but may form a particular focus:

- Reading: active reading, note taking, and summarising
- Writing: idea development and conceptual elaboration
- Content development and analysis: Exploring complex systems of ideas or phenomena
- Communication: Information visualization
- Project work: Idea management and workflow

In summary: Idea mapping technology may be seen as an alternative form of knowledge generation, organization, visualisation, and representation avoiding time consuming verbalizations of content in linear script. Both technologies have moved away from a stage approach to writing to accompany the whole writing process by mapping and documenting the core elements of the emerging text in a separate document. Idea mapping helps the writer both to prepare the core ideas of the text but also to keep control over what has already been said and what has to be said next. With digitalization, the maps can easily be modified and ideas can be rearranged to represent emerging text structures and revised in parallel to writing. Idea mapping technology thus supports or prepares decisions on linearity of content. Aside from writing, they can serve as a way to document the results of reading and note taking, record the results of discussions, explore knowledge structures, make conjectures, while supporting project planning, project supervision and metacognition.

3 Main Products

Although mind and concept maps share some basic ideas and can be produced within the same application, they have remained two separate approaches, both conceptually and technologically. A fairly complete list of technological solutions, including free ware is provided by Wikipedia under https://en.wikipedia.org/wiki/List_of_concept-_and_mind-mapping_software. Software development, however, has gone separate ways for each approach.

The first digital version of the mind map appeared on the market in 1994, initially under the term MindMan, then Mindjet, and beginning in 2006, MindManager. Techradar.com (https://www.techradar.com/best/best-mind-map-software) claims to have listed the best mind map software, some of them, however, in fact, are concept mapping software—indicating the often conflating of mind mapping and concept mapping as the technologies evolved. Of the software listed at Techradar.com, only Scapple, a mixture between mind mapping and concept mapping software, is specially designed for writers. Scapple is a comparably low-cost application, easy to handle and in a certain way it follows Rico's (1983) clustering idea: Click on any space of the screen to place a note there and repeat this until all ideas are deposed. Writers/users may then move the ideas around and start connecting them to look for concepts and structures from which the writing project can emerge. Another software that connects both kinds of mapping and is particularly designed for writers is Inspiration, see https://www.inspiration-at.com.

Fewer applications are available for concept mapping. Next to the dominant CMap Tools, there are Lucidchart, Cacoo, Coggle, yEd (both concept and mind mapping), and Visual Understanding Environment (VUE) that support concept mapping amongst other services and proposed process templates. The Wikipedia entry for Concept and Mind-Mapping software https://en.wikipedia.org/wiki/List_of_concept-_and_mind-mapping_software lists many tools and platforms and presents examples of their graphical appearance.

4 Functional Specifications

The number of idea mapping software and applications that include mapping offered today is hard to estimate. The PAT website (Predictive Analytics Today) on https://www.predictiveanalyticstoday.com/top-free-premium-mind-mapping-software/ lists 29 mind mapping tools in 2021. Wikipedia lists mind maps and concept maps in comparison, including a list of freeware under https://en.wikipedia.org/wiki/List_of_concept-_and_mind-mapping_software. What most idea mapping technologies include is:

Visualizing large numbers of ideas and concepts in one space: A key point of all mapping software is to make all elements visible on one page (i.e., at one glance) before they are linearized and hidden in the long language strings of written text.

Colours: Mind maps encourage the use of different colours for different branches, thus codifying relationships and enhancing the visibility of structures.

Shapes: Concept maps encourage the use of shapes to create visual relationships between nodes that are not linked, or to define additional attributes of concepts that their placement cannot denote.

Moving ideas and concepts around: A flexible, effortless arrangement of elements is a basic requirement and makes comfortable handling of large numbers of ideas possible. Usually drag and drop technology is offered.

Use of symbols other than words: Many tools allow users to choose or create non-linguistic symbols for more expressive maps. In some cases, this makes mapping more playful and more attractive for users.

Creative design ideas and choices for the users: Offering palettes of box shapes, colours, lines, background containers, and overall configurations is standard. Most tools try to appeal to the creative forces in users by offering them many opportunities for designing their maps. How much this adds to idea mapping is not clear.

Transfer of content from maps into script: Maps can be transferred by exporting functions diagrams. Some tools also allow maps to be exported as outlines, lists, SVG formats or Excel documents, which then can become part of the text.

Collaboration: Most browser-based tools by now have a function for real-time collaboration offering tool boxes for idea development, often enriched by white boards, story boards, containers for ideas, chat functions or blogs.

Content management: Almost all current software offers linking documents and URLs to nodes.

Animated maps: Both mind and concept mapping software can offer animations by making elements move and form developmental sequences. Usually, a presenting software such as PowerPoint, Prezi, Google Slides or similar (overview: https://www.techradar.com/best/free-presentation-software) is used in addition.

5 Research

Idea mapping technology has been studied in various settings and for different educational purposes. Research in the context of writing in higher education, however, is amazingly scarce. It seems most research has been done in second language learning and mostly for secondary education (Fu et al., 2019). The preferred context of studies is the field of reading and learning. Meta-analyses reveal a constant gain in learning outcome for the use of mind maps and concept maps when learning tasks are studied as Liu et al. (2014) showed for mind maps, and Nesbit and Adesope (2006) for both, mind and concept maps. When looking to assess the strength of the relationship between concept mapping and learning through effect sizes, they found that both, creating concept maps (0.82) and studying concept maps (0.37) were associated with statistically significant advantages over other modes of instruction such as lectures or whole-class discussions. Effect sizes are statistical indicators for the extent to which a certain treatment influences a target variable. They may be calculated differently. Positive values of 0.3 would indicate a small of 0.8 a medium size effect. If the same treatment is tested in multiple studies, then a meta-analysis may calculate aggregated effect sizes which are seen as the best indicators for evidence-based practice.

A new meta-analysis by Schroeder et al. (2018) in which they connected their data with the previous one of Nesbit and Adesope (2006) led to altogether 142 independent effect sizes from more than a hundred studies. They found an overall effect size of 0.58 for the use of concept maps as compared to other ways of instruction. Effect sizes were higher when maps were created by the learners themselves and not only offered as summaries for knowledge fields. Effect sizes were greatest when concept mapping was compared to other teaching forms such as lectures/discussions.

Batdi (2015) collected 15 studies published between 2005 and 2013 comparing the use of mind maps in higher education. In his meta-analysis, he received effect sizes of 1.05, 0.62 and 0.43 for the criteria of academic achievement, attitude towards the task, and pure retention measures respectively. Even if this study was not related to writing, its effectiveness for learning and academic achievement suggests that it might also improve writers' attitudes and engagement in writing projects, particularly with respect to a better understanding of the knowledge base of the intended text.

6 Implications of This Technology for Writing Theory and Practice

6.1 Writing Spaces, Digital and Real

Transferring the conceptual and terminological content from text to a graphical representation leads to a uniquely new digital space for thinking aside from the word processor. It might be characterized as non-linearized content representation enabling the writer to see large numbers of ideas in one view, a comfort which linear texts do not easily provide in such detail (the outline does a similar job but with less comfort and detail). While linear text can be read in one direction only, mappings can be read in various directions. What is said later does not depend on what has been said earlier. Mapping follows the logical or conceptual relations between ideas and not the sequential one in textual content-building. This is often considered the particular freedom which mapped collections of ideas provide.

6.2 Organizing Writing Processes

Mind and concept maps may precede or accompany writing processes and serve a high number of functions for text development such as planning, conceptual enrichment, thinking things through, step-by-step progress. They also prevent an early closure of idea development which may happen when writers verbalize their ideas right away, before structuring them.

6.3 Conceptual Thinking and Cognitive Processes

Both kinds of mapping technologies belong to the class of mindtools (Jonassen & Marra, 1994). They build valuable bridges from linguistic representations to more abstract, cognitive representations. Both of them show, however, that conceptual thinking always relies on terms and names for concepts without which any higher-order thinking cannot happen. There is a lot of little-explored cognitive activity involved, such as grouping thoughts, connecting them to concepts, specifying their relations, creating hierarchies of thoughts, connecting abstract and concrete issues, coordinating definitions, and isolating cause-effect relationships. Introducing a second technology next to the word processor helps understanding the conceptual side of writing and provides a deeper access to *writing-to-learn* as well as to *writing-to-think* aspects of writing. Idea mapping guides idea development and provides a semi-lexicalized structure of the possible content. Its activity comes close to that of an outline generator but it allows for a more focussed approach to interrelating content elements.

6.4 Formulation Support

Mind maps and concept maps do prepare formulation effectively, even if they do so particularly by abstaining from linearized text. They can, however, prepare a conceptual and terminological bone structure of the text-to-be-developed and relieve formulation from (some part of) conceptual thinking which has been done beforehand. It should be kept in mind, however, that there is probably a transfer in both ways, from conceptual thinking to formulation and from formulation back to the conceptualizing. Therefore, it should be recommended to develop maps not only in advance of formulation but in correspondence and close connection with the text development.

6.5 Writing Opportunities, Assignments, and Genres

Mapping approaches should not be considered separate assignments and should be taught in connection with regular writing prompts. Mind maps and concept maps are neutral with respect to genre. They can be used for stories as well as for essays or research articles, provided that terminologies and registers are adequately matched. A good opportunity might be to connect mapping approaches with the teaching of process-based writing to show what the change from conceptual to language-based idea development is.

6.6 Collaborative Writing and Collective Papers

Almost all mapping technologies allow for group work, be it synchronous or asynchronous. Mind mapping can be a good way of planning a project or paper together, while concept mapping additionally seems to be a way of jointly exploring a knowledge field. Both mapping approaches are fairly unique in instigating collaborative thinking and abstract thought.

6.7 Does the Digital Technology Improve Writing Quality?

There are indicators that the text quality of second-language writers is improved, particularly in summarising tasks (Yang, 2015). Liu (2011) found that using concept mapping as a pre-writing activity, whether done individually or collaboratively, resulted in better texts than the no-mapping condition. The quality of the concept maps also correlated to text quality, particularly for higher-level writers producing maps individually. The main effect should be that mapping technology support structuring and memorizing efforts in writing and learning. This, however, has not been studied in connection to improving writing quality as little as it has been in learning tasks.

6.8 Author Identities, Roles, and Audience

The use of mapping technology probably does add a new and favourable facet to the writer's identity by offering them a better access to the conceptual side of writing in connection with the mastery of a (complex) digital environment. This may prove as an important asset on the way of intellectual independence and critical thinking. In collaborative digital writing spaces, concept maps can be used to organize and structure collective knowledge in pre-writing stages.

6.9 Technological Knowledge

What competences are needed for future writers? For student writers, an introduction into mapping software seems necessary and useful. Both groups of tools help bridge academic writing with intellectual development and thus deepen the impact of the writing-to-think connection that writing usually has. It can lure writers away from believing that it is mainly rhetoric and style that makes a good text in favour of a more material- or content-based view. Also, it makes content better accessible to tutors and supervisors visualising the gist of the piece to be written.

6.10 Learning to Write: Can Machines Teach Concept Mapping?

Mapping tools, we believe, cannot teach themselves but need some instruction. While software has become increasingly accessible to mainstream users, understanding the linking and labelling approach that is more conducive to elaborating and reflecting on ideas on a deeper level than the simpler categorization of parent–child node structures requires some guided practice. This is may be particularly important to early-stage or lower-level writers.

6.11 Limitations and Dangers

Users following different writing strategies may react differently to such a tool. Fostering abstract thinking better than strategies built on formulation, concept mapping software favour not only conceptual thinking but also the collection of concepts and ideas, providing a valuable basis for formulating text. However, the shift from collecting and connecting ideas to formulation into text seems a critical one. Mindmap's hierarchical tree structures are easier to translate into linear text than networked concept maps, which may comprise more and richer connections between concepts. While a text can be enriched by a good concept map, it may be hindered by a poor or unclear map that represents ideas still under development.

7 Conclusions and Recommendations

7.1 Writing Practice

Connection of knowledge organization and writing can be well supported by mind or concept mapping technology. It is unclear, however, how different types of writers and writing strategies interact with the preference for such technology. Modes of using maps as pre-writing tool or as a tool accompanying text production seem both possible but are unexplored.

7.2 Teaching

Idea mapping needs some training to get started with. Training should contain both usage of the technology and introduction to a certain tool. Idea mapping tools are a good candidate for the writing course or the composition class as it can illustrate the relationship of content organization in a visualized, static way and content organization in a linearized, dynamic way as in script. It can also connect with learning theories and learning development, provide a valuable connection between language and knowledge, and allow writers to prepare the interconnection of thoughts in a text (particularly concept maps which specify relations between concepts).

7.3 Research

Studies on the uses of mapping technology in connection with L1 writing are missing in research. Also, differences between both mapping technologies are not widely explored with respect to their usefulness for writing.

7.4 Tool Development

There are currently many software applications that resemble each other and appropriating one to particular academic writing needs and processes is difficult. Software development needs to investigate devices for facilitating the transition from conceptualization in networked maps to linearization into written text. These devices could allow for indicating pathways or tagging nodes like in VUE (Visual Understanding Environment) and exporting text according to a defined structure. Too few applications allow users to import a body of text or data and easily transform it into nodes. This can be particularly useful for academic writing where outside sources of information need to be integrated into the conceptualization or pre-writing phases.

8 List of Tools

There are a vast number and variety of available concept mapping software as either software to be installed locally as desktop applications or as browser-based web services. While some are limited to text nodes and interlinking, many also offer customized icon or shape nodes for targeted diagramming uses (process modelling, flowcharts, wireframes, UML). Most online services allow some form of sharing and real-time collaboration (Table 1).

Table 1 List of a selection of concept and mind mapping software

Software	Mapping type	Access	Specificities	Licencing
MindManager (formerly MindMan) https://www.mindmanager.com	Concept map,Mind map	Local installation and web versions	Microsoft Teams integration	Proprietary
Inspiration https://www.inspiration-at.com	Concept map	Local installation	Computer and mobile devices, aimed at educators and researchers	Proprietary
Freeplane https://www.freeplane.org	Mind map with limited cross-linking	Local installation	Portable to USB drive	Open-source
XMind https://www.xmind.net/	Mind map	Local installation and web versions	Desktop, mobile and web versions	Freemium
CMap https://cmap.ihmc.us	Concept map	Local installation and web versions	Aimed at educators, research-based design, collaborative	Proprietary freeware
Scapple https://www.literatureandlatte.com/scapple	Concept map	Local installation	Freeform note connecting, aimed at writers	Proprietary
Mindomo https://www.mindomo.com	Mind map	Local installation and web versions	Outlining	Freemium
Bubbl.us https://bubbl.us	Mind map with limited cross-linking	Web version only	Limited use without sign-in, Collaborative with sign-in	Freemium
Coggle https://coggle.it	Concept map	Web version only	Adapted for touchscreen manipulation	Freemium
Cacoo https://www.cacoo.com	Concept map, Mind map	Web version only	Multi-palette nodes for dedicated uses	Freemium
Wisemapping https://www.wisemapping.com	Mind map	Web version only	Portable to other servers	Open-source, freeware online for individuals
IdeaFlip https://ideaflip.com	Sticky notes, linked or grouped	Web version only	Process templates for groupwork	Freemium

(continued)

Table 1 (continued)

Software	Mapping type	Access	Specificities	Licencing
Lucidchart https://www.lucidchart.com	Concept map, Mind map	Web version only	Process templates for groupwork, Specialized nodes for dedicated uses	Freemium
yEd graph editor (part of yWorks suite) https://www.yworks.com/products/yed	Concept map, Mind map	Local installation and web versions	Specialized nodes for dedicated uses, aimed at developers	Proprietary freeware
Visual Understanding Environment (VUE)—from Tufts University https://vue.tufts.edu	Concept map, Mindmap	Local installation	Aimed at educators and researchers. Data and ontology imports, metadata scheming, visual pathways for presentation	Proprietary freeware
Vym (View your mind) https://sourceforge.net/projects/vym	Mind map	Local installation	Some added content and task management features	Open-source

Acknowledgements The research of Christian Rapp was financially supported by the ZHAW DIZH Fellowship Call 2020.

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Digital Tools for Written Argumentation

Kalliopi Benetos

Abstract Digital tools for argumentative writing aimed, from early on, to support the use of argumentation to develop knowledge about the topic being argued. Many products were initially created to serve research purposes, and few developed in the last thirty years have made it to the educational technology market for use by instructors and writers. Others are reserved for institutional use or have become obsolete. More recently, research in argumentative writing has moved away from digital platform development specifically aimed at argumentative writing, to simpler generic diagramming and collaboration tools to be integrated in learning activities. Development has focused more on analytic approaches to generating representations of writing (processes and products), while research has shifted towards strategy instruction and related design principles. A selection of differing environments developed to support argumentative writing will be presented to highlight the evolution and the gaps in digital tools for written argumentation.

Keywords Computer-supported argumentation · Digital authoring tools · Written argumentation

1 Introduction

Argumentation has been used for millennia as a means of investigating claims through critical thinking to arrive at informed decisions and build knowledge. Argumentative writing is used in a wide range of academic contexts as a means to develop, convey and measure an individual's learning and understanding of a selected topic. While the structures, practices and conventions of argumentation may vary from one domain to another (for example in Law, Science or Medicine), written argumentation is valued as a pedagogical approach because it calls upon cognitive and meta-cognitive processes demanded by both writing to learn and argumentation. It

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_6

also calls upon cognitive and metacognitive skills particular to written argumentation such as goal setting on the topic and task level (Bereiter & Scardamalia, 1987; Felton & Herko, 2004; Galbraith, 1999), and the acquisition and application of knowledge of the structure of discourse and its components (Bereiter & Scardamalia, 1987; Flower et al., 1986). It also involves the recall and reconstitution of domain-specific knowledge and the evaluation of the validity of arguments and counterarguments (Limon, 2001), as well as a self-evaluation of both process and learning goals (Flower et al., 1986) and the capacity to engage in and self-regulate metacognitive reflection (Felton & Herko, 2004; Karoly, 1993; Limon, 2001). It offers the opportunity to consider multiple perspectives and to confront, reason and resolve contradictions that arise so as to expand and deepen knowledge and enable changes in conceptual understanding (Andriessen, 2006; Kuhn, 2001; Leitão, 2000; Scardamalia & Bereiter, 2006). Engaging in argumentative writing thus requires that a vast range of skills be learned in order to engage the critical thinking and writing strategies needed to produce academic level argumentative texts and learn through the processes involved.

Technologies for supporting written argumentation support three main activities: *learning to argue*, *arguing to learn* and *learning about argumentation* (Andriessen et al., 2003). Though there are numerous technologies and software to support reasoning and argument construction, our focus in this chapter is on technologies that aim more intentionally to support the development of skills necessary for writing academic texts using the argumentation genre to present and support a hypothesis or thesis statements within linear text formats of which learning to argue and arguing to learn is indisputably a part.

1.1 Background

Computer-supported argumentation technologies burgeoned in the late 1990's and early 2000's with early support for generating and analysing arguments through *markup* languages that could be used to analyze, formalize, diagram and visualize argument structures and components based on argumentation models drawn from Toulmin (1958) and Walton (2008), among others. These systems used diagramming devices to graphically organise units of information (textual nodes) and their relations (links) using visual properties to attribute to them their function in argumentation based on defined argumentation ontologies and models (Desmet et al., 2005; Gordon & Walton, 2006; Reed & Rowe, 2001; Smolensky et al., 1987). Current argumentative writing tools still embody selected models of argumentation or strategy instruction formalized in frameworks and markup languages and that are represented and rendered operational through the applications or devices within platforms or systems and the guidance they offer.

As digital technologies for delivering applications online evolved, an abundance of diagramming tools has become readily available through navigators (Cmap Tools,[1]

[1] Cmap Tools: https://cmap.ihmc.us.

Cacoo,[2] Diagrams.net,[3] Mindjet, etc.) or commonly used applications (Microsoft Word, Microsoft PowerPoint, Google Draw, Google Docs). Diagramming tools allow users to create text within shape forms or *nodes*, and join them together using arrows and lines to create visual *links* (see Sect. 2 chapter Creativity Software and Idea Mapping Technology). In parallel, argumentation systems designed specifically for diagramming argumentation and writing argumentative texts have become more heavily standardized systems or have given way to strategy instruction combined with simple generic tools to diagram and produce argumentations. In this chapter, we review several digital argumentation systems, their underlying technologies and functionalities, and discuss which cognitive and metacognitive skills are called upon and supported by these systems. We describe how such applications can generate representations of writing processes, support argumentation, and facilitate strategy instruction. Possible developments and tendencies leading to the divergence between multi-feature domain-specific systems with heavily prescribed uses, to more generic multi-purpose, readily available devices in combination with scripting or strategy-based approaches will be discussed. We argue that this use of technology reflects instructors' and learners' preference for versatility in software as opposed fully digitalized writing-support systems.

2 The Core Idea Behind Digital Systems for Argumentation

Argumentation systems often integrate multiple technologies to offer systems that include various devices and services for processes and activities related to generating or analysing argumentation. Applications and platforms offer various devices to scaffold argumentative writing, using diagramming and outlining, and prompts for generating, elaborating and linking arguments, alone or in combination with textual or graphical representations, to offer progress indicators on states and goals to be achieved and guide actions to be taken (see examples shown in Figs. 1,2,3 and 4). They provide process and product models for constructing arguments, with or without strategy instruction.

Within these digital environments, users learn through the process of written argumentation by completing tasks using the support embodied in various suggested use schemes and representations of components and actions to be taken to build arguments and argumentations. They can provide contextual cognitive aid through prompts for the development of ideas and the linguistic means to link these ideas. This is achieved in the tools themselves through diagramming, outlining and elaborating text. Knowledge is built by developing an argument, which creates the mental scaffolding for learning content.

Additionally, users of these digital argumentation tools can learn about argumentation through the representations and guidance. They diagram and outline their

[2] Cacoo: https://nulab.com/cacoo.

[3] Diagrams.net: https://app.diagrams.net.

argument to visualize it, organizing arguments according to their relationships to each other and the rhetorical goal. As such, digital argumentation systems offer support for learning and mastering the structure of discourse on the local argument level, and with regards to its function within the textual discourse moving towards a global rhetorical goal.

Finally, users learn to argue through practising reasoning and learning about the conventions of argumentation. Through various awareness tools that reveal traces of interactions, they can also be encouraged to collaborate with or solicit feedback from peers and instructors about the structure, purpose and effectiveness of the argumentative writing, and become aware of procedures implicit in the embedded scripts. This can be achieved through diagramming and dynamic feedback, as well as reading or elaborating text.

3 Examples of Digital Tools for Written Argumentation

Recently, digital argumentation tools have moved from purpose-specific systems to general interaction devices that can be exploited for diagramming, leaving guidance and strategy instruction to the classroom rather than embodied in the system. In what follows, we will present and discuss a selection of digital argumentation environments currently in use or development that support reasoning and argumentative discourse but differ in the forms and types scaffolding and representations they offer as well as their prescribed uses. By assessing the main similarities and differences in their affordances and prescribed uses, we will be better positioned to identify factors that may explain the scant and slow adoption of digital tools for argumentative writing in classroom settings. We will look more closely at the following representative sample of environments currently in use and their tools: Rationale, Endoxa Learning, Kialo and C-SAW.

With the exception of more generic concept mapping tools, the systems presented here were developed from academic research-based contexts aiming to improve argumentation skills and learning from argumentation in educational contexts (K-12, undergraduate or graduate levels) with the goal of building academic writing skills.

3.1 Rationale

Rationale is a pay-for-service web-based environment designed for "argument mapping" to support reasoning. It allows learners to create maps in order to "structure arguments," "analyse reasoning," "identify assumptions," and "evaluate evidence," (*Rationale,* 2022). Rationale is the most complex of this sampling of digital systems for written argumentation, offering templates and examples for scaffolding written argumentation in various contexts.

Rationale allows users to create and change a visual representation of their line of argument. This starts with a main argument, a claim, a position, a proposition, or a contention. Users then build on that argument by adding reasons to support their main argument to which objections can also be added. Reasons and objections can be supported by examples and additional nodes for citations or statistics.

There are three map types (argumentation schemes) in Rationale: *Grouping*, *Reasoning* and *Advanced Reasoning*. While *Grouping* allows learners to link ideas, *Reasoning* and *Advanced Reasoning* allow them to design an argumentation (Fig. 1). Rationale can be used to question the validity and clarity of an argument and its structural components. It offers an "Evaluate," menu where users can qualify or rate argument components. Rationale is not a synchronous collaborative tool, but users can share maps so they can be modified by others. It also offers note taking for idea-generation and multiple essay planning templates for various argumentation genres to guide drafting outlines and structuring the text as a whole (linearization). The text produced is visible in a sidebar and can be exported as a Word document.

Though the justification of the design and prescribed uses of Rationale are explicitly founded on research on the benefits of computer-aided argument mapping (Davies, 2009; van Gelder, 2007), much of the research using Rationale does not aim to look at the particular mediating effects of Rationale's specific devices and their affordances. Rather, it exploits artifacts and traces to examine the effects of computer-aided argument mapping in general on thinking and writing (Lengbeyer, 2014; Maftoon et al., 2014).

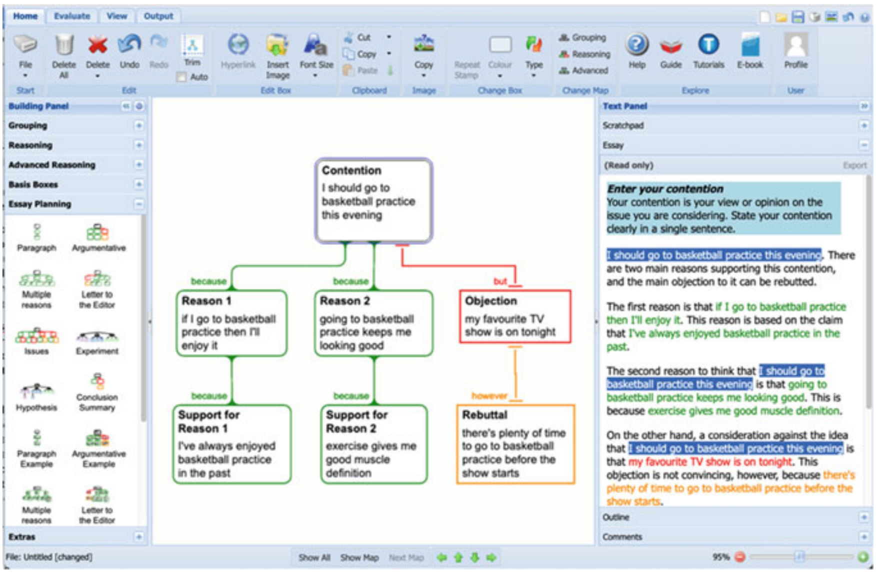

Fig. 1 Rationale interface showing categories of argumentation schemes and essay support

3.2 Endoxa Learning

Endoxa Learning is a relative newcomer to the domain of argument diagramming (graphing). Aimed at improving academic argumentation by scaffolding reasoning and critical thinking, it targets primarily educational institutions. It includes off-the-shelf lesson plans with ready-made topical argument graphs based on an existing corpus that learners can peruse or engage with and elaborate, and integrates quiz functionalities to evaluate learning acquisition. Unlike most argument diagramming systems, Endoxa Learning (Fig. 2), uses Walton's critical questions approach to engage reflection upon different argument types (e.g., analogy, generalizations, cause and effect) that is more adapted to hypothesis testing and problem-solving in science and engineering teaching domains, rather than the more commonly used Aristotelian thesis-antithesis-synthesis or Toulmin argumentation models. (Nussbaum & Edwards, 2011). Each type of argument presented by the user has characteristic ways in which it can be supported or undermined, and these are captured by the critical questions suggested (purple node in Fig. 2) While it currently uses some corpora for the generation of context or argument-type specific guidance prompts, further topic and domain specific corpora integration is currently under development.

Research specific to the use of the Endoxa Learning has yet to be published, but the website offers a whitepaper and a list of research publications upon which its design and development is founded (*Key Articles - Endoxa Learning*, 2022).

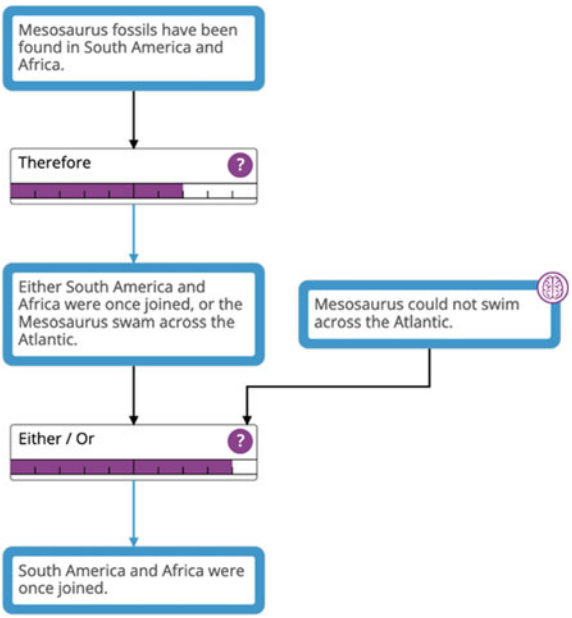

Fig. 2 An example from using Endoxa Learning a two-step argument to draw a conclusion. Questions marks raise critical questions. Brain icons call up factual information and sources

3.3 *Kialo*

Kialo is a web-based platform which aims to provide an environment for collaborative structured discourse and debate. While Rationale, Endoxa Learning and C-SAW focus more on guiding learners to create and modify an argument through learner-system, instructor-system and learner-instructor interactions, Kialo is based on peer feedback, and, to a lesser extent, strategy instruction. Discussions on Kialo can be public, or private and Kialo-edu provides closed debate spaces for instructors and classroom use with added class management services.

Using Kialo (Fig. 3), learners may create a thesis or join an existing discussion. Learners and their peers can add pro or con arguments to the thesis, and comment on the arguments. Arguments are nested in branches and threads that can be expanded and rearranged. The nesting visual interface, like Rationale, gives the learners a representation of how arguments in an argumentative essay are built.

Kialo offers little contextual guidance towards constructing a valid or sound argument. While it allows one to export a discussion in text format, it does not give any explicit guidance or devices for organizing a collection (branch) of arguments into a linear text.

The Help section, however, offers clarifications on what makes a good claim, how to support a claim and how to use sources, which can be considered a basic form of strategy instruction external to the application. The evaluation of the soundness of arguments relies on a peer voting system. This may raise awareness about the

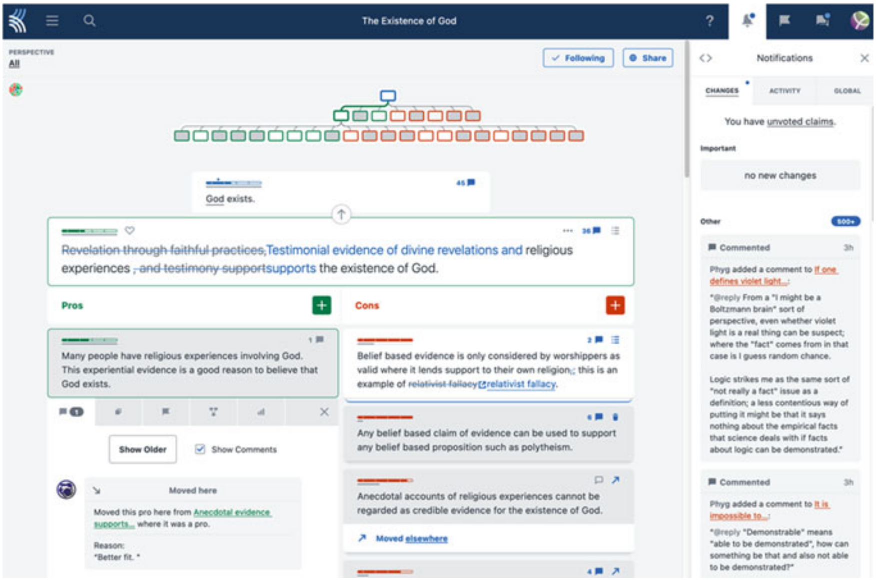

Fig. 3 Debate Structure in Kialo

target audience of a well-written arguments, but it does not provide prompts for good writing per se.

Kialo is not used exclusively for supporting written argumentation. It can also be used in different contexts for decision making. With the advent of web 2.0 technologies that spurred the social web, online debating platforms began to flourish and remain popular, but subject to short lifespans. Kialo, with its added learning management and export options has become one of the most popular digital argumentation tools, with many other similar ones available online: Acceptify,[4] Socratrees,[5] DebateGraph.[6]

3.4 C-SAW (Computer-Supported Argumentative Writer)

C-SAW, a web-based authoring software, aims to scaffold writing processes of novices within instructional designs that use argumentative writing as a pedagogical approach to develop reasoning, knowledge construction and critical thinking. It is built upon ArgEssML, an XML markup language specifically designed for developing digital tools for argumentative writing. ArgEssML and the C-SAW interface embody design principles derived from research on written argumentation, self-regulation and conceptual change and several cycles of participatory design-based research (Benetos, 2017).

C-SAW aims to help novices of argumentative text composition to develop and structure their written texts. It introduces prompts and devices designed to engage writers in the self-regulation processes that enable deeper reflection and can lead to changes in concepts and understanding. C-SAW offers a visualization and scaffolding of the composition process and product (Fig. 4). C-SAW also logs writers' actions to provide information for research or analytic purposes. It is the only system that explicitly guides the linearization process. Diagrams are generated from users' actions, but cannot be directly manipulated. Various argument schemes are available, and arguments can be reordered. There is no automated text analysis in C-SAW but there is some automated feedback in the form of various dynamically generated task completion indicators that reflect writers' actions in a hierarchical tree style diagram to give progress feedback and various textual visualizations for reviewing. C-SAW's strengths are in the contextual prompts to develop and evaluate one's argumentation with respect to the rhetorical goal and the linguistic help to link components. It also offers a teacher interface to allow instructors to modify all labels and prompts so as to adapt the language to their context and needs.

C-SAW is also one of the only tools reviewed in this chapter to have available qualitative and quantitative research studying the mediating effects of the use of its devices on argumentation, learning and writing quality (Benetos, 2014, 2015,

[4] https://www.acceptify.at.

[5] https://socratrees.azurewebsites.net.

[6] https://debategraph.org.

2017; Benetos & Betrancourt, 2020). C-SAW is currently a very highly functioning prototype that continues to be developed and tested in field studies and experimental settings using design-based research to further its development.

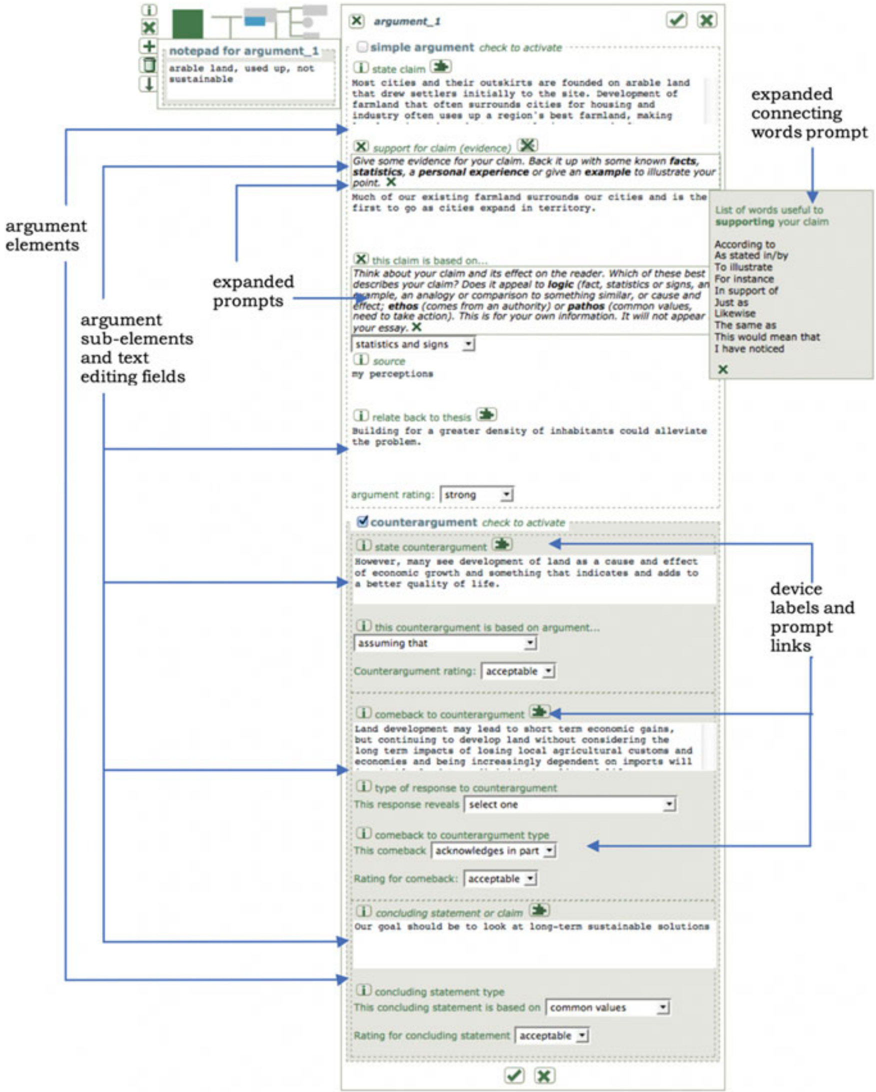

Fig. 4 C-SAW interface in editing mode (Benetos & Betrancourt, 2020, p. 305)

3.5 Functional Specifications

Computer-supported argumentation systems essentially mediate activities involved in the argumentative writing process by scaffolding various interactions between users and the system, with the bulk of the support being for learner-system interactions.[7]

Learner-system interactions in argumentation systems are varied in complexity and types of activities they mediate. For learner-system interactions, users are often offered linguistic and visual (graphic) prompts as progress and state indicators, task orientation, and goal-setting functionalities. Users can organize and visualize their argument by generating text in nodes, freeform, or in text input fields. The text can be rearranged by moving individual or groups of nodes. Learners may choose to analyze text through selecting, 'tagging,' and linking ideas. By being asked to agree/disagree or rate ideas related to the content or the structure of the argumentative text, learners are encouraged to look closer at a text. Linguistic markers offer contextual aid or help link nodes (concepts) and define their relationships within the argumentation. Other prompts may come in the form of 'empty' models or templates to be filled out. Learners may be asked to justify and validate their argument by adding sources. These types of prompts can facilitate content generation and elaboration and structuring the argumentation, but also act as aids for self-regulation of writing processes and self-evaluation of the argumentation produced.

The scaffolding focus of these functionalities are substantive (about the task) as well as procedural (how to achieve it). It can be substantive of the first order, i.e., they offer aid to accomplish specific tasks, or of the second order, as in the case of Writing Pal, in that they support learning for transfer (Noroozi et al., 2018). Writing Pal (W-Pal) is a web-based intelligent tutoring system that provides learners with "explicit strategy instruction, game-based practice, essay writing practice, and automated formative feedback" (Roscoe et al., 2014). Designed with a view to improve essay writing as a whole, not necessarily argument construction or argumentative writing, Writing Pal is covered in detail in the Sect. 3 chapter "The Future of Intelligent Tutoring Systems for Writing". The scaffolding focus in the written argumentation systems covered in this chapter, is more often procedural with respect to organization and structure, offering support for the execution of the conventions of argumentation, though prompts and examples given in systems such as Rationale and C-SAW can also aid transfer.

Interactions between the instructor and the system consist mostly of various analytics, and tools for the management of access, learner tasks and submissions by the instructor. The digital argumentation tools discussed also facilitate the interaction between learner and instructor, offering the instructor various forms of support in

[7] Earlier systems designed to study computer-supported collaborative learning placed a greater emphasis on devices to mediate learner-learner interactions.

providing guidance, assessment, or evaluation. To support the learner-learner interactions, in addition to collaborative editing spaces, these tools add evaluation or dialogue moderation devices (e.g., ratings/likes/votes, comments/chats) to increase social and audience awareness. In sum, digital argumentation tools that structure and diagram argumentation can be seen as both analytical and guidance tools for learning and instruction.

3.6 Technical Specifications

Whether collaborative or individual, digital argumentation systems almost unilaterally use strict to rather loose schemes of informal logic to construct or deconstruct text into argument components (e.g. Buckingham Shum, 2003; Toulmin, 1958; Walton, 2008) and translate them into diagrams based on standardized visual notations. These standards can also define guidance required to adhere to them that can be translated into features, devices or prompts to support text generation and organisation, and provide, awareness and activity mirroring tools and task completion guidance, using various representations. They may also, like KIE and VCRI, two early digital environments no longer supported, define forms of automated or peer-feedback to support testing hypotheses, collaborative debate, and knowledge building (Bell, 2000; Erkens et al., 2010).

To guide their development, digital argumentation systems use formalized frameworks that define argumentation schemes and practices in specific domains (e.g., law) or contexts, such as hypothesis testing, dialogue and collaborative argumentation or knowledge building. Frameworks such as Argunet's Argument Interchange Format (AIF) (Schneider et al., 2007) or Carneades' Legal Knowledge Interchange Format (LKIF) (Gordon & Walton, 2006), and markup languages such as Araucaria's AML (Reed & Rowe, 2001) or C-SAW's ArgEssML (Benetos, 2015), aim to define formal languages to represent argument structures and provide standards that can be interchangeable between different systems, as well as guide the development of digital tools for argumentation (Scheuer et al., 2010). In practice, needs for domain specificity or simplification has led to modifications that limit their interoperability (Chesñevar et al., 2006) and given rise to proliferation of standards (Scheuer et al., 2010). Of these mentioned, only C-SAW's ArgEssML presents a grammar for representing argumentative essays rather than just arguments.

4 Research

An important body of research and systems development to support argumentation has focused on using diagramming in collaborative learning situations (Stegmann et al., 2012) to hone general or domain-specific argumentation skills (learning to argue), showing how it can help better use argumentation to broaden and deepen knowledge on a particular topic (arguing to learn) (Baker et al., 2003; Muller Mirza et al., 2007; Munneke et al., 2003; Schwartz & Glassner, 2003). Much of it was not specifically concerned with writing as the central activity and how diagramming tools impacted the argumentative writing process post-debate. There is also considerable research on the benefits of using diagramming to analyse argumentative texts as sources for learning and argumentative writing (Bell, 2000; Mochizuki et al., 2019; Reed & Rowe, 2001), but these studies use complex closed systems with highly prescribed and scripted uses. Scheuer et al., (2010) present a thorough state of the art of digital systems supporting the argumentation process and developing good argumentation practices (learning to argue and about argumentation) as a means towards attaining domain specific learning outcomes (arguing to learn), rather than the writing of quality argumentative texts.

Other research has looked at how argumentation systems and their devices can work as self-regulatory facilitators, providing environments for self-monitoring, metacognitive reflection, and self-management of task completion (Benetos & Bétrancourt, 2015; Soller et al., 2005). Digital argumentation tools call upon and help develop writing skills through structural and procedural supports, visualizations, and integrated linguistic tools in individual or collaborative situations, through devices that have been found to lead to more complete and justified arguments and may facilitate linearization, leading to the writing of better argumentative texts (Erkens et al., 2010).

Technology development and research seem to have highlighted the gaps in teaching strategies and instructional design around second-order learning (Noroozi et al., 2018). Feedback, whether intelligent or simply reflective of interaction, is mostly geared to what Noroozi et al. refer to as first order scaffolding to help accomplish the task at hand, with little explicit integrated guidance for transfer. The former type of feedback requires systems to analyse user interactions and products across multiple 'compositions' of diagrams and texts. While cloud-based systems can eventually provide quantitative analytics with overviews of users' contributions and productions, there remains a gap between what systems are providing and the feedback required for second-order learning. With the exception of Writing Pal (see Sect. 3 chapter "The Future of Intelligent Tutoring Systems for Writing"), to our knowledge no currently available system integrates feedback or guidance based on a semantic analysis of the content.

Research into teaching practices in the last decade, focuses more on using combinations of readily available digital tools such as simple diagramming for pre-writing and micro-level scaffolding for text elaboration, combined with various forms of strategy learning. Reed et al., (2017) present the digital argumentation landscape as an "Online Ecosystem of Tools, Systems and Services" and the plethora of social debating platforms would concur. While these may help develop argumentation skills through text, and build repositories of argumentations for further argumentation research, they do little to develop writing lengthy argumentative texts that adhere to current academic conventions and standards.

5 Commentaries: Implications of This Technology for Writing Theory and Practice

Technology acceptance and integration into practice (appropriation) are also dependent on factors external to the technology's scope of influence (organizational, attitudinal, cultural, etc.). Many digital argumentation tools have been created as part of larger research initiatives because of the interactions tracking and data collection they facilitate (e.g., VCRI). Few make it into the educational technology markets to be used by instructors outside of the host institution and if so, fail to remain financially viable. Many quickly become obsolete when the research funding ends though some can still be found in repositories such as GitHub (see List of tools). As such, instructors may resist investing time in heavy systems, and often prefer to use simple diagramming tools like Google Draw or PowerPoint because they are familiar and are readily available. An exception to this seems to be social argumentation and diagramming platforms, with reappropriations of tools like Padlet (Dewitt et al., n.d.) or resorting to LMS forums for online debates. These tools are used individually or collaboratively in pre-writing activities or to elaborate class debates to develop arguments towards a rhetorical goal (Andriessen, 2009). Here too, there are contradictory demands. Open social debates appear to be favoured by developers and researchers (Arguman.org,[8] Kialo), but the tools that seem to survive, rely on educator targeted features that restrict and manage access, but can be easily used in externally scripted activities or strategy instruction. Additionally, Loll et al., (2010) found that while teachers are optimistic about the capacity of visualizations offered by the digital argumentation diagramming tools to facilitate learning, they also see immediate feedback as essential in unstructured informal learning scenarios. Lightweight social argumentation systems facilitate quicker interaction and feedback, compared to complex multi-task environments that require substantial and time-consuming explicit instructional design, scripting and configuration.

6 Conclusion

Current trends in digital tools for written argumentation seem to be responding either to institutional "learning management" demands for less investment in technical infrastructures and human resources, or instructors' need for versatile lightweight ready to use tools and services that are familiar and aligned with their teaching

[8] Arguman.org was a short-lived open structured social debate platform documented and available for download on GitHub: https://github.com/arguman/arguman.org.

practices. However, Noroozi et al., (2018) argue for the need for more tools that offer second order scaffolding (generalization of strategy adoption for transfer), even though this would seem to imply even more complex and curriculum encompassing systems that go counter to instructors' demands.

With the recent advances in web-based technologies, and text and web analytics technologies (c.f. Part 3 of this book), it is natural that current tool development seems to favour web-based debating or argument analysis environments, for example OVA + , where user inputs can create corpora for research and generation of visualizations or Argdown that uses a markdown coding environment to scaffold and map argumentation. Research focus in the domain of computer-supported argumentation appears to have shifted to defining principles (Benetos, 2017) and strategy instruction (Cotos et al., 2020; Noroozi et al., 2018) that can be combined with simple applications in common use, as well as with analytic approaches to generating representations of writing processes (Vandermeulen et al., 2020).

While we may speculate whether these trends are in reaction to development costs and quickly changing technologies, combined with users' difficulty in appropriating technologies into their writing and teaching practices, they raise questions as to how these shifts in technology development and use redefine the roles relegated to the technology, instructors, and writers/learners.

Innovation in educational technology is often triggered by technological advances but adoption seems susceptible to the hype-curve with effects on practices lagging on the scale of decades if not generations. After a burgeoning from about 1990 to 2010 of digital environments designed for uses within domain-specific or research contexts, few have survived or transitioned to a wider use or use outside their native institution. There is still much research lacking regarding how learners appropriate argumentation tools into their writing processes, moving from such unstructured or open debating environments to constructing written argumentation in academic contexts and how to best support them with this complex activity. As Noroozi et al. (2018) argue, it is also important that writing environments and their tools offer second order scaffolding so writers can more effectively transfer the knowledge gained in learning to argue and write through the use of digital tools into academic skills that are not dependent on a specific tool or system. This raises important questions as to the competencies and literacies instructors and learners must acquire and what strategy instruction is needed to help them navigate through an ever-changing eco-system of digital tools for argumentative writing.

7 List of Tools

See Table 1.

Table 1 Software and platforms reviewed or discussed. In italics are those no longer under development

Tool	Description	Reference and/or URL
Araucaria	Web-based drag-and-drop interface for analysing imported textual arguments. Software development documentation is still available	(Reed & Rowe, 2001), http://araucaria.arg.tech/doku.php
Argdown	MIT Licensed but developed by the Debatelab, Karlsruhe institute of Technology. Argdown offers examples and installation guides and is available for download and installation on local servers. Texts can be edited within Visual Studio Code using the Argdown extension to Markdown code	https://argdown.org/
Arguman.org	An argument analysis and mapping platform, where "users assert contentions to be discussed, supported, proved, or disproved, and argue with premises using because, but, or however conjunctions.". The web-based platform is no longer active, but the code is available for download and installation on any webserver through Github	https://github.com/arguman/arguman.org
ArguMap	A lightweight, strictly mapping mobile app for individual use that allows the grouping and linking of claims with minimal prompts within empty nodes. Maps can be shared with instructors in educator mode	https://appsolutelyfun.com/argumap.html
Argunet	Software for analyzing and visualizing complex debates. Available for download as a client-side application for offline use or as a server-side application for online sharing and collaboration with others on the Argunet server	(Schneider et al., 2007), http://www.argunet.org/,
KIE / Sensemaker (Knowledge Integration Environment)	A platform for integrating multiple sources and diagramming argumentation (Sensemaker) for collaborative debate and knowledge building	(Bell, 2000), http://belvedere.sourceforge.net/
C-SAW	Browser-based authoring tool with built-in contextual aid for developing written argumentation. It was developed using PHP, DOM, XML, and JavaScript and can be run on any server with Apache/MySQL	(Benetos, 2015; Benetos & Betrancourt, 2020), http://tecfa.unige.ch/perso/benetos/C-SAW
Carneades	Diagramming of legal argumentation, using LKIF	(Gordon et al., 2007; T. F. Gordon & Walton, 2006), https://carneades.github.io/
VCRI (Virtual Collaborative Research Institute)	An environment that hosts a suite of tools to support collaborative argumentative writing: co-diagramming, chat, co-writing, textual and graphic debate tools, chat…	(Erkens et al., 2010)
Endoxa Learning	Endoxa Learning is an argumentation diagramming environment that uses critical questions to develop reasoning and learning. It also offers topic lessons with ready-made maps to and teacher dashboard tools	https://endoxalearning.com/

(continued)

Table 1 (continued)

Tool	Description	Reference and/or URL
Euclid	Amongst the first diagramming tools for argumentation and supporting reasoning	(Smolensky et al., 1987)
Kialo, Kialo-edu	Open social debating platform with class management for educators	https://www.kialo.com https://www.kialo-edu.com
OVA +	On line drag-and-drop interface for analysing textual arguments derived from webpages	https://arg-tech.org/index.php/ova/
Rationale	Argument diagramming environment with templates for various argumentation-based genres and built-in scaffolding. Functionalities include resource integration, rating and full text export. Limited free use with web-based with offline mode	(Davies, 2009; van Gelder, 2007), https://www.rationaleonline.com/
Writing Pal (W-Pal)	Intelligent tutoring system for improving reasoning and writing	http://www.adaptiveliteracy.com/writing-pal

Acknowledgements **Loredana Bercuci** for her help in researching and evaluating functionalities of main tools detailed in this chapter.

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Digital Note-Taking for Writing

Joanna Pitura

Abstract Note-taking is prevalent in academia—it is the basis of scholarly work, i.e. searching for information, collecting and reading literature, writing and collaborating, referred to as a "primitive" that assists these information activities (e.g., Palmer, C. L., Teffeau, L. C., & Pirmann, C. M. (2009). Scholarly information practices in the online environment: Themes from the literature and implications for library service development. OCLC Research. https://accesson.kisti.re.kr/upload2/i_report/1239602399570.pdf). Researchers and higher education students take notes throughout the inquiry cycle, i.e. while designing research, collecting data, analysing data, and writing the report. In addition, with written assignments being a considerable part of student academic work, notes are taken in the writing process, from generating ideas for writing tasks, through text planning and drafting to its editing. As this process may be challenging, digital note-taking has the potential to facilitate writing in academic contexts (Matysek, A., & Tomaszczyk, J. (2020). Digital wisdom in research work. Zagadnienia Informacji Naukowej—Studia Informacyjne, 58(2A(116A)), 98–113. https://doi.org/10.36702/zin.705). Yet, despite the availability of literature concerning formal requirements of writing, such as style, structure, referencing, etc., relatively little literature deals with the note-taking activity that assists academic writing, and even less with digital note-taking. In order to bridge this gap, this chapter focuses on the note-taking activity and shows how digital tools can support note takers in the academic writing context.

Keywords Digital note-taking · Academic writing · Note-taking systems · Note-taking tools

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_7

1 Overview

A note—the outcome or product of note-taking—has been associated with the notion of information unit (Siegel, 2018) or a knowledge building block that is stored externally (Forte, 2020d). Some consider notes to be private, unfinished and meaningful mainly to the note taker (Boch & Piolat, 2005; Forte, 2018a; Palmer et al., 2009; Siegel, 2018), whereas others have maintained that quality notes are understandable for someone unfamiliar with the content (Williams & Eggert, 2002). Note-taking, or note-making (Marin et al., 2021), serves two basic functions. The first—encoding—function entails recording information in the form of a note in order to commit information to memory, whereas the other—external storage—function concerns the use of notes as a form of external memory repository that may be accessed at any time (Jiang et al., 2018). Notes can be recorded with the use of a variety of analogue and digital tools. While analogue notes can be produced in paper notebooks, on pieces of paper, printed texts, post-its, whiteboards, flipcharts, etc., notes taken digitally require the use of electronic devices (Ahrens, 2017; Forte, 2018a; Kadavy, 2021; Marin et al., 2021) and are enabled through a keyboard, digital ink or voice (Khan et al., 2020). Notes are generated through a range of strategies, i.e. by underlining or highlighting a sentence or an excerpt or witing a comment in the margins (which is associated with what is known as text annotation), as well as summarising or verbatim transcription (of texts, lectures, videos), taking screenshots, voice memoing, mapping, sketching, outlining, and jotting down of ideas (Forte, 2018a; Friedman, 2014; Palmer et al., 2009). Consequently, notes may exist in various forms, such as a quote, a passage from a book or article, a summary, a bullet-point list, a photo, a drawing, a sketch, a voice memo, etc., in analogue and digital formats.

Some guidance on note-taking techniques (methods) is available. In general, these can be classified as linear and nonlinear; while linear note-taking resembles conventional text writing, non-linear note-taking often involves graphical representation of information (Makany et al., 2009). Recommendations and advice on note-taking techniques (methods) have been published to support L1 and L2 students' note-taking in lectures and classrooms, while reading and for written assignments (e.g., Hamp-Lyons, 1983; Lowen & Metzger, 2019; Sheridan, 2021; Siegel, 2016). Existing techniques can be classified according to their purpose. As described on the Sheridan website, in order to take notes in the classroom or during the lecture, students (note takers) may adopt the Cornell method, the outline method, the matrix method, concept mapping, PowerPoint slides, or use note-taking software. To take notes from reading, students may make use of the highlighting method, information funnel method and the SQ4R method. Finally, in order to take notes for written assignments, students may take advantage of the visualising method or the cue card method.

Digital (electronic) note-taking began with the use of a computer to type notes in a word processor, which then evolved into the use of various note-taking applications (Bennett & McKain, 2018). Evernote, created by Stepan Pachikov, is considered to be a pioneer among digital note-taking tools; its beta version was released in 2008, raising considerable interest among users and soon finding its followers (*The*

History of Evernote..., 2021). Although not very widely adopted in practice, the free Zettlkasten software based on Lhumann's system developed by Daniel Luedecke (http://zettelkasten.danielluedecke.de/en/) is yet another important contribution in the area of note-taking technology. Currently, note-taking applications that draw on the idea of bi-directional linking are gaining in popularity (Appleton, n.d.). In particular, Roam Research, founded by Conor White-Sullivan, and their knowledge management tool under the same name (Holm, Rowley, & Nisay, n.d.) have attracted a lot of attention (e.g., Daniels, 2020; Haisfield, 2020a, 2020b; Keiffenheim, 2021).

Digital note-taking has been increasingly considered part of a broader strategy of personal knowledge management, wherein diverse information is recorded, managed, and used for writing, for example. At the moment, two systems are gaining traction among those that deal with writing: the digital Zettelkasten system and Second Brain.

The Zettelkasten system, developed by Niklas Luhmann, was originally based on paper index cards containing references, short notes on ideas and the content of the literature, stored in wooden slip-boxes. Ahrens (2017), who adopted Luhmann's system to better serve modern-day writers, prescribes work towards the completion of a text in eights steps. The first four of these steps focus specifically on note-taking and involve making fleeting notes (capturing ideas connected to the writing project as they appear throughout the day), making literature notes (summarising the content), which is followed by making permanent notes (one's own elaboration of others' ideas), and then adding the permanent notes to the slip-box by storing them behind related notes. With the use of digital tools, this system, referred to as the digital Zettelkasten, has become even more powerful (Kadavy, 2021).

Second Brain—created by Tiago Forte, not a scholar of writing, but who has had an impact on how people take and use notes—is a personal knowledge management system for capturing, organising, and sharing knowledge using digital notes (Forte, 2019). Forte's CODE Framework (standing for Capture, Organise, Distill, Express) is a four-stage methodology for the management of knowledge that is saved in notes (Forte, 2019, 2020c). Specifically,

- capturing (or collecting)—involves saving the ideas and insights that one considers to be worthy of saving (e.g., webpages, PDFs, stories, book and conversation notes, excerpts of texts, quotes, images, screenshots, examples, statistics, metaphors, mindmaps);
- organising—entails organising content by current projects rather than by topics;
- distilling—involves condensing notes to a summary, and also connecting and organising them;
- expressing—entails creating the output in the form of a blog post, a YouTube video or a self-published ebook.

Theoretically, digital note-taking strongly connects to writing through the perspectives on writing that emphasise memory systems (Bereiter & Scardamalia, 2009; Hayes, 1996; Hayes & Flower, 1980) as well as self-regulation and self-efficacy

(Zimmerman & Risemberg, 1997) in the production of the written text. These theories allow to understand the function of note-taking in academic writing and the importance of regulatory processes at the junction of reading sources, note-taking and writing activities.

2 Core Idea of the Technology

In general, digital note-taking technology is built on the principles that highlight augmenting the capacity of human memory/mind, productivity enhancement, and collaboration with others in the creative process (Holm, Rowley, & Nisay, n.d.; *The History of Evernote*…, 2021). As to writing, digital note-taking eases the process in two main ways; first, by making note (idea) capturing and management more efficient and, second, by supporting writers' thinking. While processing information from books, articles, social media, webpages, etc., one's own and others' ideas can be instantly and easily saved with the use of a digital note-taking tool (Perell, 2021). Once taken, unlike analogue notes that can be lost, unintelligible, scattered and hard to be found when needed, digital notes have the advantage of being located in one place, which makes them more durable, searchable, accessible, shareable with others, and editable whenever a need arises (Forte, 2018b). In addition, writers can rely on the capacity of technology to store valuable ideas and resources long term, which frees writers from the limitations of their own memory (Forte, 2019). Finally, with the increasing body of saved ideas and emerging connections between them that become visible to the writer-note taker, note-taking technology supports writers' thinking and creativity and also prevents writer's block (Forte, 2019, 2020b; Perell, 2021).

However, there are no guidelines prescribing the use of note-taking tools. As these tools resemble a clean paper notebook, it is necessary to find a way to strategically work with a specific tool by, for example, adopting or developing a broader note-taking system (Forte, 2018a), such as the digital Zettelkasten system or Second Brain. Moreover, there is no predefined target user for a specific tool. In order to help users choose a suitable note-taking application, Duffy (2021) evaluates a range of tools and offers recommendations for various users, e.g., "best for business use and collaboration," "best for students," "best for creatives" (Duffy, 2021) or for specific purposes, e.g., "best for free and open source option," "best for organising with a small number of notebooks," "best for speed," "best for text notes only," "best for team notes and task management combined." Advice like this can help writers choose the tool that best fits their academic, professional, and personal needs.

3 Functional Specifications

Digital note-taking tools typically enable the following:

- *Capturing notes.* Notes can be typed (or handwritten) or imported in many ways, such as with the use of browser extensions for saving web pages, email capture, document scanning, third-party integrations, and by attaching files (audio notes, images, text documents, etc.).
- *Storage.* Notes can be autosaved in a note-taking application.
- *Mono-directional linking.* Notes can include links to external webpages as well as other notes within the application.
- *Text editing.* Text editors usually allow bolding, italics, bullets, numbering, they also offer different font styles, colours, and text sizes.
- *Tagging.* Tags added to a note help make connections between individual notes.
- *Organisation.* Notes can be arranged into pages, notebooks, folders, groups of folders (stacks), etc., that are devoted to, e.g., different writing projects.
- *Search.* Notes can be searched within the body of saved notes by keywords or tags.
- *Sharing notes with others.* Links can be created to share with, e.g., colleagues collaborating on writing projects, who will be able to see the note without needing to create an account.

Less common features include, among others:

- *Side-by-side viewing.* The setup of display windows in the note-taking application can enable the simultaneous viewing of two or more notes (pages).
- *Bi-directional linking.* Once saved in a note-taking tool, every time a note is mentioned in other notes, the original note automatically receives a link to the page the note is referenced to.
- *Filtering.* Unlike searching, note filtering allows to avoid viewing irrelevant information.
- *Running queries.* Notes can be searched in a more advanced way by using tags, page references and logical operators (e.g., AND) to extract entries of interest.
- *Templates.* Templates can be created to be reused for notes of a similar format, such as source metadata.

Importantly, the adoption of digital note-taking tools may be initially challenging as it takes time to take advantage of their potential and, consequently, the benefits of digital note-taking may not be immediately visible. In addition, the emergence of new note-taking applications may tempt users and exporting content between the applications may take their time and effort.

4 Main Products

There exist numerous digital note-taking tools compatible with different operating systems that allow for capturing and management of large amounts of notes. Comparisons and lists of (fast developing) software are available, such as https://en.wikipedia.org/wiki/Comparison_of_note-taking_software or https://en.wikipedia.org/wiki/Category:Free_note-taking_software, but, at the time of this writing, these present two major gaps. First, bi-directional linking tools (e.g., Roam Research, Craft, Obsidian, RemNote, Hypernotes, etc.) have not been included yet and, second, information about free plans is hardly available. With this in mind, Table 1 displays author-compiled comparison of selected tools in terms of pricing and operating systems, including bi-directional linking tools (N = 24).

5 Research

Note-taking for academic writing is not a well-understood area. Research has been conducted across various disciplines, such as information science, educational psychology, linguistics, education, including language education.

Research provides some initial insight into the types and purpose of notes taken by academic writers. Specifically, Qian et al. (2020) revealed that study participants—PhD students—produce three main kinds of notes while working towards a synthesis: in-source annotations (i.e. notes within a source), per-source summaries (written condensations of main information in a source) and cross-source syntheses (depictions of an overall grasp of the study problem emerging across the sources). In-source annotations were made to identify and record elements and observations that are relevant to one's research by highlighting on either printed or digital documents and using the comment function in PDFs. Peer-source summaries contained results, theories, concepts, solutions, as well as questions inspired by the paper, written in the form of a section or a paragraph, saved by some participants in reference managers, such as Mendeley or Zotero. In addition, it was found that a tagging system was used to collect papers that could be used in specific writing projects. Participants also mentioned using the image capture tools to take snapshots from a source (e.g., to capture the picture of a specific formula). Finally, cross-source syntheses took the form of outline summaries of key ideas across the sources or a mind map, among others.

There is also research demonstrating how the note-taking process assists scholarly writing. In particular, Qian et al. (2020) show how study participants progress from in-source annotations to per source summaries, and sometimes from per-source summaries to a synthesis, which is usually a non-linear process. Participants regarded the transition from annotations to cross-source synthesis as non-linear since their per-source summaries were not always adequate, necessitating a return to previous in-source annotations. Other research shows how language changes from source text

Table 1 Comparison of selected note-taking tools (Author's elaboration)

Application	Price plans*	Compatibility*
Agenda Notes	Free, premium features	iOS, macOS
Bear	Free features, pro	iOS, macOS
Craft	Personal (free), professional, team (coming soon)	iOS, macOS
Dynalist	Free, pro	Android, iOS, Linux, macOS, Windows
Evernote	Free, personal, professional and teams plans	Android, iOS, macOS, Windows
GoodNotes	$7.99	iOS, macOS
Google Drive	Free 15 GB of storage, 100 GB costs $1.99 per month, a terabyte costs $9.99 a month	Android, browsers, Linux, macOS, Windows
Google Keep	Free	Android, browsers, iOS
Hypernotes	Personal (free), plus, business, enterprise	Android, iOS, Linux, macOS, Snapcraft, Windows
Joplin	Basic, pro, business	Android, iOS, Linux, macOS, Windows
Metmoji Note Lite	Free	Android, iOS, Windows
Microsoft OneNote	Free	Android, browsers, iOS, Mac, Windows
Milanote	Free	Android, iOS, Mac, Windows
Notability	Free starter, paid subscription	iOS, macOS
Notepad +	Free, pro	iOS
Notion	personal (free), personal (pro), team and enterprise plans	Android, iOS, macOS, Windows
Obsidian	Personal (free), catalyst, commercial	Android, iOS, Linux, macOS, Windows
Penultimate	Free, in-app purchases	iOS
RemNote	Free, pro, lifelong learning	Android, iOS, Linux, macOS, Windows
Roam Research	Free 31-day trial, pro and believer plans, scholarships for "for scholars lacking financial stability"	Linux, macOS, Windows
Simplenote	Free	Android, browsers, iOS, Linux, macOS, Windows

(continued)

Table 1 (continued)

Application	Price plans*	Compatibility*
Standard Notes	Free, core, plus, pro	Android, browsers, iOS, Linux, macOS, Windows
Supernotes	Starter (free), unlimited, lifetime	Linux, macOS, Windows
Zoho Notebook	Free	Android, iOS, Linux, macOS, Windows

*as of 11th November 2021

to notes to a summary text (Hood, 2008). Still others revealed that collaborative note-taking does not improve academic writing performance, though this process leads to the retention of more information among the students (Fanguy et al., 2021), which suggests that social interaction may affect the outcomes of note-taking in different ways.

Literature also contains studies revealing the positive effect notes have on the quality of writing. Research has shown that any type of note-taking activity is related to the good quality of written expression (Lahtinen et al., 1997). In addition, notes may have a favourable effect on the language of student essays (Slotte & Lonka, 2001) and that note-taking may serve as a writing framework, especially if notes contained phrases allowing students to express themselves in their essays (Wilson, 1999).

The issue of how specific note-taking tools (apps) are used for writing has rarely been addressed. Qian et al. (2020) found that study participants used many tools which were different for each type of notes they took. For in-source annotations, the participants used printed paper, in addition to MacOSX Preview, Zotero and Mendeley reference managers, Google Drive, and PDF readers. For per-source summaries, the participants used Mendeley and Zotero, a paper notebook, MS OneNote, Google Doc, XMind mind mapping, PDF reader and Overleaf Latex Editor. For cross-source syntheses, they used MS Word (and/or online), Google Doc, MS OneNote, MacOSX Note, Mendeley, MS PowerPoint, mind/concept mapping, and Scrivener. The participants changed tools, using 4.2 tools on average, for taking different types of notes. Moreover, tools were adjusted to fit needs for which they were not originally designed, e.g., participants used reference managers to write per-source summaries.

Literature dealing with note-taking for academic writing contains very little information about the usability of note-taking tools. Importantly, as revealed by Qian et al. (2020), the necessity to switch between several tools and platforms, referred to as "tool separation" (p. 10) was a major source of friction for academics while note-taking and writing was regarded as disturbing or delaying the writing process. Some participants developed strategies to cope with these difficulties, e.g., displaying the reading window on the left and the note-taking window on the right at the same time. Research conducted among higher education students outside the area of academic writing shows that Evernote can be helpful for organising information (Kani, 2017) and can be more advantageous as lab notebook than a paper notebook (Walsh & Cho, 2013), but also reveals challenges (Kerr et al., 2015), such as these related to web clipping and file uploading (Roy et al., 2016). Literature also contains research reports on the design and implementation of programmes, such as a system for note-taking in lectures (Kam et al., 2005), a system for note-taking while watching online videos or a mobile application for collaborative note-taking (Petko et al., 2019).

6 Implications of Digital Note-taking Technology for Writing Theory and Practice

6.1 Digitalisation of Writing Spaces

Digital note-taking considerably expands the space for writing, affording writing in real (offline) and digital writing environments. With digital note-taking tools, academic writers can write anytime, whatever they need to, wherever they are, at any stage of text composition.

6.2 Digitalisation of the Writing Process

Digital note-taking is uniquely suited to address the demands of academic writing. Although there is no one prescribed use of digital note-taking tools for organising the writing process, existing note-taking systems can help writers by providing the methodology for the external storage and management of their notes with the outlook towards individual and collaborative writing. As such, note-taking systems implemented with the use of digital tools have the potential to make the complex task of writing easier and to alleviate the anxiety associated with writing.

6.3 Learning to Write Writing to Learn

Note-taking applications have the potential to support learning to write by allowing easy access to models for writing (in the form of saved texts) and modelling the process of writing. This may be afforded with the use of templates that can be created to scaffold less experienced writers in their writing, by, e.g., displaying instructions concerning what content is needed in specific parts of the text, how to structure and organise the text at the micro, meso and macro level, and what language can be used to meet particular rhetoric purposes.

6.4 Formulation Support

Notes can be a point of departure for the writing of one's own text when they include language from the sources read.

6.5 Competences Needed for Future Writers/Technological Knowledge

As academic writers deal with an abundance of information and ideas for writing, they are in need of developing competence around digital note-taking in order to build their own workflows. With this in mind, they need knowledge and skills to do with knowledge management, familiarity with note-taking systems, strategies for writing, as well as note-taking tools. In addition, writers would benefit from the mindset that recognises the value of systematic note-taking, and that is characterised by curiosity, creativity, enthusiasm for work with their notes for learning, thinking and, ultimately, writing.

6.6 Writing and Thinking

Digital note-taking tools support the cognitive processes envisioned in Bloom's revised taxonomy (Anderson & Krathwohl, 2001), i.e. remembering, understanding, applying, analysing, evaluating and creating. In particular, note-taking tools with bi-directional linking are of special significance as they help writers organise their thoughts or consider problems/phenomena from different perspectives. In so doing, these tools support writers' creativity and the development of original ideas. In addition, as individual differences in the capacity of writers' working memory, the ability to store and retrieve information form long-term memory, as well as self-regulation processes and self-beliefs may affect the writing process, digital note-taking tools have the potential to compensate for the limitations of human cognitive abilities by serving as a reliable external space, allowing to retain, retrieve, and manipulate a large amount of information.

6.7 Impact on Digital Writing Quality

Note-taking tools may positively influence the quality of writing in terms of text content, its organisation and language. As to content, note-taking tools afford the space for idea interaction and the emergence of unique insights that can find their way in the text. Concerning text organisation, note-taking tools may store models of the written genres in the form of, e.g., published articles, that writers can follow while writing own texts. In addition, writers may benefit from generated templates that can guide writers in the construction of whole texts, sections and/or paragraphs. With regard to language, saved texts (whole or excerpts) can also help writers to model their own language in allegiance with the genre requirements in a specific discipline or field.

6.8 Writing Opportunities, Assignments, and Genres

Digitally saved notes become a rich repository of ideas and resources for writing that can be readily drawn from in order to complete any writing task, in any genre.

6.9 Collaborative Writing and Collective Papers

Individual writers may have a huge store of information saved in their note-taking applications which can be shared with colleagues in the process of writing collective papers. In addition to this, writers can develop notes together. This leverages the opportunities for creativity and idea generation for collective writing.

6.10 Author Identities, Roles, and Audiences

With an efficient digital note-taking system, author identities as knowledge/information workers are likely to be positively affected. By depending on an external system to draw ideas or resources, they are more likely to be more able to regulate their writing and improve their self-beliefs. The role of an efficient note taker emerges as being of crucial importance for academic writers, serving a supporting function to help them learn and develop. With increased productivity and creativity, writers are likely to write more, publish more, and broaden their audience.

6.11 Feedback, Discussion and Support

Communities built around specific note-taking systems and/or note-taking tools may be a source of considerable support around digital note-taking. They can constitute a valuable venue for discussion and feedback, sharing of good practice, troubleshooting and serving as inspiration for others.

7 Conclusions and Recommendations

7.1 Writing Practices

Thoughtful application of note-taking systems with digital tools for knowledge management is particularly important in academic writing work and academic success as they may support writers' memory, creativity, self-regulation and self-efficacy. Writers can benefit from adopting note-taking systems and applications for smooth workflow in one central place, helping them to remember information, but also to think and write, individually and collaboratively. Hence, although mastering specific note-taking systems and tools may be time-consuming, this investment is needed to master the ability to efficiently take notes in order to write quality texts and be more productive. With the use of digital tools, academic writers need note-taking systems that support the writing process in terms of capturing inspirational insights, generating ideas, text drafting and editing, capturing models of genres, resources, managing references, generating in-text citations and bibliography.

7.2 Teaching

As note-taking is an acquired competence that exponentially improves writing, action is needed to incorporate insights from note-taking practice and research into academic writing pedagogy in order to help writers fulfil their potential. Teaching should aim to equip academic writers, both students and researchers, with the competences that allow them to effectively capture knowledge and manage saved notes needed for writing. Teaching could focus on developing note takers' abilities in the familiarity with and the use of whole note-taking systems, as well as digital tools for note-taking, bearing in mind note takers' writing goals, needs, interests and preferences.

7.3 Research

Research on note-taking for academic writing is very modest, more theoretical and empirical work is necessary as many areas require research attention. Most importantly, research is needed to define the concept of (digital) note-taking for academic writing. Furthermore, future work can conceptualise the products and processes of (digital) note-taking, it can also take cognitive processes and social and cultural context, as well as the role of digital mediation in note-taking practices into consideration. Importantly, note-taking research can benefit from insights from the literature concerning active reading and sense-making (cf. Qian et al., 2020) cognitive artefacts as extensions of human mind (cf. Heersmink, 2020), as well as semantic memory (cf. Kumar, 2021) and semantic memory networks (cf. Hills & Kenett, 2022; Kenett & Thompson-Schill, 2020) to better understand the notion of networked thinking underpinning note-taking for the creative process.

Empirical work is needed to better understand the products of note-taking in the context of academic writing, note-taking trajectories, obstacles and facilitators in the note-taking process. Research is also needed to explore the usability and effectiveness of digital note-taking systems and tools for academic writing, individual differences among writers note takers, the impact of digital note-taking on the quality of the written text written individually and collaboratively. The issue of language used to take notes should also receive more attention and linguistically-oriented research is called for to better understand the issues such as information unit, information flow, as well as meaning making while note-taking from sources to texts. It is also worth considering whether and how language proficiency affects L2 students' and researchers' ability to take notes when their written output in not in their mother tongue.

As to methodological recommendations, research is needed for in-depth analyses of a wide range of academic note takers, including students, beginning researchers, and expert scholars. Along with quantitative research methods (experiments and surveys), researchers can adopt qualitative methods (e.g., case studies, action research, ethnography) to describe good digital note-taking practices and analyse (un)successful academic note takers. Design-based research could be particularly beneficial in designing efficient note-taking products and processes by examining and eliminating encountered friction and difficulties.

7.4 Tool Development

Theoretical models (that are yet to come) and empirical findings (yet to be obtained) may inform the design and development of note-taking systems and tools to support note takers in academic writing contexts. System and tool development efforts need to recognise academic writers (students and researchers) as knowledge/information workers, their academic/research writing goals, information needs and challenges, and the specificity of writing processes as one of larger scholarly information practices/activities (Palmer et al., 2009), without forgetting that writing is only one of the aspects of academic worklife and that work is just one of the dimensions in an individual person's life, who may or may not capture knowledge in different types of notes and for different purposes over time. In particular, for the process of academic writing, friction between tools and products may be eliminated in order to assist academic writers manage their notes and resources. Tool designers could also consider incorporating guidance (e.g., text templates) in note-taking applications for novice academic writers as part of the note-taking system for capturing and/or creating notes at preliminary stages of text writing to facilitate writing.

8 List of Tools

Tool	Description	References
Agenda Notes; Agenda; https://agenda.com/	organising notes in the form of a timeline, assigning dates to notes, and connecting them to calendar events, etc.; free and premium features*; iOS, macOS	
Bear; Shiny Frog; https://bear.app/	linking notes and using hashtags to organise them, encrypting notes; includes a focus mode and advanced markup features, etc.; free features and pro plans*; iOS, macOS	
Craft; Luki Labs; www.craft.do	arranging similar ideas (notes) into subpages, creating cards, sharing notes and collaborating on documents, etc.; includes bi-directional linking; personal (free), professional, and team (coming soon) price plans*; iOS, macOS	
Dynalist; Dynalist; https://dynalist.io/	organising notes with the use of tags, cross linking, sorting, formatting and sharing notes, etc.; free and pro price plans*; Android, iOS, Linux, macOS, Windows	
Evernote; Evernote Corporation; https://evernote.com/	synching, organising and searching notes, creating tasks, to-dos, and templates; includes a web clipper, a document scanner, and a calendar; free, personal, professional and teams plans*; Android, iOS, macOS, Windows	Kani (2017); Kerr et al. (2015); Roy et al. (2016); Walsh and Cho (2013)
GoodNotes; GoodNotes Limited; https://www.goodnotes.com/	saving and managing both typed and handwritten notes, marking up PDFs and PowerPoint presentations, creating notebooks; enables side-by-side viewing, sharing documents, using flash cards, etc.; $7.99 price plan*; iOS, macOS	
Google Drive; Google; https://drive.google.com	storing notes in files and folders, allows to share and collaborate on documents; free 15 GB of storage, 100 GB costs $1.99 per month, a terabyte costs $9.99 a month*; Android, browsers, Linux, macOS, Windows	Qian et al. (2020)
Google Keep; Google; https://keep.google.com	saving and organising notes, photos and audio, creating lists, editing, sharing, and collaborating on notes, setting reminders about a note, automatic transcription of voice notes; free*; Android, browsers, iOS	
Hypernotes; Zenkit; https://zenkit.com/en/hypernotes/	saving and editing notes, bi-directional linking, structuring notes in a the form of a hierarchical outline, visualising concepts in a semantic graph, sharing and collaborating on notes, etc.; personal (free), plus, business, and enterprise price plans*; Android, iOS, Linux, macOS, Snapcraft, Windows	

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Tool	Description	References
Joplin; Laurent Cozic; https://joplinapp.org/	taking notes in the form of an image, video, PDF and audio file, publishing, sharing and collaborating on notes; includes a web clipper; basic, pro, and business price plans*; Android, iOS, Linux, macOS, Windows	
MetaMoJi Note Lite; MetaMoJi Corporation; http://noteanytime.com	taking and saving notes, enables drawing, sketching and annotating PDFs, among others; free*; Android, iOS, Windows	
Microsoft OneNote; Microsoft; https://www.microsoft.com/en-us/microsoft-365/onenote/digital-note-taking-app	saving and organising notes into sections and pages, navigating, searching, sharing and collaborating on notes; enables ink annotations; free*; Android, browsers, iOS, Mac, Windows	Qian et al. (2020)
Milanote; Milanote; https://milanote.com/	creating notes, uploading files, saving links, and organising notes in the form of boards; free*; Android, iOS, Mac, Windows	
Notability; Ginger Labs; https://notability.com/	creating, sharing and downloading notes from other users, marking notes with digital ink; free starter, paid subscription*; iOS, macOS	
Notepad + ; Apalon; https://www.apalon.com/notepad.html	taking and organising typed and handwritten notes, including sketches and drawings, annotating images; free and pro price plans*; iOS	
Notion; Notion Labs; https://www.notion.so/	capturing, editing and organising notes, sharing with others; personal (free), personal (pro), team, and enterprise price plans*; Android, iOS, macOS, Windows	
Obsidian; Obsidian; https://obsidian.md/	graph viewing, backlinking, daily notes, tagging, searching notes, recording voice notes, presenting notes as slides, and many more; personal (free), catalyst, and commercial price plans*; Android, iOS, Linux, macOS, Windows	
Penultimate; Evernote Corporation; https://evernote.com/products/penultimate/	taking handwritten notes and sketching, organising notes in notebooks by topic, project, etc., automatic syncing to Evernote; free, in-app purchases*; iOS	
RemNote; RemNote; https://www.remnote.com/	saving and linking notes, generating flashcards from notes, highlighting and referencing PDFs and web-based articles, etc.; free, pro, and lifelong learning price plans*; Android, iOS, Linux, macOS, Windows	
Roam Research (Roam); Roam Research; https://roamresearch.com/	bidirectional linking, formatting, searching and filtering notes, asl well as side-by-side, Kanban, and graph viewing, among many others; free 31-day trial, pro and believer plans, scholarships for “for scholars lacking financial stability”*; Linux, macOS, Windows	

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Tool	Description	References
Simplenote; Automattic; https://simplenote.com/	syncing, tagging, searching, backup, sharing, and publishing notes online; free*; Android, browsers, iOS, Linux, macOS, Windows	
Standard Notes; Standard Notes; https://standardnotes.com/	creating notes in nested folders; autocompleting tags, pinning notes, archiving notes, protecting notes with a passcode, etc.; free, core, plus, and pro price plans*; Android, browsers, iOS, Linux, macOS, Windows	
Supernotes; Supernotes; https://supernotes.app/	saving and searching notes, linking and nesting notecards, creating daily and thoughts collections, exporting notecards as PDF of Markdown files, sharing notecards; includes backlinking and a night mode; starter (free), unlimited, and lifetime price plans*; Linux, macOS, Windows	
Zoho Notebook; Zoho Corporation; https://www.zoho.com/notebook/	saving, tagging and organising notes in notebooks and stacks; protecting notes and notebooks with passcodes and Touch ID, sharing and collaborating on notes; free*; Android, iOS, Linux, macOS, Windows	

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Synchronous and Asynchronous Collaborative Writing

Montserrat Castelló, Otto Kruse, Christian Rapp, and Mike Sharples

Abstract Collaborative writing has been greatly stimulated by digital technologies, particularly by word processors that have made it easy for co-authors to exchange and edit texts and also led to the development of many experimental tools for collaborative, synchronous writing. When the world wide web was established, the arrival of wikis was hailed with great enthusiasm as an opportunity for joint knowledge creation and publishing. Later, cloud-based computer systems provided another powerful access to collaborative text production. The breakthrough for synchronous collaborative writing was the release of Google Docs in 2006, a browser-based word processor offering full rights to up to a hundred users for synchronous access to a virtual writing space. Next to its easy accessibility, it was the free offer of Google Docs that opened this new chapter of writing technology to a broader audience. When Microsoft and Apple followed with their own online versions, collaborative writing became an established standard of text production. In this chapter, we trace back what collaboration through writing means and then look at the new opportunities and affordances of collaborative writing software. Finally, we briefly recount the impact of early technologies before we settle on the current generation of collaborative writing tools.

Keywords Collaborative Writing · Synchronous Writing · Writing technology

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_8

1 Background

For centuries, scholars have collaborated through writing. Charles Darwin, for example, was at the hub of an extensive network of intellectuals; his collected letters fill seven volumes. However, despite some imaginative solutions to write collaboratively (via letter, fax, and later email), until the 1920s academic papers were generally written by lone authors (Greene, 2007), and it was only in the 1990s, with the development of networked computers, that international multi-author academic writing became commonplace. Thus, the major developments in collaborative writing have arisen in the past 30 years, and this certainly is a result of various innovations in digital writing.

"Collaborative writing" is a term with many synonymous alternatives, as Lowry et al. (2004) showed, such as coauthoring, collaborative authoring, collaborative composing, collaborative editing, cooperative writing, group writing, group authorship, joint authoring, joint authorship, shared document collaboration, and team writing. We follow Lowry et al.'s (2004) suggestion to use collaborative writing as the generic term with the additional implication that today it is technologically supported collaboration. Though we mostly refer to academic and professional writing, the considerations we discuss throughout the chapter can also apply to other types of collaborative writing (e.g., school writing or writing to learn).

Theoretical foundations for research into academic collaborative writing were laid in the early 1990s, with papers on design of computer support for co-authoring and collaboration (Neuwirth et al., 1990; Sharples et al., 1993), studies on how people write together (Ede & Lunsford, 1990; Posner & Baecker, 1992), and an edited book on Computer Supported Collaborative Writing (Sharples, 1993). Taken together, these and later studies (see Olsen et al., 2017) highlight the variety and complexity of collaborative academic writing which may refer to student assignments, grant proposals, project reports, academic and scientific papers, and edited books. Academic writers (students or researchers) may start from scratch, begin with an outline, work from a prepared template, or merge and revise previous texts. Contributors may add comments, links, and suggestions but also alter or delete existing text. Participation may be balanced, or there may be a clear leader.

Some general principles and guidelines for collaborative digital writing have been extracted from this heterogeneity. Sharples et al. (1993) identified three general methods of coordinating collaborative writing: *parallel, sequential* and *reciprocal* (Fig. 1).

Parallel coordination divides the task among the writers, who each write a different part of the text according to skills or knowledge. An academic lead may then revise these into a consistent work. This is the typical coordination for an edited book or conference proceedings.

Sequential coordination is a production line. The first person in the line takes the writing task to the initial stage of production. That person hands the part-completed product on to the second person who works on it to the second stage and so on down the line. Sequential working fits a "plan—draft—revise" approach to writing,

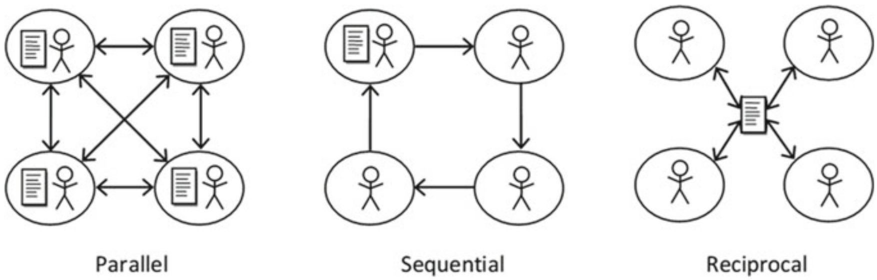

Fig. 1 Methods of coordinating collaborative writing (Sharples et al., 1993)

with the first person creating a plan, the second composing the first draft of the text, the third revising or extending the text, and so on through as many revisions and extensions as there are writers. With two or three authors, the draft can be handed back and forward, or round in a circle.

In Reciprocal coordination all the partners work together on a shared document, watching and mutually adjusting their activities to take account of each other's contributions. Reciprocal working can be used to compose or to revise. It can be synchronous, with all the writers suggesting ideas and revisions while one or more individuals type, or asynchronous with a shared computer file that everyone can write to or amend. Synchronous tools usually make all writing and editing activities of the participants visible to all others, and record them to be traced back. Web-based storage of shared documents has now blurred the former clear distinction between synchronous and asynchronous writing.

Some early collaborative writing tools imposed roles on contributors such as "co-writer" and "commenter" (Leland et al., 1988; Posner & Baecker, 1992). Contemporary tools such as Google Docs or Office 365, however, leave it to the participants to negotiate roles. Leadership is another general principle for collaborative writing. A participant can take over the lead and coordinate the writing activities (for example, through exchange of emails or a shared calendar), allowing contributors to add comments and suggestions, leaving formatting to a late stage so that authors can set down thoughts without worrying about visual appearance, and keeping a clear record of revisions so that credit can be given to contributors and changes can be undone (Sharples, 1992).

While in individual writing, the working habits of a single person determine the course of the writing process, in collaborative writing a collective writing process has to be developed. Beck (1993) explored the experiences of collaborating writers, with a focus on how they discuss content and structure of the document during writing. She found that the writing teams she studied had a range of leadership styles, fluctuations in membership, and a dynamic group process whereby tasks, leadership and responsibilities were negotiated as the writing progressed.

Posner and Baecker (1992) suggested a taxonomy to explain joint writing processes, which they derived from interview descriptions of project work. The taxonomy combines four different categories, each providing a different perspective of the joint writing process: roles (who is doing what), activities (actions performed while writing), document control methods (how the process is coordinated). It also describes five collaborative writing strategies that experienced writers deploy for text creation:

- *Single Writer Strategy:* One team member is writing the document while the others assist.
- *Separate Writers Strategy:* The document is divided into separate units and each is written by a different team member.
- *Scribe Strategy:* Group members work together and one of them writes down the results of the discussion.
- *Joint Writing Strategy:* Group members decide jointly on every aspect of the text, word by word.
- *Consulted Strategy*: A consultant for whom a writer or team works is involved; this strategy can be combined with any of the former constellations.

Based on their findings about how writers produce collaborative texts, Posner and Baecker (1992) elaborated a set of design requirements that collaborative writing systems should support, which focused on the need for flexible and permissive tools, allowing groups to transition smoothly among different strategies and processes, technologies, and between synchronous and asynchronous work by group members. As we will specify, many of these requirements have been addressed by digital tools designed to support collaborative writing in the past two decades.

2 Collaborative Writing Software: Core Idea

Software for collaborative writing was developed first in the 1980s. Posner and Baecker (1992) referred to seven different tools: Aspects, ForCom, GROVE, PREP, Quilt, SASSE, and ShrEdit, all of them released between 1986 and 1992. A decade later, Noël and Robert (2003) reported on 19 web-based systems for collaborative writing, most of them already abandoned by the time their report was written. Those systems were research projects and not designed or marketed for commercial use, with all that entailed such as integration with pre-existing writing tools.

Most of these early collaborative writing systems were limited in their support for coordination, annotation and versioning. Noël and Robert refer to the coordination methods shown in Fig. 1 and indicate that only one system, REDUCE, supported synchronous reciprocal writing. Some systems provided no facilities for commenting, others failed to let users save and restore different versions of a document. As the authors indicated, in 2003, “since none of the presently available systems offer even a majority of the features and properties that an ideal collaborative writing system should offer, there is at the least an obvious need for improvement” (Noël & Robert, 2003, p. 260). Clearly, the idea of collaborative, synchronous writing had a fairly long incubation time until it was channeled into the technologies of today’s major writing platforms.

The modern version of collaborative writing started in 2006 with Google Docs allowing co-writers to work together on a shared web document, thus offering completely new opportunities for synchronous and asynchronous collaboration in writing. In 2005, Google had bought Sam Schillace's web-based word processor "Writely" from which Google Docs was developed, also by Schillace. A first version of Google Docs was soon released in a beta version. The similarity to the Microsoft Office Suite was clearly visible, but the functionality of a browser-based word processor along with document sharing and collaboration differed considerably from it. All that users needed were a Gmail account, a browser and an internet connection to start writing collaboratively. The key innovation of this software was its ability to let several writers work in the same document and at the same time. A cloud-based file sharing system was also included. In the last decade, Google Docs has become the default tool for collaborative writing and co-authoring (Krishnan et al., 2019), though in the current post-pandemic scenario co-writing practices have moved across multiple artifact ecologies (Larsen-Ledet et al., 2020). Alternatives are considered in the next section of this contribution.

Traditionally, collaborative writing software refers to at least three aspects of co-authoring: (1) joint production of text which provides several writers with access to a document and equal rights in its creation and handling, (2) revision of text, which may consist in changing any part of the text and inserting corrections and (3) shared commenting and annotation of the text which establishes a metacommunicative level for the writers to negotiate plans and intentions. The three elements can, but need not, coincide in actual writing processes but still form a standard in the latest versions of word processing software such as Google Docs and Office 365. Additionally, collaborative writing software usually contains what most sophisticated single-author writing software offers, such as functionalities to track changes and to restore former versions. The server-side storage of text, as introduced by Google Docs, made it possible to track the text development, including all changes, and make it accessible to all users.

Synchronicity of writing, along with access to the same writing space, adds a layer of complexity to writing since it implies managing not only different writers' schedules experiences, and disciplinary backgrounds but also their intentions. It may be necessary to make these different dimensions explicit, as shown by recurrent findings regarding the benefits of using oral chats and discussions during collaborative writing, especially in synchronous writing (Li, 2018; Storch, 2019; Talib & Cheung, 2017).

Google Docs was not the end of the development but a beginning that added a dimension to literacy by coordinating collective text production in new ways with intellectual and professional activities. Since Google Docs now allows live synchronous as well as asynchronous ways of working, groups of writers have a wide and heterogeneous range of options which may need to be coordinated. Consequently, former asynchronous technologies like MS Word or LaTeX are still used for collaborative writing (Larsen-Ledet et al., 2020) making it a heterogeneous technological field.

3 Main Digital Products to Support Collaborative Writing

By far the most widespread tools for collaborative writing are Google Docs and Word 365 which provide similar functions to synchronously create and edit documents, make comments and track revisions (Larsen-Ledet, 2020). Wikis enable collaborative authoring and editing of hypertext web documents—the most popular of these is probably Wikipedia—but, in many cases, require authors to learn a markup language. Microsoft followed Google with a cloud-based version of Office in about 2013 under the name "Office 365". In a next step, Microsoft created MS Teams (launched in 2017), a collaboration platform into which the Office suite was integrated. It then changed the name of Office 365 to Microsoft 365. MS Teams is modeled as business software to organize communication within organizations. Integrated into the Teams platform, in addition to text communication, were Sharepoint (to share documents), a streaming functionality (to replace Skype), a phone service, and the former office software, all with collaboration functionality.

Different from Google Docs, MS Word can still be used locally but then needs synchronization with the cloud-based version of the text via Onedrive if several authors want to work on the document. Google, in turn, included a local version of its cloud-based word processor to enable offline writing. MS Teams allows to create "teams": groups of users who can share a large palette of documents and services both within an organization and externally. The number of such services is exploding and so is the number of still projected apps as is shown in the Microsoft roadmap at: https://www.microsoft.com/en-us/microsoft-365/roadmap?filters.

Google countered MS Teams with an expansion of its G Suite to an office package called "G Business" (launched in 2020) offered commercially to companies. It includes Gmail, Drive, Docs, Sheets, Slides, Forms, Calendar, Google + , Sites, Hangouts, and Keep.

Both MS Teams and G Business have reached a new level of complexity in which writing covers only a small fraction of a much larger kind of collaboration in business, science, or education. The focus of the technologies has shifted from the tool level to the organizational level and from text management to project management. It has yet to be discussed, what the integration of visual, oral, and textual communication devices in one platform means and to what kind of mode-crossing interactions it leads. The use of these collaborative organizational tools exploded during the pandemic when face to face collaboration became extremely limited. The level of adoption and also experimentation with a range of technologies offering very different affordances for users may have far-reaching consequences if their use persists.

Alongside Microsoft and Google, the following tools have been developed and are still available:

- *EtherPad* is one of the oldest publicly available, free collaboration tools in which the contributions and changes of each writer are highlighted in a different color. Limited functionality and basic design make it easy to use but restrict more complex editing activities. It is designed to be provided as Software as a Service.

- *Quip* is a complex business platform maintained by Salesforce to optimize sales processes. It connects documents, data, and collaboration.
- *Dropbox Paper* is a newly created collaborative software from the Dropbox company which so far has been known for its document-sharing services.
- *Tracer* is a tool to measure and visualize student engagement in writing activities by analyzing the behavioral patterns of students as they write (Liu et al., 2013).
- *ShareLaTeX* (now part of Overleaf) is for scientific collaborative writing of LaTex documents.
- *Final Draft* is a collaborative tool for screenwriting.
- *Evernote* supports shared note-taking.
- *ClickHelp* is designed for technical writers.
- *GitHub* provides a shared tool and repository for coders. The functionality of GitHub to facilitate incremental development (repositories with branching and version control), feedback (pull requests and annotation) and collaboration (access control and sharing) offers many opportunities for writers of other things besides code. Within GitHub individual writers can avail of affordances to structure text and manage iterative versions of their writing with the built-in version control but they can also avail of the collaborative opportunities afforded by the platform. Collaboration can be controlled or restricted through sharing permissions with other users and using pull requests for others to review and comment on their writing. It can also be much more open by making writing public or "open source" in the sense that others can contribute and modify the writing. One crucial difference of writing with GitHub from other tools is in text formatting. GitHub is not a word processor and typically text is written in plaintext and uses MarkDown "code" to indicate formatting requirements such as italics or headings. This can then be rendered according to the style guides or requirements of the publishing medium (e.g. pdf, xml, etc.) effectively separating the formatting process from the writing. The version control, permissions and annotation functions which are so critical to software development are equally valuable tools for writers of text rather than writers of code.
- *MediaWiki* is the leading platform for creating and editing wikis, including Wikipedia.

Looking at this long list, it becomes obvious that collaboration ability is not only a quality of specialized writing tools but a standard that more and more applies to all platform-based tools. Overviews and comparisons of collaborative writing software can be found at https://compose.ly/for-writers/online-collaborative-writing-tools/ and at https://zapier.com/blog/best-collaborative-writing-apps/.

4 Collaborative Software Functional Specifications

Functionalities that can be found in collaborative software include the following:

- *Simultaneous access to a word processor:* Writers can access independently (or by invitation) a shared, virtual writing space and write, comment, or revise text. They can see what others write, and change it in real time.[1]
- *Comment function:* Writers can make comments, answer comments, or delete them.
- *Visualization:* Means of highlighting changes in texts, individual contributions, and document history.
- *Roles for users:* The roles may be specified by the software like "read", "write", "edit", "comment" with the respective functions available or restricted. It is usually the document owner who decides on the roles.
- *Security and privacy measures:* Selective access to defined members or groups.
- *Version control and revision history:* Most recent tools record all changes, usually including time stamps, and allow users to go back into the text's history to restore former versions.
- *Integrated communication channels:* Chat or video streaming for a better coordination of writing have become standard. Writers need coordination beyond the text fields and the comment functions.
- *Export functions:* Export of documents to various formats and operating systems is necessary to allow for an exchange with different systems.

A particular challenge to collaboration software development is connected to the visualization of individual contributions. Arguably, seeing what every co-author has contributed is a prerequisite to understand collaboration but even more so to understand text development (what has been added, what changed, what deleted?). In this respect, Microsoft relied on its traditional way of tracking changes by highlighting contributions in different colours. As this may get confusing, changes may be hidden so that writers can read or write in a clean text version. Text markups can be accepted or deleted locally or for the whole document. Google Docs also uses colours to mark individual contributions but later introduced comment-like text fields at the margin which appear automatically when something is added or deleted. They contain name, date and kind of change. Additionally, Google developed a functionality called "version history" opening on a side panel on request, which offers a list of all former versions and allows to restore any of them. Although version history functionality has been present in many tools, what is new in Google and also Microsoft Sharepoint is the dynamic and ongoing versioning that does not require writers to lock them, as well as the relatively easy way to come back and restore previous versions.

[1] Changes may not be available in real-time to other authors when writers work in an MS Word document that is synchronized via OneDrive.

These visualization solutions do not live up to what technology today could offer. Southavilay et al. (2013) developed and tested three visualization approaches:

- a revision map, which summarizes the text edits made at the paragraph level, over the time of writing;
- a topic evolution chart, which uses probabilistic topic models, to extract topics and follow their evolution during the writing process; and
- a topic-based collaboration network, which allows a deeper analysis of topics in relation to author contribution and collaboration.

Another way of visualizing text progress in collaborative writing is DocuViz (Wang et al., 2015). The primary aim of this software was to develop a research tool to investigate the patterns of collaborative creation of documents and their correlation to text quality. Additionally, the tool is expected to enhance authors' awareness and knowledge of their own group writing processes, and thus, may serve pedagogical purposes (Wang et al., 2015). The current version, DocuViz 3.8, is a free productivity extension to Google Chrome. It has been used in several studies to assess its functionalities and efficacy both as a research tool to know more about how collaborative writing processes unfold and as an educational tool for raising awareness about these processes among co-writers. In both cases, the tool has been mainly used retrospectively as a way to evaluate writer's contributions, texts' evolution and characteristics of different composition processes through time (Krishnan et al., 2019; Sundgren & Jaldemark, 2020; Yim et al., 2017).

5 Research on Collaborative Writing Software

Successful collaborative writing depends on a highly complex cluster of individual and socially-shared regulatory movements (Castelló, 2022; Sala-Bubaré & Castelló, 2018). Research, so far, has only slowly begun to move beyond the study of asynchronous collaboration such as in feedback, peer reviews, and cooperative text production (cf. Olson et al., 2017; Storch, 2019). And we can assume that technological development of collaborative software has not come to a halt as Wang et al. (2017) predict. Still, today there are standard solutions to which writers are habituated and which can be studied in naturalistic settings (e.g., Google Docs documents' history or extensions) without prototype or bespoke technology and complicated experimental designs (Yim et al., 2017). Regarding methodology, qualitative retrospective tools (e.g., interviews or self-reports) have been predominant together with quantitative analysis of writers' interactions (e.g., comments, chats, discussions), and text evolution (e.g., number and type of edits, inclusions, revisions in successive drafts) (Larsen-Ledet, 2020; Yim & Warschauer, 2017).

When the first specialized software for collaborative writing was developed in the 1980s and 1990s (see Posner & Baecker, 1992, and Noël & Robert, 2003, for overviews), research focused primarily on comparisons with cooperation in conventional writing technology (paper and pencil, word processors). Olson et al. (1993)

used an experimental collaborative text editor called ShrEdit to facilitate cooperation among three-person workgroups of designers. They found that they produced fewer but better ideas. They suggested that this may be credited to a more efficient way of focusing on core issues and a decrease in wasting time when trying to get an understanding of what was going on when deciding together what should be written down and how.

A subsequent set of studies looked for affordances of different tools and technology supporting collaborative writing. One of the first attempts was conducted by Cerratto (1999), who compared collaborative writing between two groups of eight students working over 15 days. One of them used MS Word plus E-Mail, the other used Aspects, a collaboration software with synchronous writing and a chat function. They found that the group using Aspects produced lower-quality text and needed more time. They assumed that it was the group's higher coordination effort and their inexperience with collaborative software that was responsible for this result. The success of the MS Word group seemed to result from their familiarity with the tools used. In a second study of Cerratto and Rodriguez (2002), one group using MS Word to write a report sitting together in a room (so that they could talk things over) was compared with a remotely working group using Aspects. The results repeated the outcome of the first study. They conclude that not all kinds of writing tasks are equally well suited for collaborative writing tools.

Lowry and Nunamaker (2003) compared their collaborative synchronous writing tool, Collaboratus, with MS Word in a study with two collaborative writing conditions. Results indicated that the writers in the synchronous condition fared better, i.e. produced longer and better documents. The authors credited those results to some characteristics of their writing tool which provided a better basis for planning, an easier coordination, and an increased collaboration awareness. Besides differences in the training conditions (longer in the Lowry and Nunamaker's study), contrasting results for Aspects and Collaboratus can probably explained by some advanced features of Collaboratus such as the Asynchronous and web-based support and the tool orientation to parallel-partitioned work, which has been shown to greatly increase CW productivity.

Another focus of early research was the dynamics of collaboration and the related use of the tools' functionalities. Erkens et al. (2005) studied pairs of students in secondary education when writing three argumentative essays using the TC3 (Text Composer, Computer supported and Collaborative) collaborative environment. Their focus was on task-related planning activities by analyzing the chat entries. One target was collaborative coordination under various conditions, which were defined by the additional tools offered: an outline generator, a diagram tool (similar to concept mapping), a personal note pad (invisible to the others), and a tutorial on the technology use. The control group used TC3 without the additional features. Results showed little connection between the additional technologies offered and the text quality. They found that 55% of the interactions were devoted to coordination between task related strategies, cooperative intentions and communication processes during collaboration. It was the quality of these complex interactions that were responsible in large part for the text quality.

Interesting as the results of these early studies may be, it is difficult to generalize from them for two reasons. First, the tools were less developed than today, hardly comparable among each other, and of unclear quality. Second, the participants in the studies were not familiar with the new tools. Students were usually instructed in how to work with the software, but it is hard to claim this is familiarization since their level of expertise with the tools was not formally reported or assessed.

The next generation of studies used the commercialized tools from Google, Microsoft, or Apple to which academic users are usually acquainted. Today, the problem seems to be that even the best writing software will not find acceptance from all writers. Surveys about collaborative writing show at least some reservation if not resistance against the new collaborative technology or some of its functions (Wang et al., 2017). By now, however, users have had enough time to familiarize themselves with the basic appearance and functionality of the new technology such that newer studies can look at differential reactions and work patterns without asking the users into the computer lab. In practice, there are still a variety of synchronous and asynchronous tools in use (Larsen-Ledet et al., 2020) and the associated variety in practices adds a layer of complexity to research on collaborative writing in situated scenarios.

In recent years, the research focus has shifted from proving the tools' benefits or affordances to exploring and assessing the variation of writers' processes and products when writing collaboratively using digital tools. At the undergraduate level, Yim et al. (2017) explored the different strategies of synchronous collaboration by 82 students in 45 Google Docs documents and evaluated the influence of these strategies on the emerging texts. They classified the general interaction along the model of Posner and Baecker (1992, see Introduction) using DocuViz visualizations and confirmed the four distinctive strategies:

- *Main Writer* (called *Scribe* in Posner & Baecker): One participant dominates while the others remain in the background and add little;
- *Divide and Conquer* (called *Separate Writers Strategy* in Posner & Baecker): Writers divide the text into parts and work independently on them;
- *Cooperative Revision*: Parts are written separately but then revised by others;
- *Synchronous Hands-on* (called *Joint Writing Strategy* in Posner & Baecker): Sentences are created together by simultaneously extending each other's text.

Posner & Baecker's *Consulted* strategy did not apply as there were no consulting relationships among the students. The Cooperative Revision style was most common (40%), followed by the Main Writer style (31%), the Divide and Conquer style (20%), and the Synchronous Hands-on style (9%). Contrasting to frequency, the *Divide and Conquer* style tended to produce better quality text whereas *Main Writer* had the lowest quality scores. Moreover, balanced participation and amount of peer editing led to longer texts with higher quality scores for content, evidence, but not organization or mechanics. Out of the 15 groups, only six of them maintained the same style across the three documents. So, as reported previously by Beck (1993), change seems to be natural and not confined to certain group structures.

Still at the undergraduate level, Olson et al. (2017) studied 96 documents written by students in Google Docs in groups (mostly groups of four). The documents were recorded for all group members at a granularity down to single keystrokes with timestamps. Measures were developed to quantify the amount each student had contributed to the text and to determine the extent to which collaboration was synchronous or asynchronous. The data were further visualized using DocuViz and correlations were finally calculated between type of use, text collaboration and assessment of credit. The results showed that students produced text both synchronously and asynchronously. Some students even produced text exclusively synchronously. Only five documents showed no evidence of synchronous collaboration. In 77% of the documents, all members participated in writing the document, while for the remaining 23% some of them were not seen in the document history ("slackers"). For the majority, the participation rate was fairly even and only one group had a writer who usurped the writing process. A more balanced participation was correlated to document quality. In 81% of the documents, there was clear leadership, however, the leaders often changed when a new paper was written. Clear leadership contributed substantially to the writing quality. Only in 37% of the documents was the commenting function of Google Docs used. Often, comments were written into the document. Surprising for the authors was the fact that a high rate of collaborative writing took place and the participants did not distribute work to write privately, then upload their text.

Moving to graduate level and professional writing, Larsen-Ledet et al. (2020) looked at how and why a group of 32 co-authors (13 master students and 19 researchers) use collaborative writing tools working in long term projects. Through qualitative analysis, they identified three kinds of technology related to the kinds of media used in their sample:

- *Collaborative home,* when writers share an online platform which documents and synchronizes their work (e.g., Google Docs);
- *Repository*, when collaborators decide on a common service for storing and exchanging documents (e.g., Dropbox or Google Drive); and
- *Hand-over,* when co-writers decide on a file format and then share the text via email.

It would be wrong, therefore, to identify collaborative writing fully with tools like Google Docs. Collaboration also involves sharing materials and interim text as objects of work, thus collaborating on the joint understanding of the text-to-be. Those results may enrich the original discussion of methods of writing collaboratively (Sharples et al., 1993) by adding the continuum of synchronous/asynchronous modes of writing to the methods of coordinating collaborative writing. Thus, nowadays collaborative writing requires attending to and taking decisions on these two planes: synchronicity and coordination. Co-writers' decisions and actions on these planes may result in diverse processes: (a) synchronous but uncoordinated (everyone writing at the same time but in their own way); (b) synchronous and coordinated (writing together in a collaborative way at the same time); (c) asynchronous and uncoordinated (leaving a document in a shared space so that people work on it in their own time and way); or (d) asynchronous and coordinated (handing over document to another writer to achieve a particular goal with it). To what extent these processes relate to different outcomes and text quality in real contexts is still a pending issue for research in the field (Larsen-Ledet, 2020).

Moreover, in their review Talib and Cheung (2017) conclude that the regular and frequent use of collaborative tools (both synchronous and asynchronous) in pedagogical settings helps students to redefine writers' ideas of ownership, and provides new insights into sharing ideas and clarifying thoughts throughout communication at all educational levels (schools and universities). They make three general claims which they see supported by an analysis of 68 empirical studies published between 2006 and 2016:

1. Technology has facilitated collaborative writing tasks.
2. Most students are motivated by an improvement in their writing competencies in collaborative writing tasks.
3. Collaborative writing is effective in improving accuracy of student writing and critical thinking.

Accepting these general claims, it seems justified to claim that not only our understanding of writing competences has to be remodeled but also that completely new opportunities of teaching academic writing have emerged. Collaborative writing, obviously, is not an add-on to writing but has changed its substance and nature by making it a new field of interaction that feels natural in a digital world.

The educational impact of collaborative writing technology has also been specifically explored by research on L2, ESL or EFL writing. In their reviews, Li (2018) and Storch (2019) highlight how synchronous tools such as wikis and Google Docs impact on three main strands. First, tools impact on the ways interaction unfolds during the writing process that can range from cooperative and collaborative to directive/defensive ones. Besides, digital interaction during writing is complex and includes a variety of channels (textual but also oral through synchronous chats) to discuss and comment on the writing processes and text evolution. Second, impact is also observed on the characteristics of the writing products, which tend to reach higher scores when produced using Web 2.0 tools such as Google Docs. Third, the students' satisfaction and implication were also higher when writing collaboratively using those tools.

Still in the ESL field, a recent review (Yee & Yunus, 2021) has looked at the most widely used tools in enhancing collaborative writing during COVID-19, when virtual learning and writing was not a choice. The results revealed that Google Docs, besides being the most significant collaborative tool, enable students to improve writing processes and content when writing is combined with the co-authors' online discussion. This is an interesting point considering previous research results on coordination being the critical factor for text quality in collaboratively writing. It is plausible to assume the online discussions facilitate co-writers' coordination actions in the absence of any face-to-face options.

6 Future Directions for Research

Current challenges for research on collaborative writing relate to understanding how writers navigate through different technologies and why they prefer some tools above others at certain points in the writing process. Larsen-Ledet (2020) applied the notion of artifacts ecologies to explain writers' motivation to transition among tools. She distinguished four types of motivation based on functional, communicative, aesthetic and personal reasons to alternate tools when writing collaboratively. Still, relevant issues remain unexplored regarding: how those transitions help co-writers to progress in their collaborative endeavour; to what extent authorship is changing depending on the type of co-writer dynamics supported, or enhanced by, technology; and how the cognitive, social and emotional regulation unfolds when technology mediates collaborative writing processes. All of these are crucial both for technology development and theoretical integration when it comes to collaborative writing.

7 Conclusions

Collaborative writing has increased rapidly in academic and professional settings in the last three decades, in parallel with the development and popularity of asynchronous writing tools that facilitate flexibility and awareness of the co-writers' activity during the whole writing process. The lockdowns and restrictions derived from the COVID-19 pandemic have clearly accelerated this already existing trend. Technology has allowed for the creation of joint mental digital spaces when writing collaboratively, either synchronously or asynchronously. Moreover, international networked computing, the worldwide web and additional services such as automatic translation have opened new possibilities for collaboration in writing, by large multinational teams, with rapid development of documents.

Despite the increasing practices of collaborative writing and the related use of digital writing tools, research on collaborative digital writing is still scarce and mainly focused on undergraduate students. The research evidence that is available would strongly suggest that using digital tools can contribute to co-writers' efficacy and text quality. However, there is a lack of studies focusing on analyzing how tools impact on collaborative writing processes and to what extent that impact might contribute to writers' awareness and effective regulation of those processes. Issues such as to what extent collaborative writing processes and products are mediated by particular technologies or how co-writers' reflection, knowledge transformation or critical thinking unfold through digital collaborative writing are still open.

While collaborative software certainly provides opportunities to facilitate truly collaborative thinking, it seems clear that in order to avail themselves of these opportunities, users need certain competencies and abilities. Based on the available evidence, among the most urgent ones to facilitate processes and improve products are: knowing how technology works (e.g., how it is used, set up); working together and accepting others' writing processes and logics; extending feedback rules for collaborative writing; and becoming sensitive to different roles co-writers may have in text production.

Issues such authorship and writer identity in digital collaborative writing conditions also deserve a deep attention of research, especially in professional contexts. While in the early phase of collaborative writing (in the 1990s) there were attempts to impose author roles and identities (e.g., "co-writer", "commenter"), it was soon realized that for most writing these identities need to be fluid and managed by the writers, not imposed in advance. Current writing tools offer "lightweight" roles, such as "editing", "suggesting", "viewing" that can be changed as the writing progresses. What does this mean for the self-identity of a writer? Has this collaborative process changed the nature of identity and authorship either by expanding or contracting it? Moreover, synchronous tools facilitate writers to position themselves differently during writing and adopt a variety of roles (readers, reviewers and writers) when writing. That means writers need to coordinate and regulate the writing process (e.g., assign reviewers, set schedules) in some cases outside the writing tool and in an explicit way (Larsen-Ledet, 2020). Depending on the strategy followed during the writing process, it may be difficult for co-writers to have a sense of authorship.

In sum, a fascinating agenda for IT developers and writing researchers is emerging that might drive integration of existing evidence and formulation of new, relevant questions to build joint empirical and theoretical knowledge on collaborative digital writing. It is also possible that research on digital collaborative writing should not try to understand incremental change but account for the emergence of completely new phenomena. Success in such endeavor requires interdisciplinary dialogue and joint efforts of usually dispersed involved collectives such as researchers, trainers and developers. This book represents a sound initiative to move towards this interdisciplinary and integrative dialogue.

8 Tool List

Tool	Description	Reference and/or URL
ClickHelp	Designed for technical writers	https://clickhelp.com/
Dropbox Paper	A newly created collaborative software from the Dropbox company which so far has been known for its document-sharing services	https://www.dropbox.com/paper/start

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Tool	Description	Reference and/or URL
EtherPad	One of the oldest publicly available, free collaboration tools in which the contributions and changes of each writer are highlighted in a different color. Limited functionality and basic design make it easy to use but restrict more complex editing activities. It is designed to be provided as Software as a Service	https://etherpad.org
Evernote	Supports shared note-taking	https://evernote.com/intl/en
Final Draft	A collaborative tool for screenwriting	https://www.finaldraft.com/
GitHub	Provides a shared tool and repository for coders	https://github.com/
MediaWiki	The leading platform for creating and editing wikis, including Wikipedia	https://www.mediawiki.org/wiki/MediaWiki
Quip	A complex business platform maintained by Salesforce to optimize sales processes. It connects documents, data, and collaboration	https://www.salesforce.com/products/quip/overview/
ShareLaTeX	Now part of Overleaf, is for scientific collaborative writing of LaTex documents	https://www.sharelatex.com
Tracer	A tool to measure and visualize student engagement in writing activities by analyzing the behavioral patterns of students as they write	Liu et al. (2013)

Acknowledgements The research of Christian Rapp was financially supported by the ZHAW DIZH Fellowship Call 2020.

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Social Annotation: Promising Technologies and Practices in Writing

Justin Hodgson, Jeremiah Kalir, and Christopher D. Andrews

Abstract The act of annotation is intimately associated with reading, thinking, writing, and learning. From book marginalia to online commentary, this centuries-old practice has flourished in contemporary educational contexts thanks to recent advances in digital technologies. New computational affordances, social media platforms, and digital networks have changed how readers–as writers–participate in acts of annotation. Of particular interest is *social annotation* (SA), a type of learning technology that enables the addition of notes to digital and multimodal texts for the purposes of information sharing, peer interaction, knowledge construction, and collaborative meaning-making. This chapter reviews prominent SA technologies, functional specifications, key products, and insights from research, with particular attention to the use of SA in writing studies and composition. The chapter concludes by discussing implications for writing studies and suggests SA technologies can make a critical impact on student reading and writing practices.

Keywords Annotation · Higher Education · Online Learning · Social Annotation · Writing Studies

1 Overview

Annotation is the addition of a note to a text. This deceptively simple writing practice is associated with a rich history of literature and literary studies (Barney, 1991; Jackson, 2001), is relevant to many humanities and social science disciplines (Siemens et al., 2017; Unsworth, 2000), and affords the practices of multimodal composition expressed by a range of material and digital technologies (Davis & Mueller, 2020; Jones, 2015). From rubricated medieval manuscripts to

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_9

book marginalia, underlined words to marked up blogs on the Web, annotation is a genre of communication (Kalir & Garcia, 2021) that synthesizes reading with writing (e.g., Wolfe, 2002a, 2002b), private response with public engagement (e.g., Marshall & Brush, 2004), and cognition with composition (e.g., Traester et al., 2021). In this chapter, we consider annotation as a writing practice that has often been, and continues to be, expressly *social* (e.g., Kalir, 2020; Sprouse, 2018), as indicated by readers who write and exchange their notes with one another, make meaning together, and use interactive media to construct knowledge about shared texts and contexts. More specifically, we borrow and build upon a definition from Novak and colleagues (2012) that defines *social annotation* (SA) as a type of learning technology enabling the addition of notes to digital and multimodal texts for the purposes of information sharing, peer interaction, knowledge construction, and collaborative meaning-making (e.g., Eryilmaz et al., 2013; Gao, 2013; Kalir et al., 2020; Zhu et al., 2020).

Given technological developments, pedagogical insights, and enthusiastic use of SA within both composition and literature courses (e.g., Allred et al., 2020; O'Dell, 2020; Sievers, 2021; Upson-Saia & Scott, 2013; Walker, 2019), it is pertinent to review how SA is relevant to writing studies. In this chapter, we first examine the core idea of SA technologies and practical specifications. We then identify key SA technologies, offering a brief examination of specific affordances and constraints. Finally, we offer insight into existing SA research in–and adjacent to–writing studies, and critically explore the implications of SA technologies for writing pedagogy and practice. Much contemporary research about SA emerges from educational studies, and specific domains like the learning sciences and literacy education. There are a few investigations about SA within writing studies which, appropriately, we review later in this chapter. Nonetheless, SA scholarship has primarily advanced SA as a learning technology–and not just a writing technology–and has provided formative insights on the purpose, pedagogy, and potential of SA technologies and practices.

In writing about SA technologies as relevant to writing studies, we recall Bryant's (2002) emphasis on the "fluidity" of written texts; namely, that processes of composition, revision, publication, reading, analysis, and discussion are fundamentally collaborative endeavors. Readers are writers, their writing is often social, and SA practices exemplify how textual collaboration can thrive across formal and informal learning environments. Moreover, SA technologies facilitate a range of meaningful feedback loops–from instructor to student, and among learners–that are critical to writing pedagogy (Sommers, 2006), invite students to serve in multiple roles (e.g., as tutor, expert, motivator, mentor, and collaborator), and that help develop dynamic learning communities in courses.

2 Core Idea of the Technology

SA is a type of learning technology predicated on two ideas about annotation as a writing practice. First, readers are writers who, for centuries, have added both informal and scholarly notes to their texts: manuscript glosses and scholia, book marginalia, and other forms of written commentary (Jackson, 2001; Nichols, 1991; Stauffer, 2021). Second, readers in our contemporary era have, not surprisingly, brought their everyday and academic writing practices to the Web so as to mark up electronic texts, online resources, and other features of digital environments (Cohn, 2021; Kalir & Garcia, 2021; Piper, 2012). From blog posts to wikipedia entries to social media updates, there are many ways that readers write online and often do so in direct response to other texts, topics, and social contexts. Indeed, the first Web browser, Mosaic, included annotation functionality that was intended to support social reading and writing practices (Carpenter, 2013). But our scope is necessarily more narrow. Whereas, for example, wikis are social technologies that encourage groups to read shared documents, there are categorical and pedagogical differences between the composition of new texts and commentary added to existing texts. We approach SA as a learning technology that directly "anchors" (Gao et al., 2013) written notes to digital primary sources, thereby creating a more proximal and contextual environment for reader response, peer interaction, and shared meaning-making (e.g., Chan & Pow, 2020; Mendenhall & Johnson, 2010). As we review below, there are a range of SA technologies (e.g., Murphy, 2021), as well as extensive use of SA in both scholarly publishing (e.g., Staines, 2019) and transparent qualitative inquiry (e.g., Kapiszewski & Karcher, 2021), with implementations that span elementary, primary, and secondary education. In this chapter we are concerned with the use of SA in formal, higher education contexts and, specifically, writing and composition courses.

3 Functional Specifications

From a technical standpoint, SA technologies operate as browser extensions or applications, with those applications also serving the purposes of formal coursework within Learning Management Systems (LMS; e.g., Canvas, Blackboard). Broadly, SA technologies work with Web-based texts that allow users to select key elements (primarily text) and add multimodal comments. SA tools are dynamic as they allow for shared access to the same text-based artifact, adding layers of interactivity to reading practices. In addition to adding notes to a text, readers can also reply to comments, create threaded discussions, and anchor individual comments and discussion threads within the text. This adds layers of interactivity to reading practices and shifts reading from a solitary activity into one that is social, "Support[ing] social reading, group sensemaking, knowledge construction and community building" (Zhu et al., 2020, p. 262).

Zhu and colleagues (2020) provide the most comprehensive summary, to date, of the social, technical, and pedagogical affordances of SA technologies. With concern for the use of SA in both K-12 and higher education contexts, the authors reviewed 39 relevant studies and identified five types of activities that are supported by SA. These include processing domain-specific knowledge, supporting argumentation and knowledge construction (e.g., Morales, Kalir, Fleerackers, & Alperin, 2022), practicing literacy skills, assessment and (peer) feedback, and connecting learning across online spaces. Perhaps more critically, however, is that SA technologies enable rich parallels between the act of reading and the values championed in the teaching of writing, as with process-oriented pedagogy, peer-to-peer focused engagement, and other practices rooted in the *social epistemic* frame. SA technologies render the act of reading visible among a group, thereby enabling socially situated "first draft thinking" practices for learners to read and write together (Kalir, 2020).

While functional specifications and pedagogical affordances characterize many SA technologies, not all are created equal. Indeed, some social reading technologies can be used to surveil student reading (Cohn & Kalir, 2022) or inadvertently exacerbate inequitable power relations (Bartley, 2022). In the next section, we explore prominent SA technologies with a focus on those used in writing studies. Admittedly, different SA technologies have different functional affordances. For example, *Hypothesis* allows readers to add hyperlinks and embed visual media in annotations, and to determine whether annotations are public or private. Others, like *Perusall*, include AI-powered functions, like automated grading. There are also other annotation applications (like Adobe Acrobat Pro or PowerNotes) that are SA adjacent; they feature social functionality despite other primary tool uses. In these cases, SA-adjacent annotation technologies may include a range of additional features (e.g., editing annotated artifacts, downloading notes with annotated texts), but often with less dynamic social functionality that does not readily integrate within a LMS.

4 Main Products

In a recent review, Murphy (2021) noted that SA, also commonly referred to as collaborative annotation, has increased in popularity in the past few years. The advent of cloud-based technologies, improvements in network structures, and greater degrees (and ease) of access–as well as increased options within the technologies–have aided in SA technologies being adopted across a range of instructional contexts (Ghadirian et al., 2018; Murphy, 2021; Seatter, 2019). Moreover, there is a wide array of SA (and SA-adjacent) technologies, stemming from a distributed history of production, from university-supported designs, to non-profit tools, to commercial applications. These technologies collectively feature a range of technical and social affordances, with educators deploying various and complementary teaching strategies. It is prudent, then, to categorically organize SA technologies to help identify core elements and associated practices. Accordingly, we employ Murphy's (2021) tripartite structure of SA technologies–Open Web Collaborative Annotation tools; Document-based; and

Publishing Platforms–complemented by our original commentary and reference to relevant examples.

Open Web Collaborative Annotation tools allow readers to publicly and privately annotate the Web. These technologies usually layer a minimal interface on top of Web content and require browser plugins to access annotation layers. These SA technologies *bring annotation to an object to be annotated*. The most common tools in this category are *Diigo* and *Hypothesis*. Research about *Diigo* found that undergraduate students prefered this SA technology to conventional discussion forums (in an LMS), as SA practices guided learners' attention to specific textual features and created more focused peer interaction (Sun & Gao, 2017). *Hypothesis* is of particular interest as both the technology and non-profit organization have actively shepherded efforts toward creating the open annotation standard and interoperability between annotation tools (Whaley, 2017). What makes *Hypothesis* of additional interest, as Kalir (2019) has demonstrated, is that it supports readers' multimodal expression, turns texts into discursive contexts, provides users with an accessible information infrastructure, and can help learners visualize cognition and social interaction (see also Morales et al., 2022). *Hypothesis* easily integrates with other open educational initiatives and integrates well with Canvas, Blackboard, and Moodle, among other LMS.

Document-based SA technologies allow annotators to upload files, such as PDFs, into the technology whereby documents are converted for annotation. In contrast to those in the former category, document-based SA technologies *require users to bring the object-to-be-annotated to the technology*. Common tools in this category include: *Perusall*, which is primarily used in higher education contexts (e.g., Miller et al., 2018; Walker, 2019); *NowComment*, which supports K-12 literacy education (e.g., Fayne, Bijesse, Allison, & Rothstein, 2022); and *HyLighter*, which operates in both educational and commercial settings. *HyLighter* uses data analytics to help annotators make sense of annotations in context, as well as across contexts, allowing notes to be brought together from multiple sources. *Perusall*, much like *Hypothesis*, integrates with major LMS, such as Canvas and Blackboard. This integration (as with Open Web *Hypothesis* above) can help reduce instructor and student onboarding, make documents more easily accessible, and aid the coordination of SA activities.

Publishing Platforms, particularly scholarly publishing platforms, are a third category of SA technology that allows readers to participate in peer review activities associated with books (e.g., Fitzpatrick, 2011) and journal articles (e.g., Staines, 2018). Publishing platforms that offer SA functionality are similar to document-based SA technologies, but the annotation features are built into the online platform: *requiring that both the annotator and the object-to-be-annotated go to the platform*. Common tools in this category include MITs *PubPub* platform used to support open peer review of *Data Feminism* (D'Ignazio & Klein, 2020) and *Open Knowledge Institutions* (Montgomery et al., 2021).

Complementing Murphy's categories, there are several other reviews of SA technologies and research. For example, Ghadirian, Salehi, and Mohd Ayub (2018) track the rise in research publications that focus on SA technologies, offer a critical distinction between text annotation tools like *Microsoft Word* and *Adobe Acrobat* versus

SA technologies, and offer a thorough overview of *HyLighter*, *Margelina*, and *Diigo*. Seatter (2019) reviewed *Annotation Studio*, *Hypothesis*, *NowComment*, *Prism*, and *Google Docs*, evaluating each in terms of flexibility, usability, and sociality to assess usefulness and applicability to pedagogical activities. Of additional note, Seatter called for an increased focus on universal design and accessibility with open SA technologies, seeing more inclusive features as helping make Open Web SA technologies "more objectively open technologies" (p. 10).

5 Research

Having identified a range of SA scholarship across disciplines, this section focuses on research in writing studies. There is a rich history of scholars in composition calling attention to the importance of reading (e.g., Haas & Flower, 1988; Horning, 1987; Joliffe, 2003, 2007; Wolfe, 2002b, 2008) and there has been renewed interest in recent years (Carillo, 2015; Horning & Kraemer, 2013; Joliffe, 2017; Salvorti & Donahue, 2016; Sullivan et al, 2017;). But the specific turn to SA practices and technologies is relatively new, with only a handful of works fundamentally rooted in SA considerations and/or their implications for student writing in composition and English courses. Although we do not present a formal literature review, we identified the following studies as being representative of recent efforts to incorporate SA in writing studies. These collective works offer insight into:

- the "multiple reading lenses" students employ in first-year composition (Sprouse, 2018),
- the impact of SA on student writing and course outcomes (Walker, 2019),
- how SA technologies and practices alter students' perceptions of reading and writing (O'Dell, 2020),
- how SA technologies create opportunities for readerly-writing practices and allow for *textual amplification through readerly additions* (Davis & Mueller, 2020)
- how SA technologies foster active collaboration among students and leave visual traces of critical reading practices (Traester et al., 2021), and
- how SA technologies can help students situate writing in relation to knowledge building practices (Sievers, 2021).

Sprouse (2018) identified reading as critical for students in composition but noted that the practices students employ while reading remain invisible. Consequently, she integrated *Hypothesis* into a first-year composition course and examined "multiple reading lenses" that students employed to guide textual engagement. Analyzing more than 1200 annotations generated by 18 students, Sprouse identified four reading purposes in student annotation: *reading for ideas*, or understanding and use of ideas in a text; *rhetorical reading*, or analyzing rhetorical choices and genre conventions; *critical reading*, or cultural values in sociopolitical contexts; and *aesthetic reading*, or personal connection to the text. She found that students often enacted multiple and "overlapping" reading purposes in attending to complex reading, particularly in accounting for "writerly choices and their effects on readers" (p. 48). Sprouse's case documented how SA practices helped her, as the instructor, better assess the ways in which students took up reading practices. Implications from her study suggest that the visibility of student reading practices via SA allowed for better instruction and responsive feedback, made students aware of their reading lenses, and strategically oriented them to the ways in which they made sense of and used content from course texts.

While Sprouse (2018) investigated student reading practices, Walker (2019) studied the impact of SA technologies on student writing and course outcomes. Over two academic years, Walker included *Perusall* in four sections of sophomore-level English. Her study included 125 undergraduate students; 75 were in two course sections that included SA activities, and 54 were in the control sections. Walker collected data from *Perusall* (through the LMS) and from student surveys. The study goal was to determine the degree to which artificial intelligence (AI) elements in *Perusall* operated as pedagogical learning agents and helped students engage with course readings. Her view was that the more students engaged in course readings, the better they would be at leveraging those readings in their writing. While there are some concerns with this study (e.g., no substantive critique of "AI-robo" tools with heavy reliance on algorithms; little statistical difference in course outcomes given AI-based grading), the main gesture of Walker's findings suggests a positive correlation between students' use of *Perusall* and their final course grades. Walker's findings also echo related studies of SA technologies used in other disciplinary contexts (e.g., Gao, 2013; Kalir et al., 2020; Nokelainen et al., 2005) that demonstrate students' positive statements about SA activities and technology in narrative reflections about their learning.

O'Dell (2020) sought to better understand how SA technologies "alter student perceptions of reading and writing" (p. 2), and, moreover, how this technology impacted creative and collaborative writing practices in composition courses. From 2016–2019, O'Dell deployed *Genius* in five First-Year Writing Seminars, choosing the tool because it was accessible, operated with an attractive, aligned interface (i.e., Wolfe, 2008), encouraged collaboration, and mirrored social media practices familiar to students. O'Dell replaced traditional reading responses with low-stake *Genius* activities and encouraged students to "write down what they noticed and what interested them [in a reading], to bring in sources, to discuss their thoughts with others, and to ultimately use these insights to help create an argument for their essays" (p. 16). SA practices helped students to engage in close reading and gather textual evidence and information they could consolidate and integrate into "long-form writing" (ibid). Her analysis of survey data found that students perceived *Genius* favorably; the tool made "it easier [for students] to organize and communicate their ideas" (p. 2). O'Dell also discusses considerations for bringing digital technologies into the composition classroom and provides a nuanced frame for thinking about the inclusion of annotation technologies in writing courses.

Davis and Mueller's (2020) essay considers the history of the page and the multi-modality of texts as central to students' composition practices. They argue that shifts in materiality–and the means of textual production over the past 500 years–gradually shifted reading from a "readerly-writing" experience into more passive consumption. However, they observe that digital technologies have "reinvigorated our attention to the page" (p. 112), alongside related practices of interaction as with annotation. They discuss how SA technologies have created opportunities for readerly-writing practices and how acts of *textual amplification through readerly additions* invite a reorientation of reading and writing pedagogies. But the act and space of textual amplification itself has been amplified by SA technologies, which make "social modes of readerly interaction" (p. 117) available and at speeds and scales never-before encountered by the printed page. Indeed, SA tools like *Hypothesis* are rooted in this idea of textual amplification by creating space (and a text-based interface), for multiple users to extend the ideas of others' writing, embed competing perspectives, and enable a complexity of understanding.

Traester, Kervina, and Brathwaite's (2021) study explored tool- and pedagogy-based interventions as a response to "the challenges associated with critical reading in the digital age" (p. 330). Each author integrated *Hypothesis* into their composition courses at three different institutional settings across the United States. The study rejected the idea that digital mediums of reading "preclude critical reasoning" (p. 329). Moreover, the authors found that SA technologies can aid in students building complex reading competencies and that annotation invites movement between higher- and lower-order cognitive engagements. Further, SA technologies facilitate understanding, situate differing viewpoints in-text, and enable situated responses, enhancing cognitive engagement and helping to make meaningful connections with texts/peers. Lastly, SA technologies can bridge *close reading* and *distant reading* practices, blur the line between public and private domains, and lead to personal reflection and to valuing reading as a way to (in)form a belief system.

Traester and colleagues (2021) further argued that the social dimension of *Hypothesis* can "foster active and voluntary collaboration" among students, and that students were inclined to "take on some of the more challenging tasks associated with expert reading" (p. 346). Additionally, SA activities allowed students to leave "visible traces" of their engagement within the text, "foreground[ing] the text in their conversations," and thereby creating a space "for more empathetic forms" of interaction (p. 347).

Sievers' (2021) study of a general education literature course focused on the relationship of SA practices to student writing. Sievers' case focuses on analyzed data from a single undergraduate course in 2016. She found that SA technology *Hypothesis*, "[w]hen used early in a student's career" can help better habituate students to "knowledge building through writing" and to "the collaborative, social, discursive nature of interpretation" (p. 432). As course instructor, she observed how *Hypothesis* moved up the work of interpretation and critical engagement (to "first encounters" with a given text), allowed students to model critical reading processes for one another, helped normalize the act of making inquiries and working through challenges (and doing so in open [i.e., public] ways), and situated knowledge making as "a community effort" (p. 447). Further, Sievers suggests students' SA activities influenced subsequent essay writing: "Triangulating their papers with their annotations and blog posts revealed […] close connections among these activities: their papers used textual quotations more and in more precise ways, drawing closely on observations and ideas first articulated in their annotations and short writing assignments" (p. 447). Additional research should substantiate Sievers' claim and determine how SA activities influenced student writing; nonetheless, the overarching findings of her study have important implications for SA technologies and practices in writing courses.

6 Implications of this Technology for Writing Theory and Practice

With the advent of better, faster, more accessible digital tools, applications, and infrastructures, we have seen digital technologies have a major impact on how we teach composition. Moreover, with an increasing attention on digital literacy and digital creativity in higher education, there has also been a shift in what we teach in composition, in our learning outcomes, and in the architecture of our writing programs (Porter, 2009). This augmentation, reflective of an increasingly digital culture, places greater emphasis on digital ways of knowing, doing, and making (Hodgson, 2019) and invites the development of new pedagogies rooted not only in digital forms and functions, but also with a continued (and growing) interest in collaborative and interactive methods of learning (Kim & Bagaka, 2005). Or, as Gao (2013) put it, we are undergoing a shift in focus in higher education: moving from "learner-content interaction to learner-learner interaction" (p. 76). The challenge then is not if writing teachers will embrace digital technologies in the classroom, but rather how we come to understand the impact particular technologies have on the range of practices, purposes, and pedagogies we employ.

To this end, there is a wide assortment of possibilities for how SA technologies may change writing with respect to well-established characteristics and key considerations facing writing studies and practices.

First, SA technologies are particularly well-suited for low-stakes assignments that provide situated writing opportunities in texts as discursive contexts. Conventional reading responses, such as posts to a discussion forum, can be replaced with SA activities that allow students to move away from summative responses to analyze specific details, phrases, genre-specific conventions, and authorial choices. Additionally, SA technologies do not do away with discussion forums, but rather provide tools for anchoring threaded discussions in the text itself. This creates an opportunity to invite more complexity in student reading and thinking, as situating writing in-text offers a means for deeper reading engagements (O'Dell, 2020). When peers and instructors work through student annotations, they can prompt additional exploration by responding to an annotation, asking a question, pushing back against a particular perspective, and constructing new insight together (e.g., Morales et al., 2022).

SA technologies, then, provide an avenue through which to invite more complexity in student reading and thinking by (1) allowing writing teachers to situate rhetorical inquiries in-text for students and (2) letting students respond to those inquiries in writing and, in some cases, through networked and layered media, all anchored in textual context.

Second, SA technologies have the capacity to enable high-quality feedback and support. Instructors can provide meaningful feedback about course readings by engaging with students' annotations and by situating inquiries and commentary directly in the text for students. Doing so can prompt further consideration, refocus analysis that may be off target, confirm lines of thought, and offer additional insight and expertise. Moreover, while SA technologies are primarily rooted in the kinds of reading practices students enact in writing classrooms, they can also be used among learners to facilitate peer review of their writing, allowing reviewers to anchor their feedback directly in the text as well.

Finally, SA technologies expand the physical margins of a text by adding a digital layer through which student annotations can be placed in the text and into conversation with others' annotations. As discussed, annotations may be multimodal and hyperlinked to other media or resources, crafting a multimedia tapestry for meaning making practices. SA technologies create new spaces for multimodal writing and composition, for content engagement, and for peer-to-peer collaboration. When thoughtfully implemented in coursework, SA technologies can effectively help readers to focus on writing quality as a part of their annotation process. Further, the planned pairing of SA technologies and writing practices can help students better understand texts, aid clarity and coherence in subsequent writing activities, and can expose students to a range of writing styles and strategies. SA technologies can make a critical impact on student writing and reading practices and have the potential to improve the quality and complexity of student learning.

7 List of Tools

Annotation Studio	A suite of collaborative web-based annotation tools under development at MIT	https://www.annotationstudio.org/
Diigo	An abbreviation for "Digest of Internet Information, Groups and Other stuff," is an online platform that is intended to "streamline the information workflow" through the organization, annotation, and sharing of online resources	https://www.diigo.com/

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Genius	A music encyclopedia where users annotate song lyrics	https://genius.com/
HyLighter	A web-based annotation tool that allows for marking up digital texts and sharing comments and notes with other users	https://www.hylighter.com/
Hypothesis	Open-source software that affords "a conversation layer over the entire web that works everywhere, without needing implementation by any underlying site."	https://web.hypothes.is/
Marginalia	An open source web annotation system used to enrich online discussion. It works with various web browsers and allows users to highlight text and write margin notes. The program is a successor created by Geof Glass to Andrew Feenburg and Cindy Xin's TextWeaver	http://webmarginalia.net/
NowComment	A free platform primarily used in K-12 educational contexts that provides a platform "for group discussion, annotation, and curation of texts, images, and videos."	https://nowcomment.com/
Open Review Toolkit	Open source software that facilitates open review by allowing users to convert book manuscripts into a website	https://www.openreviewtoolkit.org/
Perusall	A social-reading platform that integrates with LMS and allows students and teachers to digitally annotate texts	https://perusall.com/

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PowerNotes	A digital notetaking platform that allows for annotation of digital texts, source management practices, and note-downloading capabilities	https://powernotes.com/
Prism	A tool for crowdsourcing interpretation by allowing shared mark-up and with each being categorized: creating a visualization of engagement with the text	http://prism.scholarslab.org/
PubPub	An open-source publishing platform for knowledge communities	https://www.pubpub.org/

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Multimodal Chat-Based Apps: Enhancing Copresence When Writing

Tracey Bowen and Carl Whithaus

Abstract This chapter examines how digital platforms and social media may be integrated as part of academic writing processes. These digital tools can be used to facilitate students' development as writers who are agile across modes of text production, collaboration, and dissemination. Writing on multimodal apps and platforms such as WhatsApp and Discord have encouraged students to write in ways that are collective and collaborative. Students are taking up brainstorming and "pre-writing" activities on these public platforms as a way to *come* to writing in virtual contexts in the copresence of others. These forms of "prewriting" are increasingly becoming part of writing processes and bleeding over into how students' final academic pieces of writing take shape. Students are not only using these social writing processes and genres in their academic writing but they are also becoming digital content creators as they enter their professional spheres.

Keywords Academic writing · Collaboration · Copresence · Multimodal composing · Social media writing · Writing processes

1 Overview: Introduction

Digital technologies have impacted writing practices across almost every genre and context. Networked, chat-based tools that support collaboration and allow for multimodal composition have played a role in this transformation. Academic writing and production are no exception. The processes and activities an individual employs for preparing *to write* for both academic, creative and information sharing purposes, or what we term "coming to writing", including research, information gathering and coordination, are not always evident or recognized parts of the writing process in a

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_10

traditional sense. Increasingly this *coming to writing* process involves digital writing across different platforms and within social environments. In this chapter, we examine the potential of chat programs (i.e., WhatsApp, Discord, and Gather.Town) for idea generation and coordination, peer community access, and resource sharing to support *coming to writing* activity and prewriting practices. The examination is predicated on a review of how researchers have named and understood the affordances of chat and IM for writing in academic contexts. While using chat and IM is a common phenomenon in practice, it is only emerging as an area of explicit research in writing studies. However, to date much of the work focuses on the potential of chat-based platforms as learning environments in Higher Education (Alt, 2017; Mpungose, 2019; Nyasulu & Chawinga, 2019; Zulkanain et al., 2020), students' chat-based interaction and engagement in secondary education learning communities (Durgungoz & Durgungoz, 2021; Rosenberg & Asterhan, 2018), or anecdotal accounts of students integrating chat-platforms into their academic work.

In this chapter, we consider how the integration of these "non-academic" platforms have shifted the ways in which students are coming to writing and how they compose multimodal academic works. Affordances highlighted by Friedman and Friedman (2013) and Quan-Haase (2008) facilitate possible connections that could provide further insight on the ways in which informal non-academic writing and exchange on networked platforms are part of more institutionalized writing practices. The potential of these tools for academic tasks needs to be investigated in more detail by writing researchers. *Coming to writing* offers a particularly robust framework for understanding how the messy, pre-writing stages of text production have become blended into almost all stages of students' writing processes. Writing has become a process where multimodal chat-based forums are always on, always available, and influencing the development of their ideas through the copresence of others. Copresence provides individuals access to collective ideas and resources through networked communities (Latzko-Toth, 2010). Copresence provides the context for examining how academic writing activities shift to social network systems. The chapter concludes with suggestions about future research on how the copresence of individuals within IM or chat communities afford information sharing and exchange that potentially translates to concrete composition processes and the end product of academic writing.

Coming to writing names the conceptual process for writing preparation more broadly. *Coming to writing* is not solely tied to academic writing, it can apply for novelists, artists, and social media influencers. It's the mental and social preparation for writing. Within an academic context, *coming to writing* might include research-based preparation, organizing lecture notes, coordinating resources, and developing an understanding of the genre conventions that are recognized and rewarded in relation to specific disciplines. This chapter examines how chat-based apps such as WhatsApp, Discord, and even Gather.Town have contributed to this process. These chat-based apps have expanded the idea of coming to writing through online networks that facilitate the copresence of others to support the process. The sense of copresence promoted by multimodal chat apps have shifted how writers understand and engage these early stages of their writing processes through online social mechanisms. *Coming to writing* involves all the social interactions that inform, test, and confirm ideas, strategies, and techniques, including idea formation and coordination through the casual conversations that emerge from social interactions. Dialogue is afforded by networked platforms accessible to students continuously, anytime, anywhere. *Coming to writing* practices may not be identified in relation to a specific course or assignment. Rather they are interwoven into routine writing activities that help us coordinate diverse components of everyday life using "portable digital writing devices" that keep us digitally connected (Pigg, 2014, p. 252; Spinuzzi et al., 2019). Two particular forms of networked communication, chat platforms and Instant Messaging (IM) apps, provide convenient, accessible and affordable sites for prewriting activity and the process of coming to writing.

IM through social media and ICT apps, and digital platforms that afford interactive chat rather than sanctioned Learning Management Systems (LMS) have become ubiquitous for connecting, sharing, querying, and as part of note taking for documenting and remembering (Pigg et al., 2014; Quan-Haase, 2008). Students engage in chat and messaging activity as a large part of their everyday writing practices and are comfortable moving conveniently and fluidly between managing messages and coordinating conversations, researching (through Google), ideation, testing or confirming ideas, setting up social engagements, remembering "stuff" (Pigg et al., 2014, p. 102) and supporting others in their networks. Vie (2015) has sketched out strategies for incorporating social media into higher education writing courses. Often pedagogical approaches like Pigg et al.'s, Quan-Haase's, and Vie's integrate social networking systems that allow instructors and students to work simultaneously, across digital platforms and environments. Students in particular have all this activity turned on in the background all the time, so coming to writing and composing becomes more diffuse, not always distinct from everyday details within digital chatter. While students may not use messaging or chat to work through an outline for their next essay, their academic work and pre-writing composing activities cannot be separated from their everyday digital writing practices and spaces.

The affordances of collaboration and content sharing enabled by chat platforms and apps are ripe for helping students "come" to writing outside the classroom, through socially embedded knowledge construction in social contexts not usually considered learning environments. Using social networks for *coming to writing* involves discussing possible topics related to the course and thinking about potential purpose, function, audience, and genre of the writing. *Coming to writing* entails thinking together with others in preparation for writing. These processes replace some of the formal prewriting activities that were part of early process movement writing pedagogies. Overall, the social processes involved in *coming to writing* in these alternative spaces affords "dialogic thinking" (Alt, 2017, p. 626). Networked spaces such as chat platforms facilitate idea generation and coordination, peer cooperation and collaboration, and multimodal resource sharing to support *coming to writing* activity and prewriting practices. Students can use multimodal chat platforms later in the process to return to brainstorming or to open opportunities for revising and extending a section of their academic papers. The use of chat platforms and apps has evolved in ways that afford socially situated prewriting, organizing, and composing with the support of individualized on-demand communities.

2 Core Idea of the Technology: Developing Copresence Contexts in Chat Apps and Platforms

Originating in the 1970s during an energy crisis, the primary function of early chat technologies was to enable conferencing and collaboration between individuals who were geographically dispersed (Latzko-Toth, 2010). Early chat afforded online community building through small group communication that could be physically scattered across locations, yet digitally connected - the core idea surrounding chat as a platform-based technology. Chat, including IM, further evolved since the early development of ICQ (I seek you) in 1996 emerging as an application that is "near-synchronous communication between two or more users who are known to each other" (Quan-Haase, 2008, p. 106). The development of chat platforms has afforded users access to multiple conversations on a need or want-to-know basis occurring simultaneously alongside other everyday, personal, professional, and academic activities. While mobile phone-based texting may not have originally appeared to be a promising technology to use alongside academic writing activities by the early 2000s, university students were incorporating IM in their academic activities. Early online sites developed for conferencing and collaboration created ground for later apps to develop the always available, on demand forms of copresence that many students now incorporate into their academic writing processes. For the purposes of this chapter, we see *chat* as both platform technology and digital production/practice. The following sections further describe the affordances of chat as an enabling technology, a social practice that supports copresence, and a *coming-to-writing* environment.

2.1 Chat as a Site for Academic Writing within a Community of Writers

The ubiquitous use of chat-based apps as well as the technological development of the apps themselves has facilitated an increase in the ways students incorporate chat-based forms of communication into their academic writing processes. Apps such as WhatsApp, Discord, and Gather.Town offer students spaces where they can be co-present with others and draw on the availability of "on demand" groups to answer questions related to their writing activities. These "always on" groups may be from within their particular courses, from their wider university communities, or even emerge as more distributed groups across different geographic areas and institutions. Examining how these apps have developed both inside and outside of academic spaces provides insight on how multimodal, "chat" apps are influencing students' academic writing practices. While there might be some ambiguity in terms of what sorts of writing we are talking about, we argue that the porous nature of multimodal, chat programs as "preparation" spaces for academic writing means that it is the interplay, the ways in which ideas move between chat programs and formal academic writing spaces is key.

As "chat" programs have changed over the last thirty years, their utility as places where students can connect, share ideas, and coordinate activities around academic writing assignments has transformed in profound ways. The move from text-based chat applications to multimodal apps has seen software platforms evolve from tools to enhance brainstorming and peer-to-peer feedback to cross-platform mobile apps that promote a sense of copresence and promise "on demand" community support. The technological developments of these "chatroom" apps have been driven by changes outside of academic circles; however, within writing studies there has been a steady investment in working to adapt and utilize chat programs for academic writing tasks. For instance, in the late 1980s, the "InterChange" module was developed by writing researchers, teachers, and programmers at the University of Texas as part of the Daedalus Integrated Writing Environment (DIWE) (LeBlanc, 1992). The early work of Lester Faigley (1993) and others on using these LAN-based chats evolved into more sustained conversations around how platforms could be used to build "communities of writers" within college and university courses during the early 1990s (Crawford et al., 1998; Essid & Hickey, 1998; Palmquist et al., 1998). While writing researchers, writing program administrators, and software designers were wrestling with creating and integrating chat software into college writing courses, the use of chat technologies was growing rapidly outside of academic contexts. SMS texting on mobile phones exploded as a form of digital, written communication (albeit brief and extremely short form). Students increasingly turned to these non-academic, but familiar tools when they needed to take part in cooperative or coordinated actions for their writing assignments.

Much of the recent research on instant messaging and chatting focuses on the sociability afforded by networked communications engaged by individuals for different social purposes. However, little research exists on how instant message and chat platforms afford a purposeful sociability that supports idea generation and organization for academic writing through mobile devices. Pigg et al. (2014) position mobile phones as "remarkably agile writing technologies" or "writing devices" (p. 95) that afford students speed, reach, continual access, and interactivity (pp. 92, 95). They situate writing as a form of coordination and managing activity in everyday life as well as academic life. Pigg et al. (2014) argue that students at college and university use writing as a way of organizing "personal, professional, and academic memory, sociability and planning" (p. 93). Students in their study ubiquitously used mobile phones as devices for coming to writing, coordinating activity and for actual writing production (p. 100). Students were customizing a sense of copresence and individualizing the groups they were connecting with through their phones. Their writing processes were being reshaped in ways that they valued.

Chat threads have also served as archives of thoughts and places for the coordination of events and conversations. Students catalog notes, observations, and ideas so they may be retrieved as a reminder later on. The social practices and archival affordances of chat support academic work in the prewriting stage through reminders of ideas, resources, through links and lecture notes sent to oneself. The on-demand individualized networks support the evolution of this archive. Students' writing processes, as Pigg et al. (2014) and Quan-Hasse (2008) have shown, are developing, and changing based on the availability of multimodal, chat apps. Programs such as Discord, WhatsApp, and Gather.Town have come to reach across devices; they are available simultaneously on mobile phones, desktops, laptops, and tablets for students. Students' reliance on apps that provide, or claim to provide, access to individualized, "on demand" communities and anytime access to peer feedback to answer questions about writing tasks has shifted how students come to a writing task. These technologies have not only digitized writing, but they have also digitized the conversations that happen around writing within information rich social networks.

3 On-demand Copresence

Latzko-Toth (2010) defines chat activity as "social synchrony" based on a participant's presence via some form of networked digital screen. He contends that chat, particularly chat that has evolved through IM requires "simultaneous *presence"* a form of "*copresence*" within a virtually shared space (p. 362). Chat affords the sustained copresence between individuals who know each other and have mutual interests that support the connection. Chat-based platforms assume a synchronous reciprocity of the co-present chat group members, a form of conferencing, while instant messaging, a sub-form of chat, assumes a background *copresence* where individuals respond if available (Latzko-Toth, 2010). IM is always on—always available and presents as abbreviated conversations rather than content laden communications like email. The brevity of messages affords immediate conversation coordination, exchange, and feedback. The affordance of copresence is based on the receiver(s) choosing to interact and acknowledge the presence of others. IM copresence is "self-centred" relying on social relations that already exist based on a shared purpose, rather than more traditional notions of a gathering site (chat room) or "*conference"* where individuals are attracted to the site to gain new social connections (Latzko-Toth, 2010, p. 369). Latzko-Toth (2010) states that copresence is "an affordance more than a reality" as it exists within the individual's "awareness of" the potential presence of another who can lend support in a myriad of ways (p. 369). The copresence of chat and IM is predicated on networks of individual need and preference, what Manuel Castells (2001) calls "networked individualism" (pp. 128–129) or what we have termed, *on-demand communities.*

Networked apps and platforms afford communication, content sharing, collaboration and copresence through on-demand peer communities outside the conventions of the traditional classroom context. Students use platforms such as Instagram, Whats-App, Discord and Gather. Town to connect socially to access information and engage in what Pigg (2014) terms "composing habits," to navigate everyday routines within information rich nonacademic virtual spaces. Many apps, particularly those perceived as familiar virtual spaces which have provided positive support in the past, afford social connection, open and constant conversation that becomes a comfortable and convenient learning/writing space. The ways in which students access chat platforms through mobile devices for academic work and coming to writing, highlights their familiar ways of communicating through networks.

3.1 Copresence as Peer Support in Non-academic Spaces

The ease of accessing information and communication channels through Discord and Whatsapp provides the opportunity for anywhere, anytime collective learning. WhatsApp developed as a cross-platform text messaging and voice-over-IP (VoIP) service, foregrounds users' access to each other through mobile devices. It enables users to not only send text and voice messages to each other, but also to share images, documents, and other content. Whereas Discord, originally designed as a chat platform to supplement online gaming, has evolved into a social media platform that connects participants through online servers where they can use text or voice chat. The written chats are frequently saturated with gifs, emojis, and other multimodal forms of writing on these servers. As a virtual office app, Gather.Town on the other hand shares some of the affordances for connecting with others and using multiple modalities (i.e., visual and audio elements) to support writing activities available in WhatsApp and Discord. However, as a platform designed to allow users to set up an online space where they can meet with others, Gather.Town's interface and functionality more closely resembles a top-down viewed video game rather than a chat designed for mobile phones. WhatsApp, Discord, and Gather.Town employ user-driven processes, with user-driven dynamics that have been appropriated by students from their everyday non-academic lives in the service of academic work within their socially networked communities. Alternative, non-academic communication spaces provide students opportunities to engage with others in ways that are meaningful to them, potentially inspiring collaboration in new ways (Alt, 2017). The copresence afforded by chat platforms and apps supports group communication that provides an always available space for generating and trying on ideas, discussing logistics, sourcing, and sharing techniques, creating socially inspired field notes, and for provoking feedback to everyday composing habits that are part of the *coming -to -writing* process within peer support communities.

4 Functional Specifications: Idea Generation, Peer Networks, and Resource Sharing

The perception of copresence fostered by multimodal chat platforms and apps offers support for writers' idea generation and coordination, peer community access, and resource sharing to support *coming to writing* activities and prewriting practices in academic writing contexts, even though these software tools were not originally designed for these purposes. Coworking, a precursor to copresence in the sense that individuals work alone but within a physical proximity to each other (Spinuzzi, 2012), and copresence, working in virtual proximity, afford the possibility of momentary and spontaneous collaborations that may be part of idea generation within the coming to writing process. Collaboration is organic in this case, spontaneous between available individuals. If we consider the functional specifications and affordances of WhatsApp, Discord, and Gather.Town, we come to see how these multimodal chat apps and platforms enhance how students generate ideas, access peer feedback, and share resources through a community of networked writers. The copresence of other writers provides opportunities for them to connect with other students in their courses, at their educational institutions, or from more distributed networks of students at other universities.

Given the increasingly frenetic pace at which academic writing processes are being digitized, it is not surprising students are using these apps and the connections they create to generate ideas, to coordinate with others, to gain access to peers working on similar issues, and to share resources. As multimodal chat apps, WhatsApp and Discord not only provide affordances related to developing a sense of copresence as students work on academic writing activities, but they also stretch writing beyond the textual, beyond the alphabetic, into realms where visual and audio elements impact students' thinking and writing processes. The commonalities across how WhatsApp, Discord, and Gather.Town are being used highlight how university students value copresence as they work on academic writing tasks. They are not the only apps and platforms being used by students and faculty to support idea generation, the development of peer communities or networks, and resource sharing for academic writing tasks. However, they provide us with popular examples where multimodal connections with others are being used to support students' academic writing.

Friedman and Friedman (2013) recognized key characteristics of social networked technologies, of which chat platforms and IM are a part. These characteristics provide the capacity for communication, collaboration, community, and creativity. The functional specificities afforded by the copresence of chat platforms support three aspects of coming to writing and ensuing composing habits identified as idea generation, peer network support, and multimodal resource sharing, all of which include the characteristics of socially networked technologies.

4.1 *Idea Generation: Multimodal Brainstorming as Starting Point and Recursive Activity*

Chat platforms and apps shift prewriting processes from being a technique integrated into students' composing habits to something that emerges from a blending of social interactions and the idea formation required by academic writing assignments. It's a different way of brainstorming by utilizing available social conversation to generate ideas for academic tasks through peer support communities. The text-based threads of chat and IM platforms enable individuals to keep track of conversations even if they choose not to contribute in the moment. The conversation threads function as "always available" records of the interactions that individuals can return to, expand on, and recirculate for potential feedback from co-present others inviting spontaneous albeit momentary collaboration. Voice-channels as well as text-channels assist in developing ideas. These important multimodal features of chat are being used more frequently in the form of livestreaming and composing, a way of recording similar to putting music to an Instagram post. In addition, users/composers can express affect by using emojis to signify their emotional responses to ideas and to the feedback they receive. Students describe using chat and IM platforms such as WhatsApp to discuss their initial topic ideas for various academic writing, particularly for collaborative work where idea brainstorming can be further fleshed out using other platforms such as Google docs or Zoom.

Copresence supports open idea generation within selected peer communities, where individuals try on ideas freely and reinforce relationships with others that support prewriting within an informal social environment. Spinuzzi's (2012) research on coworking provides insight on what could be considered the precursor to virtual copresent working through social networks in terms of idea testing and peer support (see also Spinuzzi et al., 2019). Coworking, according to Spinuzzi, lessens isolation because of a feeling of community through the presence of others. The philosophy behind coworking places emphasis on communities made up of lone individuals working in the same physical space, i.e., individuals "working alone, together" (Spinuzzi, 2012, p. 400). The physical proximity of others within coworking spaces affords opportunities to collaborate on such things as idea generation and brainstorming, even if the collaboration is only momentary - a moment of "bouncing ideas" off others present. Students use chat and IM platforms to come to writing through social and communal support and resource sharing—a virtual extension of coworking that accentuates the anywhere, anytime opportunity for collaborative moments with copresent individuals. Working with the support of copresent others in media rich multimodal environments inspires questions such as what else can I do, and what else is possible, thereby enhancing the writing endeavor (Bowen & Whithaus, 2013).

4.2 Peer Networks: "Always There" Access to Individualized Communities

Copresence of chat platforms and apps function as consistent "sustained" communication channels that enable "peer teaching and resource sharing" (Durgungoz et al., 2021). Individuals use socially networked platforms to form relationships and clusters of relationships, and easily move between private and public communications and conversations within the space of the same mobile devices. For students, these relationships provide both intellectual and emotional support for constructing knowledge and answering questions around content, technique, and resource sharing. Whatsapp and Discord facilitate micro-community building, relationship forming, inquiry, testing, and social gathering logistics. These activities can occur simultaneously within the same space, providing continuous available support to writing and composing habits through background channels.

Students create micro-communities that support a diverse range of daily activities and composing habits including their academic writing through their "desire to dwell with friends" (Rosenberg & Asterhan, 2018). Chat platforms such as WhatsApp exist as part of students' worlds, encouraging connectivity and conversation within the social environments in which they are afforded multimodal communication, and in which they are most comfortable. In Discord, servers can be created and moderated by anyone. Reyman and Sparby (2019) have examined how Discord relies on users to moderate content on servers they have created or servers they have joined. In many ways, the process of running a server may be more like curating an open and ever evolving stream of comments and resources and less like what we think of as traditional forms of moderating a discussion. These curated writing resources are "always there," they are accessible not as artifacts, the way they would be on a static website, but rather as points within a discussion that can be revisited.

4.3 Resource Sharing: Multimodal Content Gathering and Sharing

Students report that they use Whatsapp and Discord for addressing questions and sharing resources around writing techniques and expectations, exchanging ideas and resources related to content creation and fielding logistical questions about events and opportunities. They use chat platforms and apps to learn about writing, to group chat about writing events, discuss techniques and conventions particularly around editing, and to organize further meetings, both virtual and face-to-face, to focus on the writing itself. Chat platforms such as Whatsapp and Discord facilitate the exchange of multimodal resources that may be used to augment learning about a topic or be integrated into the presentation of content within the writing product itself.

Chat and the copresent availability of resource sharing has increased multimodal opportunities for writing and composing. However, the focus on integrating multimodal texts within academic writing has shifted from discussion around innovative pedagogical practices in the field of writing instruction (Bowen & Whithaus, 2013; Reiss et al., 1998) to mainstream expectations that the digitalization of writing affords more experimentation with image, sound, and video as part of academic texts (Blevins, 2018). Chat platforms such as Whatsapp or Discord support the sharing of images/photos/memes, videos, and audio that create media rich environments, still within the flexible convenience of mobile devices. Multimodality in some of these instances is the multiplicity of voices through copresent support and information sharing and momentary collaboration, as much as it is compositions that are augmented by image and video. Writing within media rich environments offers the user the flexibility to use the tools that afford the most appropriate mode of interaction and one that is best suited to the context and purpose of the interaction (Rosenberg & Asterhan, 2018). Chat platforms and apps provide media rich environments that conveniently and easily facilitate resource sharing and composing through everyday, always on mobile devices.

5 Implications for Writing Theory and Practice: Copresence and Ambiance for *Coming to Writing*

When students use WhatsApp, Discord, or Gather.Town to support their academic writing, they are tapping into spaces originally designed to facilitate other forms of social interaction. These students are repurposing WhatsApp, Discord, or Gather.Town and making them into digital writing environments to support their "real" academic writing. Writing researchers, particularly those interested in the digitization of writing, need to continue to examine the details of how students are using these multimodal chat and virtual office apps as part of, their academic writing processes. The digitization of writing has seen shifts in the way we write every day and within academic and learning environments. However, further investigation is needed to better understand the impact of copresent writing with others within digitized virtual spaces. New forms of collaborative practice for academic writing are emerging and will continue to emerge and evolve through "non-writing and non-academic" apps and platforms. We need to document what is emerging in these cases and identify how to better facilitate these new forms of writing.

In the context of academic writing, students' activities in these apps help them draw on the copresence of other student writers. Students participate in these forums for a variety of reasons, one of which is the coordination of their activities across a number of media environments in which they engage as part of their daily composing and socializing activities. Additionally, students garner support for their writing activities and gain a sense of belonging within an ambiance in which they feel comfortable and supported. Chat and virtual office apps allow students to build micro communities where they are not obligated to other members in a traditional sense, but rather participate in a drop in space where support and relationships exist in an always available form.

Students also use the channels on WhatsApp and Discord or the spaces in Gather.Town for sharing resources that help them complete the course-specific writing tasks they are working on (i.e., examples of successful essays from previous versions of the course or other resources). They are using these pieces of software to connect with clusters of people who will support their writing activities, their coming to writing. It's not really a community in the traditional sense. It's "relationships" but relationships to the content, the work, as much as it is to other users. As writing researchers from across multiple disciplines, we need to examine how these new communities of writers and their sense of connecting with others is shaping their academic writing processes. Chat platforms and virtual office apps provide sites for communal composing habits that support coming to writing through the copresence of others. These sites offer extensions to traditional spaces of academic work. However, what we still don't understand in terms of coming to writing through the copresence of available others, is the tangible impact on the end-product, the textual evidence of the words and perhaps the images and the sounds that make it into academic writing, into academic presentations about the topics the students are writing on. We do know that copresence is becoming increasingly essential for students' academic writing processes–it's about writing and connecting with others and what is meaningful to them. It's about the supportive chat conversations where you post and someone else responds. But the exact contours of its dialogic nature have not yet been mapped out.

The conversations students have with others in these apps appear to be meaningful, connective, and hopefully productive. However, how does the copresence of others when you reach out with an idea or question or something new to share, impact the assignment you as a student writer are working on? There is the potential that someone will respond. Students are present together… working and writing in parallel with each other. However, we still don't know the impact of copresence, through the opportunity for idea testing and access to feedback within individualized communities, on students' development as writers. Questions around the differences in impact based on the discipline you are working in may have implications for working in design, in biology, in engineering, or in the humanities. Do you draw on different types of multimodal evidence in your academic writing depending on how you interact with others in WhatsApp, Discord, or Gather.Town? What about how each app or platform offers its affordances to the users? Do these make a difference? How are instructors deliberating incorporating these technologies into academic writing activities? These types of questions and the empirical studies to develop answers to them point to the necessity of continuing to examine how digital platforms are impacting students' academic writing processes. Answering these questions is not only about developing particular platforms for academic writing, but also about considering how students actually experience the digitization of academic writing based on their lived experiences with multimodal chat and virtual office apps, and shape how they write and the others they write with.

6 Terms

Chat-based app: emerged from programs such as ICQ and mobile phone texting capabilities; as cross-platform technologies became increasingly present on mobile devices, laptops, and desktops, chat-based apps became a primary mode of synchronous communication; the next evolution in these tools was the development of multimodal chat-based apps that enabled both synchronous and asynchronous forms of communication (e.g., WhatsApp and Discord). Later collaborative tools (e.g., Gather.Town) incorporate elements from chat-based apps but also create a fuller place-based simulation.

Coming to writing: a way of naming the combined mental, conceptual, and physical process for preparing to write.

Copresence: the capacity to access the presence (and guidance) of others for information gathering and sharing through networked digital technologies

Multimodal: ways of communicating that draw on visual, linguistic, aural, gestural, and/or spatial modalities rather than only alphabetic text.

Prewriting: seen as activities that students and writers engage in before starting a formal writing task in classic writing process theories; as writing theory and research has evolved, prewriting and brainstorming have remained important steps; however, the recursive nature of writing processes have been recognized in writing process research since at least the early 1990s and–as we argue in this chapter–changes in information technologies have increasingly blurred the boundaries between distinct stages in the writing process.

Writing process(es): classic writing process theory suggested five stages–prewriting, drafting, revising, editing, and publishing. Advances in writing process theory, post-process approaches, work in Writing Through the Lifespan (WTTL), and other more situated approaches to understanding how writers work have emphasized not only the recursive nature of writing processes but also the plurality of writing processes. That is, different writers write differently, and these differences may vary not only among writers, but also between different contexts (i.e., one writer might go through different writing processes depending on the writing task they are engaged in).

7 Tools

Tool	Features	Specificities
Discord	Chat based, multimodal app	Initially developed as a copresence platform for gamers, for connecting with each other while gaming and/or livestreaming https://discord.com/

(continued)

(continued)

Tool	Features	Specificities
Gather.Town	Place-based simulation, incorporates chat-based functionality	Tool for collaboration, includes text-chat; its multimodality emerges from the place-based simulation rather than within voice or text chat https://www.gather.town/
ICQ	"I seek you" chat-based platform	One of the original text-chat based platforms on the internet; used heavily in the late 1990s
Instant Messaging (IM)	Instant Messaging, emerged from mobile phone-based texting and computer-based texting (AOL "Instant Messenger"), now a common cross-platform functionality between phones, computers, and mobile devices	Text-based chat using AOL IM was a common form of real-time communication in the 1990s for users of AOL. In many ways, the functionality of IM and mobile phone-based text messaging have converged in cross-platform apps such as WhatsApp and Discord
WhatsApp	Chat based, multimodal app	Developed to connect users of mobile phones with each other; widely used around the world, particularly where there is limited access to high-speed internet connections https://www.whatsapp.com/

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Learning Management Systems (LMSs)

Susan Lang

Abstract This chapter provides a brief overview of the history of Learning Management Systems before turning to those currently in widespread use. While surveying these systems, the chapter will focus on the extent of the ability of these platforms to contribute to writing instruction, writing analytics, and learning analytics. It will also discuss the development of LMSs designed specifically for writing instruction.

Keywords Learning Management Systems (LMSs) · Online writing instruction

1 Overview

Learning Management Systems (LMSs) have a curious relationship to writing instruction. LMSs have a nearly century-long history; however, the development of these systems is best understood by focusing attention on the "Management" aspect of them, especially if we consider the ways in which many of the LMSs currently in use focus primarily on collecting and storing data while providing a framework for organization of that data—not unlike popular Content Management Systems (CMS) such as WordPress or Drupal. The LMSs do not, however, generally consider what type of data and in what format would be of the greatest use to writing instructors or writing program administrators. While administrators and instructors can certainly make use of such essentials as login and module/page viewing data, as well as the gradebook typically included with any LMS, that data often provides only a snapshot of student engagement via a submitted project, instructor comments, and a grade. And those textual data points (student writing, instructor feedback) are usually not stored in a way that makes them easily extracted for analysis independently of other course materials.

LMS designers, however, do not bear sole responsibility for the lack of features conducive to writing pedagogy found in their applications. Richard Fulkerson (1979, 1990, 2005) returned three times to the articulation of philosophies/theories of

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_11

composition and teaching methodologies; while in 1990, Fulkerson appeared hopeful that composition in the United States was reaching a philosophical, if not pedagogical, consensus, his final article on the subject (2005) saw composition as an increasingly contentious discipline without a consensus on outcome or pedagogy. This dissensus among composition scholars, combined with the increasing trend for first-year writing courses to be taught by graduate students or adjunct faculty, may be one reason more writing researchers were not at the table when LMSs were designing or adding features. Instead, those writing researchers who believed in the potential of digital/electronic writing spaces often built software to instantiate their preferred writing pedagogies; for approximately 20 years, this work was often begun by an individual or small group of faculty, then moved to a collaboration with a textbook publisher, such as with the Daedalus Integrated Writing Environment, which was built by a group of graduate students at the University of Texas and then sold to Pearson Education. All of these initiatives ultimately failed because of incompatible goals of faculty and publisher but provided glimpses into what writing-focused LMSs could be. What follows here is (1) a look back at the development of proprietary and open-source LMSs, (2) a look at development of writing software that could have been/can be integrated into an LMS or that had LMS components, and (3) an assessment of the future relationship between LMSs and writing pedagogy.

1.1 Early LMSs

Consider two contemporary definitions of Learning Management Systems:

- Prasad (2020) defines a Learning Management System as "a software application that helps with the management of digital training content.
- Fry (2022) explains that an LMS, in plain language, "is software that helps you create, manage, organise, and deliver online learning materials to learners."

Even in the post-pandemic world, the language used to describe LMSs emphasizes the mode of delivery rather than the actual instructional act; this focus on scalable learning has been a part of the LMS since it was created. Sidney Pressley is credited with developing the first LMS, the Teaching Machine, in 1924. In 1956, Gordon Pask designed SAKI (Self Adaptive Keyboard Instruction) in order to train key punch operators. SAKI was able to adapt its instruction to the level of the person using the machine. PLATO (Programmed Logic for Automatic Teaching Operations) was developed at the University of Illinois in 1960 and was the first LMS used for teaching at multiple levels and in diverse disciplines. Etherington (2017) notes that PLATO pioneered several "firsts" for eLearning: it was the first distributed system, running on over 7,000 terminals and distributing material in over 150 courses by 1980. PLATO's developers are also credited with driving development of the first Bulletin Board and Chatroom functions. Finally, the graphical user interface of PLATO was said to inspire Xerox and later Apple to create GUIs for personal computers. The last PLATO system, used by the Federal Aviation Administration, was decommissioned in 2005. In 1983, Massachusetts Institute of Technology (MIT) began Project Athena, designed to provide students with access to computers. James Paridis and Ed Barrett's contribution was the Athena Writing Project, the first attempt at an online classroom that allowed students to "edit and annotate papers, present classwork, and turn in assignments." While digital technologies would assume increasingly integral roles in the act and teaching of writing, LMSs themselves remained on the periphery of digital writing pedagogy.

1.2 Contemporary LMSs

Although contemporary LMSs were developed for use in online courses, LMS platforms had become increasingly a part of onsite education in the 2010s. That does not mean that the LMS was embraced by writing program administrators or instructors. Hewitt (2015) notes that "*[E]very LMS has [deficiencies], albeit some worse than others*," while many others have noted that LMSs lack the flexibility for instructors to use established writing pedagogies and practices without compromise. Hutchison (2019) argues that the inherent turn toward efficiency in LMSs creates a "wicked problem" for writing instructors. And York (2021) calls for more detailed assessment of the use and effects of the digital surveillance tools baked into most LMSs.

Clearly, given the propensity of the LMS to rely on quizzes and rubrics, writing instructors have argued against the temptation to rely on drill and practice exercises such as those used for grammar instruction; another concern is that instructors who want to shorten the grading process will rely on rubrics that they have inserted into the LMS to grade student writing, without additional comments that explain *why* a student earned a certain score on their paper. Another potential problem involves the possible use of automated writing evaluation if/when such systems are integrated into LMSs. Researchers such as Nunes et al. (2022) have found such systems useful in the context of comprehensive writing instruction. The problem occurs when students are asked to submit papers for automated evaluation without sufficient instruction and context from an instructor.

Against this backdrop, the COVID-19 pandemic placed LMSs at the center of nearly every educational institution's operations—with mixed results. TrustRadius reported results of a Digital Promise survey that found that while 98% of educational institutions moved operations online in April, 2020, over half of the students enrolled experienced connectivity, hardware, or software problems severe enough to impact their ability to complete courses. Further, statista.com predicts the global LMS industry to reach $370 billion dollars in sales by 2026. LMSs have been developed as both proprietary and open-source systems designed to provide structure for courses in many disciplines. But some contain more features conducive to teaching the writing integrated course than others, as described in the following section.

2 Core Idea of the Technology and Functional Specifications

LMSs are first and foremost management systems for various educational processes. They were not and are not designed for any type of iterative, process-based writing instruction. Most are administered and initially configured for use at a particular institution by an institutional-level office in collaboration with the LMS vendor. At this level, the LMS is set up to provide an educational workflow that can be used for different environments including in-person, online (both synchronous and asynchronous environments), and hybrid courses. Once configured for an institution, the LMS allows the end users—usually instructors of and students enrolled in course—to do the following:

- Collaborate and communicate within the system—both instructor with students and students with students
- Import SCORM-compliant content from educational content producers
- Create, administer, and score assignments and tests
- Generate reports for students, teachers, and administrators
- Integrate with common classroom tools such as Google Apps; and
- Enable mobile access as well as desktop/laptop computer access

LMSs also allow instructors to create and import educational content within/into the LMS. Often, instructors and/or students can set individual goals and then track progress to those goals. In the last year, many LMSs have also integrated plug-ins for integrated video conferencing in Zoom, WebEx, or other applications. The current market leaders in the LMS field are Canvas, Blackboard, Brightspace by D2L, and Moodle. Though Moodle was among the earliest to do so, many LMS have included wiki-like features for individual or collaborative writing allowing students to produce hypertexts with some form of versioning assignments (e.g. Moodle wiki, Canvas pages). Main products Standard LMS systems, which contain functions that allow writing but do not explicitly support writing, while continuing to fine-tune analytics and other features, can be considered more mature technologies in terms of the management of student learning. In the United States, Google Classroom, Blackboard, Canvas, Moodle, and Brightspace by D2L are the most commonly used in higher education. Blackboard advertises itself as LMS+ ; that is, while the features discussed above are part of the Blackboard Learn LMS application, the company provides companion pieces: Blackboard Collaborate, a virtual classroom/conferencing tool; a mobile application for instructors and students; Blackboard Analytics, a comprehensive data analytics tool; and Blackboard Ally, to assist institutions in constructing more inclusive learning environments.

2.1 Writing Software Developed By Writing Researchers and Instructors

As noted previously, lthough the dominant LMSs do not overtly cater to writing pedagogy, a robust series of writing software was developed by educators in the United States over the past 30 years in part to address the shortcomings of the conventional LMS. First generation writing software that focused on aspects of the writing process included Hugh Burns's *TOPOI*, Bill Wresch's *Writer's Helper*, and Von Blum, Cohen and Gerard's *WANDAH* (later *HBJ Writer).* One of the first-generation style analysis programs was *Writer's Workbench*, first sold by AT&T as a part of UNIX 7. And the Daedalus group (a group of University of Texas graduate students) created the Daedalus Integrated Writing Environment (DIWE) for use in locally networked computer classrooms. In 2001, veterans of the US computer and writing community met during the annual Computers and Writing Conference to discuss tools of the present and recent past, as well as the role of the writing instructor in using these tools; Consensus of this panel was that while these pieces of software were developed by educators for educators and students and were grounded in good pedagogical theories, the likelihood of these tools being overwhelmed by LMS and other commercial applications, such as then, WordStar or WordPerfect, and later, Microsoft Word, was high; this would be unfortunate, as pedagogical need should drive innovation.

And pedagogical need, as well as lack of LMS development informed by writing professionals, did result in several applications that approached the idea of a writing-specific LMS. *Emma* and *Marca,* both developed as open-source applications in Georgia, responded to what Ron Balthazor saw as the trend in LMSs, to simply push content rather than focus on active writing pedagogy. Fred Kemp of the Daedalus Group, following an unsuccessful attempt to partner with Pearson Publishing on widespread distribution of the DIWE software, began coding the Texas Tech Online Print-Integrated Curriculum (TTOPIC) application. In 2006, recoding of TTOPIC and expansion into a writing program management software (WPMS), known as RaiderWriter, was started by Susan Lang and Robert Hudson. Joe Moxley at University of South Florida worked with a team of programmers to develop My Reviewers. While all of these applications incorporated common LMS features, such as grade books, syllabi and assignment modules, they included pedagogical or administrative features particular to writing instruction and writing programs. For example, while most LMSs contain mechanisms by which students submit final drafts of writing projects, writing-focused LMSs housed prompts, workspaces, and storage areas where students could work through all parts of their writing process, from brainstorming to intermediate to final drafts. Some systems doubled as electronic portfolios for writing courses; students could maintain copies of all of their work for a course within the LMS. Others focused on specific aspects of the writing process, such as peer review. University of South Florida's *My Reviewers* and Michigan State University's *Eli Review,* focused on aspects of peer and instructor review. As

Eli Review notes, applications like these "became necessary because no technologies existed to support the feedback and revision cycles that lead to better learning and more effective writers." For example, RaiderWriter evolved into both an LMS and a WPMS to meet the needs of all of its users—writing program administrators, instructors, and students—by providing evidence-based insight into all phases of writing instruction. In addition to the standard syllabus, assignment submission and evaluation, and gradebook features, RaiderWriter contained features that enabled administrators to view and comment on instructor commentary for training purposes; instructors and administrators could view trends in numeric scores given by instructors to students across all sections of a given course. They could also see trends in student activity—whether assignments were turned in late or on time, or if student absence patterns or lack of engagement with assignments were reflected in grades on particular assignments. And this information was available throughout the current academic term, which meant that opportunities existed to add instruction in particular areas in which students were struggling.

Unfortunately, except for Eli Review, none of these are still currently in development or use. In part, the inability of these, and other, projects to sustain came from either English departments' inability or refusal to provide professional credit for software development, or to support faculty who developed software in other ways, or the inability for such projects to become the centrepiece of publisher/faculty partnerships. Too often, these applications were considered by publishers as "too unique" to their institutions to be commercialized for more general use—not always an accurate assessment. In the case of Eli Review, its developers maintained from the outset that the application would not "include features like a gradebook, a communications system, a mind-mapping tool, a plagiarism detector, or peer editing software"—features that we usually associate with LMSs. Perhaps Eli Review's success has happened because it has never been marketed as an LMS.

Thesis Writer is a bilingual (German, English) writing software developed by an interdisciplinary team at Zurich University of Applied Sciences. A main reason for creating TW was that that at the faculty (Management and Law) of one of the founders had roughly 800 students per year enrolled in an introductory course on academic writing and a roughly equal amount of BA thesis to supervise. This created management problems (Rapp & Kauf, 2018) and a way was sought to unburden supervisors and instructors from routine tasks to leave more time for e. g. giving feedback, discussing research designs, etc. Therefore, certain standard LMS features were integrated in TW: (1) authentication was implemented via the university LDAP, i.e., students, instructors could login with their university credentials; (2) collaboration on texts was integrated (several students can edit a document and give feedback); (3) a supervision workflow (student, supervisor) was integrated where supervisors can give feedback, have an overview of status of supervised projects through a dashboard; (4) one-to-many instruction (tutorials, videos) was integrated. Missing and potentially unachievable is a seamless integration of TW and the university LMS (Moodle) that would allow TW-based writing assignments for students enrolled in a Moodle course that could be included in, for example, Moodle grade books.

2.2 Research

Much current research into LMS use in writing instruction focuses on the various analytics contained within the system. Duin and Tham (2020) remind program administrators and instructors that they must increase their understanding of the information gathered by LMSs as well as how that information is used in decision making. Greer and Harris (2018) examine the simultaneously difficult issue of dealing with out of the box, mandated LMS systems (more common than ever post-COVID) and internal department cultural resistance to moving online. In an earlier article (2017) they discuss how institutionally-mandated LMSs can constrain the process of designing an environment for writing instruction vs content delivery since most LMSs focus on functional users of the technology vs informed or critical users. Hutchison (2019) summarizes the range of issues surrounding LMS use in writing courses, finding that the general design of most of the LMS systems optimize information storage and retrieval rather than the "communicative, recursive interaction that writing theory and pedagogy values" (p. 5). She recommends examining what efficiencies current LMSs allow for online writing instruction, as well as what would be considered sufficient for such instruction. The global COVID-19 pandemic has made Hutchison's call even more critical as much of writing instruction since March 2020 migrated to online environments. Post-secondary writing faculty who pivoted their courses online used the available features of their LMSs and worked outside them as well—using email, cloud services for storage, and conferencing and presentation capabilities of Zoom, WebEx, and other communication software to conduct instruction. While some LMSs, including Canvas and Moodle, have started incorporating more tools to facilitate response cycles and collaborative writing, instructors who incorporate these pedagogies into their courses may find that such generic tools aren't particularly useful—especially if one is teaching a course on writing in a specific discipline. An interesting intersection for research would be to study the software used by professionals to write collaboratively, conduct peer reviews, and then see how such tools could be mirrored or adapted in LMSs used in post-secondary education. Other research can be conducted on data sets of texts—those produced by students and responded to by instructors outside of LMS environments to understand how and when the feedback process is used in writing instruction—and how much of that is lost if instructors and students are constrained by the LMS environment—i.e., if they only have access to features provided for annotating texts in a particular LMS. Additionally, since texts in most disciplines now integrate visuals and add audio or video components, understanding how feedback is given on those modalities would be useful to LMS developers. Finally, since much writing instruction in post-secondary institutions in the United States is taught by graduate students and term faculty, incorporating WPMS features such as those discussed in the RaiderWriter software could prove beneficial to students, faculty, and administrators.

3 Conclusion

The consensus of research is that LMS applications developed for full-on institutional use are not sufficient for online writing instruction. Most features are far more consistent with content management systems than e- or hybrid learning. Numerous attempts to have writing faculty create software have not resulted in sustainable work, either because of technology obsolescence or because no comprehensive system existed to distribute the software and reward or acknowledge faculty developers. While LMS applications are a part of instruction going forward at most institutions, much work remains to make them more applicable and supportive of writing pedagogy. It is also uncertain at this point whether or not more specialized LMSs for use in writing programs have a future, given the prior inability to market these to wider audiences.

4 Tools

Tool	Type	Reference
Google Classroom	LMS (available free with limited features and for purchase)	https://edu.google.com/workspace-for-education/classroom/
Blackboard	Proprietary LMS	https://www.blackboard.com/
Canvas	LMS (available free with limited features and for purchase)	https://www.instructure.com/
Moodle	Open Source LMS	https://moodle.org/
Brightspace by D2L	Proprietary LMS	https://www.d2l.com/
Emma/Marca	Proprietary Writing Software and LMS	No longer available
RaiderWriter	Proprietary Writing Software and LMS	No longer available
MyReviewers (now USFWrites)	Proprietary Writing Software with LMS Components	https://www.usf.edu/arts-sciences/departments/english/writing-programs/writing.aspx
Eli Review	Proprietary Writing Software	https://elireview.com/
Thesis Writer	Proprietary Writing Software	https://thesiswriter.zhaw.ch/

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Teacher Feedback Tools

Chris M. Anson

Abstract Before digital technology, students submitted handwritten or typed papers to their instructor, who responded with handwritten marginal and end comments, often with the infamous "red pen" (Dukes & Albenisi, 2013). After the introduction of word processing, students typically printed out and submitted hard copies of their final drafts, on which the instructor would handwrite comments. Today, most instructors (and all who teach online) ask students to send their (digitally produced) writing as email attachments or upload them to a learning management site or other cloud-based repository, allowing them, in turn, to provide digital feedback. Tools for such feedback have enabled instructors to comment with greater efficiency, clarity (avoiding the longstanding problem of students having to decipher scribbled remarks), and support. After a brief historical introduction, this chapter will describe four types of digital tools for teacher feedback: digital annotation tools, text expansion tools, voice-to-text tools, and tools for audio and audio-visual feedback.

Keywords Digital feedback tools · Teacher response · Teacher evaluation

1 Overview

Teachers' feedback on students' written work, either to evaluate and comment on a final submission or to make suggestions for further revision, has been central to the teaching of written composition. In her conclusion to a presentation about her longitudinal study at Harvard University, Sommers (2005) remarked that "It was clear from the Harvard Study of Undergraduate Writing that feedback, more than any other form of instruction, shapes the way a student learns to write." Dozens of other scholars have also noted the importance of instructor feedback in the process of improving writing ability (for a small sample, see Anson, 2012; Beach & Friedrich, 2006; Peñaflorida, 2002; Sommers, 1982; Straub, 1999).

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_12

In educational contexts where students are required to submit written papers, teachers usually provide either formative or summative feedback (see Bloom et al., 1971).[1] The former often occurs before a student has revised a draft for final submission and evaluation, and offers suggestions or responses for improvement. The latter takes place at the end of the writing process and is intended to evaluate the quality of the final product, usually for a grade. The two modes of feedback entail different subject positions for the teacher, either as guide and coach or as judge (Black, 1993).

Before the availability of digital technology, teachers who assigned writing to their students commented on and evaluated the papers with handwritten marginal comments, intertextual corrections, "shorthand" symbols or abbreviations (such as "awk" for "awkward" or special codes explained in a handbook—see Anson, 1989), and longer comments at the end of the text or in separate "memos" or letters (Bardine & Fulton, 2008). With the exception of face-to-face meetings between teachers and students (typically to provide formative feedback; see Murray, 1979), all feedback took place in the form of written text.

Still before the widespread use of computers, voice-recording technology offered teachers the option of giving oral feedback to students about their work, but this opportunity was taken up only after the availability of cassette tapes and portable tape recorders. Typically, teachers procured cheap cassette tapes for their students and recorded formative or summative feedback on their writing, and the cassettes were exchanged in class. Students could then play the instructor's feedback at home or, if they did not own a cassette player, on equipment in their college library or audio-visual lab. Although not digital, cassette technology prefigured the use of screencasting and digital voice recording for feedback, to be discussed below. The provision of oral feedback precipitated new research on the differences between written and spoken response and students' opinions about these differences (see, for example, Anson, 1997, 2000; Sommers, 1989, 2002, 2013).

After the replacement of cassettes with CD-ROM (compact disc) technology, recorded oral feedback to student writing died away for a few years; students no longer used cassette tapes or owned tape players, and digital technology platforms did not have the memory capacity to hold or convey the significantly large files produced from digital voice recording. CD-ROM technology was cumbersome and ill-suited to the kind of oral feedback teachers wanted to provide to students, and few teachers had equipment that could record on disks. Initially, MS Word included an option to insert voice comments in a text, but these comments were necessarily very brief (because of limited memory capacity of floppy disks) and thus not useful to teachers who wanted to comment more extensively. Eventually, portable flash storage technology (flash drives, thumb drives, keychain drives, jump drives, or pen drives) increased in memory capacity and could hold more extended voice files (the first drives marketed in 2001 held only 8 MB of memory, and it wasn't until the mid-2000's that they could handle more than 500 MB). Like cassette tapes, USB

[1] The term "feedback" is common in the pedagogical literature and will be used here; "response," "evaluation," "assessment," "commentary," and "marking" are also used but are not entirely synonymous.

drives could be exchanged in class and contain more extended oral feedback about students' work, but both teachers and students needed compatible recording and playback applications.

It was not until the development of faster WiFi transfer, cloud-based technology, and learning management systems (LMSs) that further options for feedback became available. First, tape-recorded feedback, which had relied on magnetic technology, could now be created digitally and conveyed online, freeing up the physical exchange of flash drives between teachers and students. Voice recording and podcast systems would soon become available, including YackPack, Garage Band, Audacity, Spreaker, Podcast Generator, Vocaroo, Voicethread, Snagit, and Google Voice (see http://www.litandtech.com/2015/10/using-google-voice-with-student-writing.html). These and other tools, including those embedded in or linked from LMSs, afforded teachers opportunities to speak to their students about their work or to carry on asynchronous exchanges with them. On the heels of voice recording technology, screencasting added a visual dimension so that instructors could make brief videos of themselves working through, annotating, and commenting on a student's print or multimedia project.

At the same time, instructors made use of other digital options for feedback. Word processing software included review functions (such as MS Word's Insert Comments and Track Changes features), and digital annotation programs could be used for PDF documents, websites, and PowerPoint presentations. Text expanders (sometimes called "macro generators" or "keyboard expansion utilities") offered teachers the option of creating pre-written advice that could be placed into the margins of a student's text with a simple keyboard shortcut. As voice-to-text tools became more accurate and refined, teachers could speak their thoughts and have them converted into text, making feedback faster and more thorough than is the case when typing. These technologies, now universally available, will be described and demonstrated separately in the following sections, starting with those that provide textual feedback (in the same mode as students' written papers) and moving toward those that provide audiovisual feedback. Tools for oral and audiovisual feedback are covered in one section because of the way that the modality of spoken feedback changes the student experience.

2 Core Idea of the Technology

2.1 Digital Annotation Tools

Although annotating text as a means to provide feedback can be as simple as using the Insert Comment feature in MS Word, a number of tools now allow for more sophisticated and diverse kinds of feedback on documents, especially those rendered in PDF format. An annotation tool (sometimes called a "markup tool") allows the user to create a "layer" of text or images on top of an existing text, web site, PowerPoint slide, table, or other material. For some instructors, these tools offer a convenient method to comment on students' work in ways that can link words to visual annotations such as circles, arrows, underlining, exclamation points, icons, and other marks, which afford a wider range of both informational and affective response to students' work.

Most annotation tools also allow a user to annotate projects in various media such as PowerPoint presentations, blog posts, web pages, spreadsheets, still photos, and videos. With collaborative annotation tools, users can work together to comment on a document or site, which can be useful for students (see "Digital Student Peer Review Programs" in this volume) or for instructional development when a group of teachers want to discuss a sample text and norm their evaluative judgments.

2.2 Text Expanders

Text expanders allow for stock comments to be saved in an application and associated with specific designated keystrokes which, when typed, instantly insert the stock comment into a text. This technology is often used in business settings to save time when a "boilerplate" message, introductory material, a long and complicated URL, an auto-reply, or other frequently repeated text is required in a new document. Although cutting and pasting from previous messages is another option, text expanders work much more quickly and efficiently.

From an instructional perspective, teachers can create advice or other kinds of responses that they frequently type in the margins or at the end of student papers. In MS Word, a teacher can open an "insert comment" in the margins of a student paper, type the abbreviation associated with the stored advice, and watch the expanded text instantly appear in the margin. For example, if a student has not sufficiently supported a claim, a teacher might have stored the following text in a text-expander application and associated it with the keystrokes +SUPP:

> When making a claim of this kind, it is important to offer some supporting evidence for its truthfulness or basis in fact. This might take the form of a reference to some authoritative research. Sometimes it's also possible to use personal experience, but be careful not to assume that what happened to you or someone you know is more widely experienced.

The inserted text can also be quickly edited to make it more personalized (such as adding the student's name at the start: "Christine: When making a claim... "). Text expanders can also facilitate the use of comment banks and preconstructed rubrics, saving instructors time when providing feedback (see Brady et al., 2019).

2.3 Voice-to-Text Tools

Voice-to-text (VTT) tools, sometimes called automated transcription tools, digitally convert spoken words into corresponding written text, freeing up the user to speak instead of type. VTT technology can be used to speed up the process of giving feedback by digitally converting spoken text into written text. Initially rather poor at deciphering the variations or dialect features of people's speech or recognizing all spoken words, VTT programs have improved greatly and have much-expanded lexicons, requiring very minimal editorial correction. VTT does not change the medium of commentary (as do oral or audio-visual commentary), but teachers can usually provide more feedback, in more detail, by speaking it than by typing it. However, the processes of speaking to text can at first be challenging to instructors used to typing out their responses instead of dictating them.

In the following example, the text was produced using the "dictate" application associated with MS Word. In a research proposal written in a graduate course, a student has claimed that little to no research exists on a question they want to pursue in their own research. The teacher speaks the following comment, which is almost simultaneously turned into written text in the margin:

> This sentence may be a bit overstated, Karl, because in fact there has been quite a bit of research on the relationship between student self-efficacy and writing ability, even stretching back to the mid-1980's. Try a few more searches to see what you can come up with, because your proposal needs to build on a foundation of prior inquiry.

In this case, the app typed the spoken words exactly as shown above, and in considerably less time than the teacher would have taken to type them. From the perspective of the learner, the dictated text may look very similar to what would be typed; however, this depends in part on the nature of the speech register being used.

2.4 Tools for Oral and Audio-Visual Feedback

Digital voice recording (such as podcasting) as well as audiovisual recording are used for dozens of purposes online, including, in higher education, the provision of retrievable lectures (see McGarr, 2009). These technologies, however, have been adopted by teachers of writing to provide both formative and summative oral feedback on students' work. In contrast to handwritten or typed feedback on students' work, oral feedback with and without accompanying screen recording provides an entirely different experience for students working and reflecting on their writing. First, an orally recorded comment can be much longer and more detailed than a written comment but can take the same amount of time to produce. In one study, the average amount of text teachers wrote on first-year college students' papers in a foundational writing course was 100 words, while the average number of transcribed words when five-minute-maximum oral screencasts substituted for written commentary (with um's, ah's, and repetitions removed) was almost 800 per recording (Anson, 2018). Second, unlike typical marginal comments that point to errors or use words or brief phrases to call attention to something (such as "awk" for "awkward" or "too informal" to point a shift in style), oral feedback more often explains the teacher's concern because it can be provided so easily and quickly: "I notice a shift in your style in this paragraph, James; did you want to start sounding very informal here compared to the rest of your introduction?" Third, because teachers are freed from the burden of typing or writing comments in laborious detail in the margins of students' texts, they are more likely to focus on meaning-related concerns when speaking instead of quickly marking surface errors. Fourth, the linear nature of a recording compels students to attend to the teacher's response, in comparison to the habit of flipping or scrolling to the end of a document to see the evaluation and skipping the marginal commentary. Finally, the presence of a teacher's voice closes the distance between teacher and student and creates stronger positive affect, as documented in research reported below.

The following excerpt demonstrates a teacher using Garageband, a popular voice and music recording program designed for Apple computers, to provide feedback to a college student on a draft of her paper. This comment appears about halfway through the voice recording (at 3 min and 36 s):

> OK, now I'm on page three of your paper, Emily. You start your third paragraph by writing, and I'm quoting, "One of the main challenges of recycling programs is who acquires the recycled material, how much they are willing to pay for it, and how far they are from the source of the recycling." I actually see three challenges here that you might want to think about discussing separately.

Oral and audio-visual feedback can be provided either formatively (to promote revision) or summatively (to evaluate a final draft). The content of the feedback will often differ, the former pointing to possibilities and further choices in the "future" of the text, and the latter pointing to choices already made in the past, with judgments accordingly.

3 Functional Specifications

3.1 Digital Annotation Tools

Digital annotation tools vary from sophisticated, team-based apps that allow for multiple commenting to more basic tools with options to insert figures such as arrows pointing to text or circles surrounding it, or to draw freehand (such as to circle a paragraph of a student's paper). Comments can be inserted at various points in a paper and collapsed into unobtrusive (word) that expand when clicked or hovered over.

Some digital annotation tools have the additional functionality of allowing comments within comments. This can be useful when teachers and students want to create more dialogue within a marked-up document, when a student wants to add an idea to an instructor's comment, or when peers use the tools to comment together on a students' paper.

3.2 Text Expanders

Text expanders rely on *snippets*, bits of text activated by keyboard shortcuts and inserted into a text being composed. Snippets don't have to be brief; they can be pages long if desired. *Shortcuts* are the keystrokes that, when typed, trigger the snippet to be inserted in the text. To help the user remember the snippets, text expanders often include *labels*. For example, a snippet that calls attention to the lack of a thesis statement or controlling idea in a student paper might be a paragraph in length. The *label* for this snippet might be "lacks thesis." And the shortcut abbreviation (triggering the insertion of the paragraph) might be "-THS" (without the quotes). Case can be included or ignored (so that -ths would work the same as -THS).

Snippets can also be programmed to prompt certain words to be typed at certain locations, called *fields.* To customize the thesis example above, a field might be included at the start of the paragraph prompting the user to type in a name, such as that of the student whose text a teacher is responding to. Other fields include automatically calculated future dates (from the date of the writing) or databases. Visual images such as jpgs and gifs can also be included in some text expanders.

Typo and spelling correction is another functionality of text expanders. The app can be programmed so that, for example, keystrokes for the incorrectly spelled word *expresso* will trigger the correct replacement, *espresso.* Although most word processors provide flags or auto-corrections for spelling errors, they allow words to be mistyped that are not in their databases for autocorrection. The writer has to see that the word has been questioned and then return to examine it. Text expanders instantly correct the word instead. The same feature can be used to auto-correct simple grammatical mistakes; a novice writer can program the text expander to recognize incorrect "should of" for "should have" (as in "They should of passed the legislation") and instantly correct it. Of course, incorrect keystrokes cannot be correct in other circumstances or the text expander will erroneously make the substitution: a text expander can be programmed to add the missing apostrophe in *cant,* but when the writer then wants to use the word *cant,* as in "He was disgusted with the sanctimonious cant of the politicians," it will turn the word into the erroneous *can't.*

Although text expanders are primarily used by individual writers, some programs have team-related features built in. TextExpander and aText, for example, allow snippets to be shared with groups of writers. This feature can be useful for instructors of the same course or module who want to regularize their feedback or create comment banks, or student reviewers who can be trained to insert pre-written responses into peers' papers to learn how to critique more effectively help and to help the writer understand certain discursive features.

3.3 Voice-to-Text Tools

Early VTT programs did not have robust lexicons, requiring the user to edit incorrectly "heard" words and, if the program allowed it, to add those words to the database for future tasks. In addition, early programs often lacked the ability to interpret some speech unless it was carefully enunciated, also requiring time for rescanning and correcting or editing the transcribed text. Today's programs are far more advanced, requiring minimal correction and also avoiding transcribing clearly irrelevant words such as "um" or "ah." Most programs interpret certain words as commands (such as "period," "comma," and "new paragraph") and more advanced programs have a larger set of such commands. Some programs are installed on the user's computer while others operate online. Some require a headset with a microphone while others allow the user to speak into the microphones built into the computer. Programs such as Google Assistant include other capabilities such as opening files or looking up information when commanded.

3.4 Tools for Oral and Audio-Visual Feedback

Although voice recording apps differ in their functionality, at base they provide a simple way for instructors to talk about students' work, save their feedback, and upload it for retrieval. However, voice recording lacks the visual display of the students' work, so teachers must refer to specific locations in a paper and assume that the student is also finding their way to that point.

Although some applications, such as GarageBand, have extensive capabilities for recording and editing sound, they can be used for simple oral feedback without much investment in learning the intricacies of the program. Others, such as the tools in MS Word, allow for voice commentary to be inserted at specific points in an online document. These are the equivalent of handwritten marginal comments but can be more extensive without intruding on the student's work or displaying an intimidating amount of inserted text. A number of LMSs now offer voice recording tools as part of their evaluation and feedback capabilities.

Because many voice recording programs such as Voicethread now have screencasting options, teachers are more apt to record their comments on students' work in audiovisual format. Functionally, screencasts create video recordings of whatever takes place on a computer screen or part of a screen. Typically, a teacher opens a student's paper onscreen and enlarges it to fill the screen. Optionally, the teacher inserts comments into the text first, although it is also possible for a teacher to demonstrate the experience of reading students' work aloud and commenting along the way. Once the screencasting tool is activated, the teacher can then work through the paper, scrolling to and highlighting specific points where a comment is warranted, and provide ongoing oral feedback on the work. After saving the file in an appropriate replayable format, the teacher can upload the video to a cloud space such as the LMS being used in the course or another YouTube-like repository. Some screencasting applications provide unlimited time for each recording, while others may have a time limit. Jing, produced and made popular by TechSmith, offered a five-minute window for recording, with a bar displaying the elapsed time. Some teachers favor this time limitation because it compels them to be concise, automatically holds them to a response "standard" for all students, and ensures that they don't spend inordinate amounts of time commenting on students' work. Jing has since been replaced by TechSmith Capture, which offers a picture-in-picture window that can show the instructor's image, but the time limitation has been removed, requiring instructors to decide on their own time threshold.

Some screencast programs, such as the web-enabled version of Panopto, allow post-recording editing but do not allow the user to pause mid-recording unless the program is installed on the computer. This can limit an instructor's or peer responder's ability to think or review while recording. Other programs such as Camtasia provide more extensive editing capabilities as well as pause options. Most programs allow the user to start over without exiting the program.

4 Main Products

4.1 Digital Annotation Tools

Annotation tools divide themselves into those that offer methods to mark up documents, such as PDFs, and those that allow the user to annotate multimedia material and websites. BugHerd, for example, lets users create a "layer" of annotations on top of a website that only they and others they designate can see. Comments are expanded from pins on the site. A popular annotation tool for teachers is Diigo, which can bookmark and tag web pages and attach sticky notes, as well as comment on others' annotations. Adobe is perhaps the best known for a suite of tools to create and annotated PDF files. A.nnotate is an easy-to-use tool that can be used with a single document shared for others to add comments; it also has an indexing function. Markup.io provides a menu of tools to annotated websites and web pages. NowComment, a social annotation tool, allows for annotation of websites, PDF documents, and online books. Kami, another easy-to-use tool, is a web-based suite of tools that allows annotation of PDF documents, texts, and more. XODO works similarly but does not function as a browser extension. Among the more sophisticated tools, Hypothes.is and Mendeley are known for their support of collaborative annotation and their usefulness in research. An extension for the Chrome browser provides annotation tools for Google Docs and the Windows suite.

4.2 Text Expanders

aText is among the historically most enduring text expanders and now has many added features, including images and multimedia content. TextExpander was acquired by a team of developers at Smile in 2006 and has been through at least seven iterations. Originally designed for the Mac OS, it is now cross-platform. PhraseExpress has most of the features of other popular text expanders including a clipboard manager. Auto Text Expander is an extension added to the Chrome browser that has basic expansion functionality. ActiveWords has a challenging user interface but provides some features absent from other text expanders, including programmable actions such as sending emails or opening other applications. PhraseExpander (for Windows) is marketed to professionals such as doctors and data-entry personnel and includes form and template creation. Breevy is a basic text expander with customizable features. Fastfox does not allow for customizable abbreviations but provides them for association with inserted text, but it learns from the user's typing behavior and suggests text insertion when this feature is activated. For a list of some of these and other text expanders, prices (if not free), and main features, see Moore (2018).

4.3 Voice-to-Text Tools

The most popular voice-to-text or automated transcription tools include Dragon Anywhere (previously Mac Speech Dictate for Apple), Otter, Google Assistant, Google Docs, SpeechTexter, and Speechnotes. Some programs such as Dragon tout 99% accuracy. Built-in Dictation resides inside Windows and Mac OS, offering the convenience of an already accessible tool that, in addition to providing speech-to-text transcription, is also used for an array of voice commands and has a numbered screen grid for the user to specify operations within specific tiles in the grid.

4.4 Tools for Oral and Audiovisual Commentary

Digital recording tools range from simple voice-recording applications to highly sophisticated studio-like systems that allow for professional sound manipulation. Among the former are applications built into learning management systems such as Moodle, Blackboard, and Canvas. Some LMSs have video recording devices that allow the user to turn off the video to create a voice-only file. MS Word has a function to insert voice comments into locations in a document for later replay. Google Docs includes Voice Note, an audio recording function. Other simple audio recording applications include Vocaroo, Chirbit, and Voice Memos attached to Apple products. Among the more sophisticated voice recording programs, Audacity, Garageband, and Ocenaudio allow for both recording and editing.

Because screencasting provides visual as well as voice response, instructors may be more attracted to screencast tools than to audio capture tools. Simple programs include Screencast-o-matic (now with some editing capabilities), TechSmith Capture (formerly Jing), Loom, and Vimeo Record. Programs that allow for more sophisticated editing include Camtasia, Adobe Captivate, and Open Broadcaster. Most instructors who have many student projects to comment on opt for simpler programs, although it is possible to use the basic features of more robust programs and ignore their editing and production options.

5 Research

5.1 Digital Annotation Tools

Much of the literature on digital annotation tools is anecdotal and pedagogical, focusing on how to engage students in social (collaborative) annotation of written of multimedia texts (Castet et al., 2014; Wolfe, 2002; Wolfe & Neuwirth, 2001; Zyrowski, 2014). No formal research studies of annotation tools from an instructional perspective were found. Future research could analyze the effectiveness of iconographic feedback with or without alphabetic text on students' interpretations and revisions. Teachers' use of alternatives to alphabetic text (such as icons or other visuals) through the use of digital annotation tools could also be compared with their conventional written commentary, and qualitative studies could explore their feelings about various forms of annotation.

5.2 Text Expanders

Some text expanders capture data when the user activates snippets, and this is periodically reported to the user as hours of work saved. However, no studies of instructors' time savings were found as of this writing. In addition, although anecdotal scholarship exists, few studies were found about the effects of either instructors' or students' use of text expanders. In a personal account, Moore (2018) reported saving time commenting on students' writing, providing more robust comments, and not finding that her comments became more impersonal. Other anecdotal or instructionally descriptive articles include Campbell's (2016) advocacy of TextExpander for commenting on large numbers of student papers, and Mandernach's (2018) collection of strategies for automating response to writing, including text expansion. In a survey-based quantitative dissertation study, McKinney found that of 328 postsecondary instructors, 208 (64.8%) adopted text-expander technology to respond to student writing.

Because text expanders insert prewritten or "canned" response into students' rough drafts (formatively) or final drafts (summatively), future research could gauge the extent to which students learn from the material (especially when it is repeated in subsequent papers) or apply it to revisions or further papers. In addition, although inserted text can be personalized quickly, students can compare responses or realize that their instructor is using canned material instead of individualizing their response. The effects of this realization on the teacher-student relationship has not been studied empirically to test Moore's sense that a text expander did not make her comments more impersonal. Finally, anecdotal literature has claimed that using text expanders compels instructors to write clearer and more helpful comments (because they will be used multiple times), but no research has confirmed these claims.

5.3 Voice-to-Text Tools

Research on the use of voice-to-text technology in educational settings has focused predominantly on the effects of oral composing for certain groups of students (see Liu et al., 2019, for a review of the literature). However, as of this writing, research on the effects of voice-to-text technology on teachers' feedback is lacking. In one content analysis of 58 typed and dictated comments on student writing, Batt and Wilson (2008) found no significant differences in the quality of the response and that students could not tell the difference between response in the two modalities. Future research could focus on whether the technology speeds up the process of responding to writing, allows for more detailed comments, or changes the nature of the written text in such a way that it affects students' interpretation of the comments. Studies of teachers' feelings about the differences between typing or speaking comments are also needed.

5.4 Tools for Oral and Audiovisual Feedback

Early work on oral commentary includes a series of studies by Sommers (1989, 2002), Mellen and Sommers (2003), Carson and McTasney (1973), and Stratton (1975), all of whom found that students were enthusiastic about the method, and that teacher response was fuller, more helpful, and more personable than in a written mode. Considerable research exists comparing conventional written comments with comments provided in audio and video format, in the context of both first- and second-language instruction (see Li, 2021, for a review of the latter), and in both online and face-to-face courses. Most studies of students' perceptions of feedback in those modalities show positive results, particularly in the context of online instruction where instructor presence was enhanced (see Olesova & Borup, 2016). Positive student responses to asynchronous audio and screencast feedback were also found in studies by Bush (2020), Denton et al. (2008), Ice et al. (2019), Kelly and Banaszewski

(2018), Kim (2018), and Vincelette and Bostic (2012). Other findings include greater length and specificity of feedback and feedback that is more tailored to individual students (Silva, 2012; Stannard, 2007; Thompson & Lee, 2012; Vincelette, 2013; Warnock, 2008). In a mixed-methods study of students in different courses across the curriculum, Anson et al. (2016) found that students perceived much stronger positive affect from their instructors in the screencast mode than in conventional written comments. Anson (2018) found that screencast comments provided over seven times more commentary in the same amount of time as written comments and that students perceived the screencasts to be more helpful for writing improvement. Although this is just a small sample of many studies, overall, research on audio and audiovisual feedback points to important differences (compared with written feedback) in students' understanding of the feedback and of their affective responses to their teachers' personas, which are enhanced through the vocal medium.

Future research could consider how students interpret and use feedback that comes to them in the different forms described in this chapter. In particular, do students with some learning and cognitive styles benefit from certain response modalities, or do some modalities inhibit their learning? Can some negative aspects of instructor response become more prominent when spoken (e.g., miscorrections of students' dialect features; see Matarese and Anson, 2010)? Are some learners more disposed to learn from written comments, which remain on the page, in contrast to fleeting oral comments (even though recordings can be replayed)? What more can we learn about the affective and relational aspects of response provided through different technologies? Anson (forthcoming), for example, demonstrates how students' preoccupation with "facework" (dealing with the interpersonal dimensions of response to their writing; see Goffman, 1955; Brown & Levinson, 1987) can divert their attention from a focus on their writing, subverting their learning. More studies are needed that consider the affective responses of students to their instructors' commentary, in whatever form it is provided.

6 Implications

Among the most important criteria for the use of digital tools to respond to student writing are teachers' investment of time, the depth and quality of the response, and students' perceptions of the response as a function of the modality. The overall results of research and teacher experimentation suggest that digitally mediated response can be beneficial. None, of course, can match the helpfulness of in-person conferences with students about their work, but typical teaching loads and class sizes make this method of response challenging if not impossible for many teachers. Because so much time is devoted to feedback, which has been shown to be crucial for students' development, any digital method that makes the process more efficient while also improving or at least maintaining quality will be embraced. However, efficiency also depends on the challenged required for uptake of the tools as well as teachers' personal preferences, based on experience, of one feedback modality over another.

On the student side, these tools reconfigure the spaces in which feedback occurs, adding oral and visual elements to conventional text response. They also affect writing processes to the extent that students may process feedback differently and enact that feedback, when formative, in revision. Although we do know yet know fully whether competence is enhanced as a result, it seems prudent to assume that when students are more fully engaged in the processes of writing and then interpreting expert feedback, they will become more mature both in composing and in the social interactions usually involved in the production of text and multimedia.

In the realm of privacy protections, especially in the context of evaluation, some platforms are vulnerable to hacking or to inadvertent public posting. In screencasting, instructors not used to clearly defining a screen area can fall prey to unknowingly revealing parts of their screen with sensitive information (such as a list of student grades or a personal email). In addition, any new technology for response to students' work takes time to learn and may initially affect the nature of response.

In summary, developments in the digitalization of academic writing have offered instructors new tools for providing feedback to students about their work. In addition to widening the types of feedback—written, iconographic, oral, audiovisual—as well as enabling feedback on a wider range of products such as still and moving images and multimedia texts—these tools also open up a broader range of relational and identity-based aspects of both the provision of feedback and its reception by students.

7 List of Tools

Software	Description	URL
BugHerd	Annotation tool; freemium; Chrome extension; Website annotation	https://bugherd.com
Diigo	Annotation/book-marking tool; freemium; browser extension; web pages & PDFs	https://www.diigo.com
A.nnotate	Annotation tool; freemium; Web-based; PDF, image, & CMS annotation	hhttps://www.diigo.comttp://a.nnotate.com/
NowComment	Annotation & curation; Web-based; discussion-based annotation & commentary on texts, images, & videos	https://nowcomment.com/
Kami	Annotation & classroom workflow management tool; freemium; Web-based; social annotation of PDF, docs, & more	https://www.kamiapp.com/

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Software	Description	URL
XODO	Annotation tool; freemium; Web-based; online PDF editor & filler	https://xodo-pdf-reader-editor.en.softonic.com/
Hypothes.is	Annotation tool; open source; browser or LMS extension; annotation of all media; collaborative	https://web.hypothes.is/
Mendeley	Annotation & reference management tool; freemium; download; reference management & annotation for research	https://www.mendeley.com/
aText	Text expander tool; free trial then low download cost; inserts images, text, etc., into any application; autocorrect; built-in snippets	https://www.trankynam.com/atext/
TextExpander	Text expander tool; monthly fee; download or Chrome extension; inserts snippets into text; collaborative	https://textexpander.com/
PhraseExpress	Text expander tool; proprietary; download & shared phrases in cloud; inserts snippets into any media; collaborative	https://www.phraseexpress.com/
Auto Text Expander	Text expander tool; free; Chrome extension; inserts snippets into text	https://chrome.google.com/webstore
ActiveWords	Text expander; proprietary (annual fee); Web-based; autotext & autocorrect in any language; sync between devices; other commands; add-ins	https://activewords.com/
PhraseExpander	Text expander tool; proprietary; download; template builder & autocomplete; for professionals; creates fillable forms & expands text; spellcheck; productivity stats	https://www.phraseexpander.com
Breevy	Text expander tool; free; download; simple text & abbreviation expander; syncs with Dropbox	Multiple sites
Fastfox	Text expander tool; proprietary; download; text expansion & image insertion	https://www.nch.com.au/fastfox/index.html
Dragon Anywhere	Voice-to-text tool; proprietary; Web-based; speech recognition & dictation to cloud; share docs; smart phone compatible	https://shop.nuance.com/
Otter.ai	Voice-to-text tool; freemium; Web-based; automated transcription; audio & video	Otter.ai

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Software	Description	URL
Google Assistant	Voice-to-text tool; freemium; Web-based; voice-to-text with domain specificity	https://cloud.google.com/speech-to-text
Google docs	Voice-to-text tool; free (built in); Chrome-based; voice-to-text in Google docs	Google.com
SpeechTexter	Voice-to-text tool; free; Web-based; voice-to-text with editing menu	https://www.speechtexter.com
Speechnotes	Voice-to-text tool; freemium; Web-based; voice-to-text, automatic transcription	https://speechnotes.co/
Windows/Mac Dictation	Voice-to-text tool; free with PC/Mac; built in; voice-to-text, commands	Built in
MS Word recording	Audio recording tool; free with Word; built in; audio commenting	Built in
Voice Note	Audio recording tool; free; built into Google docs with Chrome extension	https://chrome.google.com/
Chirbit	Audio recording tool; freemium; all audio; upload to social media or QR code	https://www.chirbit.com/
Apple Voice Memos	Audio recording tool; free with Apple; built in; audio recording on iPhone, transferable	https://support.apple.com/
Audacity	Audio recording and editing tool; open source; download; multitrack audio recorder & editor	https://www.audacityteam.org
Garageband	Audio recording & editing tool; free with Mac; built in or download; recording studio with sound & music presets	https://www.apple.com/mac/garageband/
Ocenaudio	Audio recording & editing tool; donation; download; cross-platform, real-time preview, spectrogram	https://www.ocenaudio.com/
Vocaroo	Audio recording tool; free; Web-based; simple voice recorder with downloadable MP3 files	https://vocaroo.com/
Screencast-o-matic	Screencasting tool; freemium; Web-based; record audio and/or video; save or upload to cloud server; add-on tools	https://screencast-o-matic.com/

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Software	Description	URL
Techsmith Screencast	Screencasting & image capture tool; freemium; download; included annotation tools; upload files to cloud; create queue	https://www.techsmith.com/screencastcom.html
Loom	Screencasting tool; freemium; download; includes emoji reactions, time-stamped comments, & interactive features	Loom.com
Vimeo Record	Screencasting tool; freemium; Chrome extension; screencasting & webcam recording; record from phone; editing tools	https://vimeo.com/
Camtasia	Screencasting & editing tool; freemium; download; screencasting with multiple sound & visual editing tools; save or upload files to cloud	https://www.techsmith.com/video-editor.html
Adobe Captivate	Screencasting & web recording tool; freemium; download; screencasting, presentation recording, project bank, asset store, VR capability	https://www.adobe.com/products/captivate
Open Broadcaster	Screencasting & livestreaming tool; open source; download; video & audio capturing & mixing; editing tools; scene setup; studio-like capabilities	https://obsproject.com/

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Digital Student Peer Review Programs

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Abstract Student peer review of drafts in progress was a staple of writing instruction for decades before computers: students exchange and discussed typed or handwritten drafts in small groups of three or four. With the advent of digital connectivity, students could circulate electronic versions of their texts, then read and annotate drafts online. Simultaneously, digital peer review systems were developed that not only facilitated student response but included learning analytics as well as features such as repositories of comments to prompt student response, badges, sticky notes, and feedback mechanisms that evaluated the quality of the response; anonymous response also became possible (see Lu & Bol, 2007). After a brief historical introduction, this chapter focuses primarily on digital peer review systems and peer review systems built into LMSs such as Canvas. The chapter describes the nature and range of digital peer review systems and includes a summary of research on their effectiveness.

Keywords Digital peer review · Feedback programs · Machine learning

1 Overview

Student peer review of drafts in progress had its genesis at the start of the process movement in writing instruction (see Anson, 2013; Crowley, 1998), although the method was used occasionally many decades earlier (Walker, 1917). Broad shifts in theories of learning positioned students not as competitors but potential collaborators, and fears that students would "steal" each other's ideas or writing were replaced with theories of intertextuality in which texts are inevitably influenced by other texts and ideas (Bazerman, 2004). Research on the cognitive processes of composing pointed to the role of feedback in supporting revision (see Becker, 2006). Early advocacy for peer review argued that the method helps students to improve both their specific projects and also their overall writing ability (Brooke

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_13

et al., 1994; Nystrand, 2002; Nystrand & Brandt, 1989). In addition, the peers themselves gain competence through the process of reading, commenting on, and, in the group meetings, grappling with textual decisions on behalf of the writer (Bruffee, 1973, 1978, 1984; Elbow & Belanoff, 1989; Flanigan & Menendez, 1980; Hardaway, 1975; Hawkins, 1976; Palincsar & Brown, 1984; Spear, 1988; Topping, 2008; Van Den Berg et al., 2006). Anecdotally, the effectiveness of peer review has met with a range of instructional opinions, but some research has shown that its success depends on careful preparation and orientation of students beforehand (Brammer & Rees, 2007; McGroarty & Zhu, 1997; Min, 2006).

Student peer review began predominantly with the exchange of papers followed by small-group, face-to-face meetings in class (or sometimes in out-of-class meetings) where students discussed their drafts (see Vatalaro, 1990, for several methods). In some cases, especially in content-focused courses across the curriculum, students simply exchanged their papers in class, commented at home, and handed their comments to their peers during the next class. Conferences were supported by peer-review guides and sometimes teacher-led orientations to help students understand what they were supposed to do (Flanigan & Menendez, 1980). Follow-up often included student reflections on the feedback and plans for revision. Early digital technologies such as word processing still required printed copies because there was no other practical way to exchange work. It was not until the arrival of the internet that students could begin to exchange writing and comments online.

Before the development of specific platforms, the earliest uses of technology for peer review involved the digital exchange of papers and comments. Word processing facilitated the provision of intertextual or end comments by peer reviewers, and eventually the exchange of documents was managed online (Dickenson, 1986; MacArthur, 1988; Owston et al., 1992). Since then, cloud-based servers, feedback mechanisms based on machine learning, and markup programs have all enhanced both the practicalities and the learning features of peer review. However, some of the most theoretically important dimensions of peer review, especially the way face-to-face meetings engage students in extensive and helpful discussions and negotiations that lead to fortuitous revision and deeper learning, can be reduced or bypassed online.

2 Core Idea of the Technology

Digital peer review programs have been designed to simplify peer response to students' work in progress and its transmission. Typically, students upload drafts of papers to the program where they are available for other students, usually in pre-determined pairs or small groups, to read and comment on, sometimes anonymously and sometimes not. The basic principle under which such systems operate is the exchange of drafts and comments to facilitate productive authorial revision. However, because novice writers often lack the ability to diagnose problems or make critically useful suggestions on either their own or others' work, the systems are usually accompanied by features designed to help students with these processes in order to improve their own learning about text and to assist their peers in revision. In addition to the goal of improving writing, many systems also are geared toward improving the experience of the peer review process itself, especially because this process is fundamental to much writing in collaborative work settings. Digitizing the processes that ordinarily take place physically in classrooms offers opportunities for the inclusion of many such features to be described under functional specifications.

3 Functional Specifications[1]

The most basic digital peer review processes utilize existing programs and platforms to enable students to comment on their peers' drafts in progress. Most word processing programs offer tools to comment on drafts in the margins, interpose comments using features like MS Word's Track Changes, and write comments at the end. However, it can be cumbersome for students to work on one draft in a group using word-processing programs because drafts need to be exchanged one student at a time. Different versions of the draft can become confused in transit, and files can be lost. Students can each share their comments on a separate draft, but the author must then consider each in turn, and students cannot comment on each other's feedback to agree, disagree, or add material to the feedback.

Google Docs, One Drive, and other cloud-based applications allow students to write a draft online and share it (with editing privileges) with their peers, who can then insert comments at various points in the text. Collaboration is one advantage of this method because students can all comment on a draft (even simultaneously in real time), and each peer's comments are differentiated. The author can then easily accommodate the comments during revision and remove them, yielding a clean text. However, unlike face-to-face peer review, it is difficult to have a conversation about the draft or the suggestions. Students must be shown how to avoid privacy breaches and also how to work with the files when they want to pull them off the platform.

Some more sophisticated peer review systems are built into existing LMSs. These systems have additional functionalities to augment the simple exchange of commentary. Teachers can include rubrics to guide students' analysis and commentary and create small groups for the review, and students can make both marginal and summative comments and use markup tools to highlight words, paragraphs, or sections of a draft. Because the systems are built into their LMS, students often find it convenient to access and use them. Some LMSs such as Moodle and Google Classroom offer ways for instructors to acknowledge students' peer reviews and build them into a grading scheme based on posted criteria.

Freestanding peer review systems can be adopted to facilitate a number of interactions around drafts in progress. Some systems include features that allow students to create drafts of papers based on smaller writing tasks and upload material in several

[1] The digital peer review systems discussed here are those used for educational purposes rather than for professional peer review such as anonymous journal manuscript review.

formats. Peers can comment on these progressively drafted pre-writing materials along the way, helping the writer to shape a text even before it has been developed into a full rough draft. Instructors can include checklists or prompts for students to consider. As students submit peer comments, instructors can also intervene and help to shape the responses effectively. Authors can also give feedback to the peer reviewers, assessing whether the feedback was helpful, well presented, etc., in a process called "back evaluation." More robust systems also offer analytics that show, for example, the extent to which students' drafts improve, how effective the feedback was, and what sorts of plans students made for revision.

Training-based peer review systems are designed to help students to provide effective comments on peers' papers by including a review feedback component. Typically, students read and comment on preexisting papers using guided questions tied to evaluation criteria, and then score the papers on a scale. Automated feedback lets the students know how well they have done with the trial peer reviews. This prepares the students for the review of their peers' submissions (often but not always anonymously). If the same rubric is used, the quality of students' reviews can also be determined, and grades can be assigned based on the system's determination. Some systems allow students to later compare their own reviews with those of the other group members to see what they missed (or what their peers missed). The educational goal behind such systems aims to improve not only the individual peers' papers but the reviewer's ability to critically read work in progress and provide insightful and helpful feedback. Instructors can manipulate the system through the provision of assignments, questions, and evaluation rubrics.

Currently, training-based peer review systems are being augmented with machine-learning capabilities (see Lin et al., 2018). For example, specific kinds of comments can be assigned labels based on whether the comment makes a suggestion, identifies an error, or points to a specific place in the text. Labels can be determined by trained raters until agreement is reached, and scores can be assigned to labels based on the accuracy of their characteristics. This label information is used as inputs to create an algorithm that can determine scores for subsequent student reviews. Feedback to reviewers from the system can prompt them to improve their comments. The system can also assign grades for the quality of peer review comments at the end of the cycle. Continuous data input improves the accuracy of the system; as reviewers are assigned scores, the system can "learn" who the most competent reviewers are and add features of their reviews to its database (see Leijen, 2014).

Some platforms enable peer review of multimodal texts such as video. PlayPosit, for example, has functions that allow a student to upload or connect to a video. Students review the uploaded material and then are prompted to offer comments and suggestions. The system is interactive so that multiple reviewers can see and respond to each other's comments as if in conversation. Rubrics and criteria can be included.

4 Main Products[2]

Among the simpler forms of digital support for peer review are Google Docs or word processing programs that facilitate extensive commenting, such as MS Word. Google Classroom primarily facilitates the sharing of files and comments, allowing for the distribution of assignments, which invites students to engage in peer review. Students can insert comments into text boxes. Most LMSs include some form of peer review support. Moodle, for example, has an add-on to its Assignments function that organizes peer reviews and provides various metrics. Canvas includes a peer review option in which students open a peer's paper within the LMS and provide comments. Students can access both peer and instructor comments. Instructors can include rubrics for students to rate certain aspects of their peers' papers. Comment buttons allow students to add marginal feedback at certain points in the paper. Other tools facilitate drawing, highlighting, or striking out text. General comments (not tied to specific parts of the text) can also be added, and files can be attached.

Freestanding peer review systems available for classroom use include Peer Studio, a free cloud-based tool developed at Stanford University and the University of California at San Diego that relies on instructor rubrics. The system also allows students to consider a peer review against a comparison submission to make judgments for revision. The comparison feature is generated by AI-based, machine-learning technology that analyzes each student's reviewing history and that of their classmates to identify optimal comparison submissions. PeerGrade, a subscription-based program, works in a similar way: the instructor sets up an assignment, the students upload papers, each peer can write comments in the margins and also communicate with each other about the comments, and the teacher gets a complete overview at the end of the process. iPeer is an open-source tool that manages the peer review process. Among its affordances are the provision of rubrics, a way to review student comments before releasing them, a progress reporting form, and export functions in different formats.

Among the peer review systems that include training, analytics components, and machine learning, Kritik offers instructors a way to customize rubrics and provides a feedback mechanism through which students rate the effectiveness of their peers' comments. A gamified reward system provides incentive. SWoRD (which stands for Scaffolded Writing and Rewriting in the Discipline) was developed by researchers at the University of Pittsburgh and has been used not only to support student peer review but also to research the effects of peer review on students' learning and writing processes. When a student uploads a paper to the system, it assigns four to six peer reviewers automatically. Instructors can include evaluation prompts or rubrics designed themselves or pulled from a shared library. Instructors can also share their prompts and rubrics with specific collaborators. The student revises the paper based on the peers' comments and resubmits it, after which the same reviewers examine the revised version. The algorithm in the system analyzes the peers' ratings for agreement and bias, and the author rates the reviews for their helpfulness. Reviewers are assigned grades based partly on how accurate they are and partly on how helpful they

[2] URLs and other information about the systems are located in the table at the end of this chapter.

are. Because the system relies on machine learning, instructors don't need to determine the effectiveness of the reviews. Students are therefore trained in peer review while authors receive feedback for revision. Analytics built into the system provide information for teachers to improve their assignments and instruction. SWoRD is now licensed by Panther Learning and is called Peerceptiv.

MyReviewers (recently renamed USF Writes), developed and housed at the University of South Florida, includes the usual document management tools in most peer-review software but also offers workflow management for students, instructors, and administrators and a number of resources. Drafts are uploaded to a cloud-based storage space. Teachers and/or students can then use various markup tools to highlight text, add sticky notes, insert text boxes, or enter links; preloaded rubrics automatically calculate weighted scores on the draft. The system has built-in learning analytics, such as inter-rater agreement, that can assess student performance.

Expertiza, developed and housed at North Carolina State University, is a peer review system incorporating machine-learning features for review assessment. Students are assigned rubrics to review the work of peers who have uploaded files; both author and peers are anonymous. Questions on the rubric (which guides the students' evaluations) can be assigned scores and students can add comments. Student authors can consider aggregated advice and scores as they rethink their drafts; they also use another rubric to rate the quality of their peers' feedback (such as how helpful, accurate, and respectful the advice is). Instructors can include the scores from this feedback in their assessment of students' work. The system allows more than one iteration of feedback and response. Currently Expertiza is incorporating machine learning to collect data on the quality of peer reviews by assigning "reputations" to certain reviewers and using the reputations to estimate reviewer reliability. The algorithms in the system compare a student's reviews with the scores of other reviewers of the same text, as well as distributions of scores and how lenient or strict a particular reviewer is. Another feature of Expertiza is the peer review of learning objects in different disciplines. Students produce reusable materials such as discussions of difficult concepts or animated lecture slides. These objects are submitted for peer review, resulting in the highest-rated objects being incorporated into instructional materials for the class or in presentations.

Eli Review, developed at Michigan State University, is an online peer review platform that allows instructors to create prompts, organize reviews, and design checklists in order to realize specific learning goals. They can also watch reviews in real time as students provide each other with comments, then make decisions about further coaching. Students can nominate specific peer reviews as models for other students to follow. Iterative stages allow students to plan revisions in their work based on the reviews. Analytics show improvements in drafts, quality of feedback, and both plans for revisions and the revisions themselves.

Calibrated Peer Review (CPR) was developed at UCLA by Dr. Orvill Chapman with the assistance of funding from the (U.S.) National Science Foundation and the Howard Hughes Medical Institute. Like other training-based peer review systems, CPR involves anonymous peer review of student work and provides feedback to reviewers about their reviews. In the pre-review training component, students write brief essays on provided prompts with supporting questions. After submitting their essays, the students then score three "calibration" essays in order to practice peer review, followed by scoring three of their peers' essays. In the final step, students return to their own essays, which they re-read and score. Instructors can create their own assignments or use one in the system's databank. A full description of the program, applied to an introductory biology class, can be found in Robinson (2001).

5 Research

Research on peer review, in both L1 and L2 contexts, is voluminous. It is not the purpose of this chapter to review research on the more general use of peer review but to cite studies that focus specifically on the use of digital technologies to facilitate the student peer review process.

Many studies have been conducted by the developers of specific peer-review platforms. Previous research on SWoRD is summarized in Schunn (2016) and individual studies mentioned there will not be cited here. Some studies showed agreement between student ratings and instructor ratings; in one study, student ratings in Advanced Placement classes using SWoRD were similar to the ratings of experts trained by the College Board to evaluate essays. Other studies showed improvements in student writing as a result of peer evaluation. In studies that masked the origin of feedback, students' ratings of helpfulness of peer feedback were similar to their ratings of instructor feedback. Other studies found that students improved their own writing as a result of providing feedback to their peers.

Research was conducted at various stages in the development of then-named MyReviewers. Warnsby et al. (2018) examined the role of praise, criticism, authority, and power relations in a corpus analysis of 50,000 peer reviews curated through MyReviewers across multiple institutional contexts. Results revealed a mix of functions, and also that students used more positively glossed feedback than negatively glossed. Results also varied by institutional context and other factors such as writer experience. In a comparison study of 46,689 peer and 30,377 instructor reviews submitted to MyReviewers, Moxley and Eubanks (2015) found that student ratings were higher than those of instructors but that this difference declined over time. In addition, higher-scoring students on instructor ratings gave scores on peers' paper that were closer to those of instructors. The most recent studies of MyReviewers emerged from a multi-institutional grant from the (U.S.) National Science Foundation. In one study (Anson et al., 2021), corpus analysis was employed to compare key concepts used in peer reviews in foundational writing courses with courses in the disciplines, in part to see whether these terms transferred across contexts. Although some transfer occurred, it did so less effectively when instructors in the disciplines did not use the rubric function of MyReviewers to reactivate the knowledge gained in the foundational course.

Ramachandran and Gehringer (2011) demonstrated that automated classification of peer reviews in Expertiza based on quality and tone is possible when applied to student review data. Metareviewing (reviewing reviews) is tedious for instructors and problematic for students (who may not have been trained to evaluate the quality of reviews), but machine learning techniques such as latent semantic analysis can automate the process. The researchers report on experiments showing that certain programming steps can predict metareview scores of students' reviews, thus providing valuable automated feedback.

A study of Calibrated Peer Review used in a lecture-based zoology course (Walvoord et al., 2008) found that the system assigned higher scores to student essays than did instructors. In addition, students' abilities to write technical material or summarize scientific articles with full understanding of the material improved over the course as a result of peer review. In addition, the system reduced the time instructors spent grading student work. However, an interview-based article published in UCLA's *Daily Bruin* (Rosenbluth & Lewis-Simó, 2018) reports that students using the version at the time did not find it to be very effective.

6 Implications

Compared with conventional student peer review, digital peer review offers several advantages, the first being speed and convenience of exchange. Students can usually manipulate text for font size or other aspects of readability, which is impossible on paper, to accommodate learning differences and visual impairment. There is usually unlimited room for feedback which is not the case with paper copies, and from a psychological perspective, comments can be provided in different ways (such as through collapsed boxes or stickies) to avoid overwhelming a student writer with heavily marked up text. Built-in rubrics, feedback, and training systems can, unlike conventional review, compel students to consider certain questions or to learn how successful their commentary is based on machine-learning feedback algorithms. From an instructional perspective, the management of peer review can be greatly facilitated by providing access from a single online portal, by auto-generating quality of feedback scores, and by tying feedback to grading systems. Because texts and comments typically reside in safe spaces for backup and retrieval, material is not lost.

Digital peer review also has the advantage of generating data that can be useful to individual instructors as well as in classroom research, action research, or formal studies. Curation of student peer reviews and revisions can, over time, yield enormous data sets that can be digitally analyzed for more robust findings than the mostly classroom-limited and small-group studies of peer review in the past. In addition to the reports that some of the systems can generate, raw data in the form of student reviews, use of stickies or prepared comment banks, and drafts and revisions can be analyzed for many features including the relationship between student reviews and specific kinds of revision, the affective dimensions of peer feedback, and comparisons of student and teacher feedback.

As stated previously, existing digital peer review systems do not allow for the kind of deep discussion of drafts, with live consideration and negotiation of possible revision, that are the hallmark of conventional face-to-face meetings. In addition, many peer review systems push students toward an evaluative stance (e.g., by asking them to make grade-based or other decisions about the quality of a draft), rather than encouraging a more formative, advisory stance even with the provision of rubrics. The use of rubrics with a few questions can direct students' attention to salient issues but also reduce more impressionist and holistic responses to student texts, or create a "checklist" mentality to what is usually a complex response involving interpretation of multiple textual dimensions. Finally, depending on the system, confidentiality and privacy can be a concern when files are transmitted, shared, stored, and returned.

Because peer review involves complex interpersonal and affective dimensions of collaboration and response in both face-to-face and online settings, more research is needed to explore which aspects of peer review are effective relative to students' perceptions. For example, research has shown that when students become preoccupied with the interpersonal nature of response to their work, they can be diverted from a focus on their texts and how to improve them (see Anson, forthcoming). These affective and interpersonal responses can be influenced by perceptions of difference, including students' identity constructs, racial and ethnic characteristics, and other factors.

7 List of Tools

Software	Description	URL
Google Docs	Peer review function; free; Web-based; share function for others' feedback; specifies reviewer; can reveal changes	https://www.google.com/docs
MS Word	Peer review function; proprietary; Web and download; individual feedback using tools such as Insert Comments	Microsoft.com
Google Classroom	Peer review function; proprietary; Web-based; full suite of functions including peer review	edu.google.com
Moodle	Peer review function; freemium; Web-based; LMS includes peer review function in Assignments; review metrics & analysis; reusable comments; can flag poor reviews	Moodle.org
Canvas	Peer review function; proprietary; Web-based; LMS includes peer review function; can assign or randomize groups; guides process; can include rubrics and feedback tools	https://www.instructure.com/canvas

(continued)

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Software	Description	URL
Peer Studio	Freestanding peer review platform; free; Web-based; automates many functions; uses instructor-provided rubrics; AI-based review analysis; guides process	https://www.peerstudio.org/
Peer Grade	Freestanding peer review platform; free trial then student fee; Web-based; teacher provides assignment and rubric; students provide review & engage in discussions of it; provides teachers with overviews	https://www.peergrade.io/
iPeer	Freestanding peer review platform; open source; Web-based; assignment & rubric creation; reminders & scheduling; student feedback system; can be team-based	https://ipeer.ctlt.ubc.ca/
Kritik	Freestanding peer review platform; proprietary; Web-based; LMS integration; includes training, machine learning, & analytics; students rate reviews; gamified reward system	https://www.kritik.io/
SWoRD (Peerceptiv)	Freestanding peer review platform; proprietary; Web-based; coordinates anonymous peer review; offers rubric options; students provide back evaluations; includes analytic features	https://peerceptiv.com/
MyReviewers (USF Writes)	Freestanding peer review platform; student subscription; Web-based; Workflow management, markup tools, rubrics, automated score calculation and learning analytics	myreviewers.usf.edu
Expertiza	Freestanding peer review platform; open source (request account); Web-based; rubrics; automated scoring & aggregated advice; machine learning & reputation ranking	https://expertiza.ncsu.edu/
Eli Review	Freestanding peer review platform; free trial then student subscription; Web-based; create reviews, checklists, & prompts; manages review process; allows revision plans; provides some analytics	https://elireview.com/
Calibrated Peer Review	Freestanding peer review platform; proprietary; Web-based; assignment library; training calibration; anonymous review; scores produced for writer & reviewers	http://cpr.molsci.ucla.edu/Home

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Reference Management Systems

Antje Proske, Christina Wenzel, and Manuela Barbara Queitsch

Abstract This contribution focuses on reference management systems that help writers capture, store, organize, use, cite, annotate, and share source material for their writing. Reference management has become easier, faster and more social over the years: Originally introduced to reduce the effort required to correctly edit citations, reference management systems have evolved over time to incorporate new features such as online management of source material or bibliographic social bookmarking. The usefulness of typical functions of reference management systems for the use of source material in academic writing is discussed. Different reference management systems are described, focusing in particular on their unique features. Furthermore, research on the effectiveness of reference management systems is shortly summarized. The contribution concludes with suggestions on how to achieve wider acceptance and adoption of reference management systems by writers in their writing routines.

Keywords Reference management · Reference managers · Writing from sources · Referencing · Citations

1 Overview

The use of source material is essential in academic writing. By integrating sources in the body of their text, writers contextualize their ideas, demonstrate the breadth and depth of their critical engagement with the available literature, and acknowledge the work of other authors. They underpin their own ideas, arguments, and opinions with evidence (Cumming et al., 2016). Sources are typically included in a text by

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_14

in-text citations in the form of summaries, paraphrases or quotations that are linked to the list of works cited at the end of the text (i.e. reference list or bibliography). Referencing entails thus acknowledging a source in the text *and* in the bibliography. A reference indicates a scholarly source by providing a standard set of information (i.e. citation information) that allows readers to easily identify, search, and retrieve the source (Kali, 2016). In order to ensure consistency in the format and layout of citations, it is common for writers to use a specific citation style.

In the past, source material often was manually documented and organized on small-sized index cards and stored in boxes. Each card contained information related to a source, such as summaries and paraphrases of important information, quotations, personal comments, or author data and bibliographic information. Location information, when included, allowed for a quick return to a specific passage in the source material. Keywords made the documented information be reused. This manual management of references was tedious and time consuming (Fenner et al., 2014).

Reference management systems, also referred to as reference/citation managers, or as bibliographic management systems or software, allow for the computer-assisted management of sources. Today, they enable the personal collection, organization, and use of citation information and support the management, analysis, and further utilization of the corresponding source material (i.e. full text, e.g., Murphree et al., 2018).

Originally introduced in the 1980s to reduce the effort of editing citation information, early desktop applications for reference management (e.g., Endnote, ProCite, Reference Manager) mainly provided functionalities for collecting references and integrating citation information into one's own text in a formally correct manner (Kali, 2016; Murphree et al., 2018; Steele, 2008). Writers had to manually add the citation information as individual entries into the respective digital reference library, but could enrich them with personal notes. Full texts could usually not be saved or accessed directly.

In the 2000s, the desktop applications for reference management evolved into web-based systems (e.g. Refworks, online versions of desktop applications, Zotero), making it possible to manage references online. In addition, it was now possible to automatically import citation information and full texts from online bibliographic databases such as Web of Science, Scopus, PubMed, or Google Scholar, but also directly from web pages.

The most recent development since the 2010s has been in the direction of bibliographic social bookmarking (Fenner et al., 2014). Online social bookmarking tools such as CiteULike and Bibsonomy, as well as reference management systems such as Mendeley or ReadCube focus on the public sharing of references. This functionality helps writers capture, manage, and reuse source material, as well as complete and accurate citation information (Giglia, 2010). It also enables, for example, the generation of usage statistics as a novel means of measuring scientific impact (Chen et al., 2018).

2 Core Idea of the Technology and Functional Specifications

Many researchers agree that the quality of writers' engagement with the source material is an important predictor of the quality of a scientific text (e.g., Plakans & Gebril, 2013; Spivey & King, 1989). Thus, one's text product is built through the purposeful interplay of source comprehension and text production processes (e.g., Cumming et al., 2016; Jakobs, 2003; Parodi, 2006). Reading and writing processes are blended in which writers actively collect, select, analyze, interpret, organize, and connect information of different sources (Drake, 2013; Parodi, 2006; Spivey, 1990). This requires writers to deal with a variety of source material and to organize this information in a consistent way for their text (Jakobs, 2003). Yet this also makes it necessary to clearly identify where ideas from source material have been used in one's own text (Jakobs, 2003). Not only is this a way to avoid plagiarism, it also allows readers to distinguish between writer's own words and ideas and those of others. Reference management systems can assist in many of these source material engagement activities (Francavilla, 2018). They help capture, store, organize, use, cite, annotate and share source material for writing.

Unfortunately, reference management systems are not explicitly designed to support writing, but to facilitate the organization and management of bibliographies (Francavilla, 2018). Therefore, some functionalities are not completely aligned with a writing process (Vaidhyanathan et al., 2012). Moreover, many of the functionalities that reference management systems offer to support writing are not visible to the writer at first glance. Often, an in-depth knowledge of the respective reference management system is necessary to profitably use these functionalities for one's own writing process. Familiarization with a reference management system requires a considerable amount of time and effort that writers may be able to invest in one, but usually not in several reference management systems. As a result, many of the system functionalities that can support the writing process beyond the formally correct preparation of citation information are not or only very rarely used (Melles & Unsworth, 2015).

Nowadays, reference management systems are mainly organizational tools (Perkel, 2020). They are typically desktop applications with an associated web-based interface that allow writers to remotely access their individual libraries (i.e., self-compiled, self-structured, and annotated collections of source material). Further, these reference management systems often include browser plug-ins, which facilitate the simultaneous import of citation information and the corresponding full text from scientific databases, journal web pages, or other online sources. Most reference management systems also provide mobile apps that allow writers to add, read, and annotate sources from smartphones or tablets.

The organizational functionalities of reference management systems facilitate the analysis and elaboration of source material in earlier stages of writing projects as well as an alternating work on writers' text produced so far, their annotations, and the sources during actual text production. Most reference management systems allow writers to organize their individual source material collection into folders. Tags can also be used in most reference management systems to organize the source material. A tag is a kind of individually generated label or keyword that the writer can add to a reference entry to classify and remember it (Giglia, 2010). With most reference management systems, it is also possible to add notes to each source. All sources can be searched by author, keywords, text and notes. PDF viewers—in most cases built-in—allow the writer to access and read the full text of a source. After accessing, for example by double-clicking, the writer can annotate the full text and highlight important passages using the PDF viewer tools. In other words, the full texts are typically not processed via the reference management system, but only accessed. The annotations are saved in such a way that they are available for subsequent work on the full text even without access via the reference management system. Some reference management systems (e.g., Endnote, Zotero) can even import further sources or missing meta-data and full text via included search functions.

The editing and correct formatting of citation information (i.e. in-text citations and the corresponding reference list) is supported in most reference management systems through integration with word processing software, for example, in the form of add-ins. These allow the writer to insert in-text citations (i.e. the citation information acknowledging the source of quotations, paraphrases, or summaries) into documents as they are written. Reference lists are automatically created in the required citation style and reformatted on the fly when the citation style changes. Finally, reference management systems typically allow writers to share their individual libraries with colleagues so that it can be used in co-writing situations or as a shared knowledge base. In this way, not only collaborative writing but also collaborative thinking and exchange of ideas is supported.

3 Main Products

There exist more than 30 different reference management systems at present. A continuously updated overview can be found in the Wikipedia article on comparison of reference management software: https://en.wikipedia.org/wiki/Comparison_of_reference_management_software. This overview contains a description of the basic functional features of the respective system as well as information on whether a reference management system is regularly updated. Using a reference management system without regular releases is not recommended.

By now, all common reference management systems provide basic functionalities for capturing and storing source material, for the insertion of citations into one's text, as well as for web-based reference management and social bookmarking. Nevertheless, the various systems are developing so quickly and in part unpredictably that an overview of the system features could look quite different in some time.

In the following, we will discuss unique features and/or functionalities of five important reference management systems, illustrating the diversity of those on the market. These five systems are frequently used, and usually referred in literature and research (e.g., Lorenzetti & Ghali, 2013; McMinn, 2011).

By now, all five systems offer the basic functionalities described above. These include functionalities for

- collecting references with full texts and organizing them into folders and/or (sub)collections,
- tagging reference entries,
- annotating and highlighting full text via (built-in) PDF viewers,
- citing references in different citation styles via (a) add-ins for word processing software or (b) (automatically) creating and updating BIB files for (La)Tex,
- synchronizing references between desktop app and mobile version as well as between different computers, and
- sharing references with colleagues.

3.1 Citavi

Citavi is a good example that the border between reference management systems, word processors, outliners, and idea management is fluent. Citavi is a proprietary software of the developer Swiss Academic Software. It was developed in 1994 as a project named LiteRat. Since 2006, it is known as Citavi. In February 2021, Citavi was purchased by QSR International. Citavi is compatible with MS Windows and the interface is available in different languages. Citavi offers an add-in for MS Word to insert references from a Citavi project into a document in a specific citation style. It also helps creating manuscripts with the TeX typesetting system.

In addition to the typical basic functionalities, Citavi offers two unique tools – the knowledge organizer and the task planner. The knowledge organizer supports writers' engagement with the collected sources and working on one's own text product using the annotated source material. Using the knowledge organizer quotations, paraphrases, summaries, and notes can be automatically collected and structured. A built-in full text editor assists in automatically extracting highlighted passages from the full texts into the Citavi system. The extracted elements are called "knowledge items" and can be assigned to user-defined hierarchical categories in Citavi. These categories can then be exported to a text as chapter headings via the Citavi MS Word add-in. Using this add-in, the knowledge items can also be further adapted. In addition, the corresponding citation information and a reference list in the required citation style are automatically integrated into the manuscript.

The task planner supports the planning and definition of (sub-)tasks related to the writing project and time management. Unfortunately, there is no export option or exchange with MS Outlook or any other task management software.

Team work was already possible since 2018, but the cloud-based collaboration required the Citavi desktop application for each team member and thus the use of MS Windows. Since 2021, Citavi is available via a web interface, so that now cross-platform team work with different operating systems is possible.

3.2 EndNote

EndNote is one of the earliest and most widely used reference management systems (Childress, 2011; Karavaev, 2016; McMinn, 2011). EndNote Desktop is a proprietary software, but available for MS Windows and MAC OS. It offers an add-in for MS Word, Apple Pages and Open Office that allows writers to insert in-text citations and create a reference list at the same time.

EndNote was launched in 1988 as desktop application by the developer Thomson Reuters; currently it is produced by Clarivate. A free web version "EndNote Web" is available since 2006. Although EndNote Web does not have all the features of Endnote Desktop, it is a good alternative to the proprietary version. "EndNote Web serves as an online supplement to EndNote Desktop, though it can be fully functional on its own. One does not have all the features of the other, and vice versa; they are complementary to each other" (Zhang, 2012, p. 47). For sharing references and collaborative writing, EndNote Web is necessary.

EndNote is one of the few reference management systems that does not offer an extension to collect references directly via web pages. There are extensions for data transfer, but these require a roundabout via import files. It is not a one-click process as in Zotero, Mendeley or Citavi. However, EndNote Desktop offers many import formats for a wide range of databases, catalogues and other platforms. In contrast to most other reference management systems, Endnote does not import citation information and full texts simultaneously, but rather sequentially. It also offers writers some degrees of freedom. For example, writers can define entirely new reference types to add non-typical entries such as photos or paintings with their special meta-data.

In addition, EndNote offers a function for searching in external databases. This search function should not be used in early stages of a writing project to locate and read relevant literature. Fitzgibbons and Meert (2010) compared the integrated EndNote search with direct searches in different databases. They showed that the comparability of the hits depends on both the database searched and the technique used for the search. Therefore, in early stages of a writing project it seems to be more meaningful to use the direct search in databases to be able to gain an overview of the current state of research. Furthermore, Endnote does not support a parallel search in multiple databases. Thus, the integrated Endnote search function is helpful, for example, to add citation information of already known sources to writers' reference library.

3.3 Mendeley

German students developed the first version of Mendeley in 2008. Mendeley is free of charge, but not open source. In 2013, Elsevier purchased Mendeley. In the following years Mendeley was continuously developed. At the moment, Mendeley provides a desktop app for MS Windows, MAC OS and Linux, as well as a web version. It also offers a browser plugin to collect references and full texts directly from web pages and an add-in for MS Word and LibreOffice. Using Mendeley requires a personal account. Besides Mendeley Free a proprietary premium version “Mendeley Institutional Edition” is available. This edition provides more cloud storage space and more collaboration features, for example to create an unlimited number of shared groups.

Now, a radical change seems to be pending, as, according to statements on the product homepage, users will no longer be able to download and install Mendeley Desktop software after September 1, 2022. Mendeley’s new reference management suite consists of three fully integrated applications. Mendeley Reference Manager can be used to organize and share source material, the Mendeley Cite add-in for MS Word to generate and format in-text citations and bibliographies, and the Mendeley Web Importer browser extension to create customized collections of source material when searching online.

A unique feature of Mendeley is that it automatically checks the correctness and completeness of the meta-data after importing new reference entries. To this end, a huge data collection is used, which is derived from the collected and corrected references meta-data of other Mendeley users. In this way, the laborious and time-consuming individual assessment and correction of inaccurate meta-data can be substantially facilitated and supported (Salem & Fehrmann, 2013).

3.4 RefWorks

RefWorks is a proprietary, web-based reference manager founded in 2001. In 2008, RefWorks was purchased by ProQuest (now Clarivate). Like EndNote, it is one of the earliest and most widely used reference management systems (e.g., McMinn, 2011). RefWorks offers add-ins for MS Word and Google Docs.

A unique feature of Refworks is that the collected source material is only saved in the cloud, not on a local computer. Thus, syncing and sharing references is very simple. The interface is intuitive to use, an integrated search in selected external databases is possible, as well as a subsequent addition of full texts.

3.5 Zotero

Zotero has similarly advanced features to support the use of source material in writing as Citavi, but is free and open source, supports all major operating systems, as well as various word processors in more than 30 languages. It was developed by a group of Librarians at the Roy Rosenzweig Center for History and New Media at George Mason University in 2006. The first version of Zotero was only a browser extension for Mozilla Firefox that collected and organized references. Since 2011, Zotero is available as a desktop application for MS Windows, Mac OS and Linux, as well as a web-based interface. Zotero still offers a browser plugin for Mozilla Firefox, Google Chrome, Safari and MS Edge to collect references and full texts directly from databases, catalogues and websites. For synchronization and collaboration, a Zotero account is needed. Zotero offers plugins for MS Word, LibreOffice and Google Docs.

As of March 2022, Zotero also includes an integrated full-text editor for annotating, tagging, and extracting full-text passages and images. Zotero saves these as notes, similar to the "knowledge objects" in Citavi. Using the word processor plugin, the writer can insert the notes into their own text; the corresponding citation information is automatically added and formatted according to the selected citation style.

With Zotero, writers have also a unique opportunity of expressing relationships between sources, as different references can be linked to each other using the "related items" feature. The writer decides for themselves according to which criteria they want to establish the relationship (for example, according to the content of the sources or according to formal criteria). In this way, the identification of relations between different sources and/or the sources and the writer's own positions is also supported, a very important activity when engaging with source material.

Zotero offers further a function for searching in external databases to import metadata by standard identifiers such as ISBN, DOI or arXivID. This search function uses databases such as WorldCat, CrossRef and PubMed. In this way, the citation information of already known sources can be added quickly to writers' reference library.

Finally, due to its open source character, there are numerous third party extensions that make Zotero even more powerful. For example, "zotfile" renames the related full text PDF-files according to a constant scheme. This renaming makes it easier to find sources, for example on a local computer, because the new PDF name includes the authors' name, the publication year, and the title of the publication. Other extensions such as "Zotero Citation Counts Manager" track the citation counts of publications. Citation counts show the impact of publications in the scientific community. Note that they are provided for Zotero by free platforms such as Google Scholar and CrossRef, not by proprietary databases like Web of Science or Scopus. In addition, extensions like "Better Bibtex" or "LyZ" support writing with LaTex or further Tex-editors. All Zotero plugins can be found at Zotero's plugin documentation web page: https://www.zotero.org/support/plugins.

4 Research

Over the last two decades, much has been published on reference management systems (e.g., Emanuel, 2013; Fourie, 2011; Tramullas et al., 2015). Most of these publications compare different reference management systems (see, for example, Tramullas et al., 2015 for a review). In addition, much has been said and written about the decision to use a reference management system. There is agreement that this decision depends on the conditions and preferences of the writer, as well as the writing context (e.g., Perkel, 2020).

There are very few peer-reviewed publications (e.g., Emanuel, 2013). The research in most cases focuses on how bibliographic data are captured, edited, and generated (Tramullas et al., 2015). In addition, most of the research focuses exclusively on locating and using new sources (Whittaker, 2011). Research on how the source material is organized for future (re-)use is almost not existent (Drake, 2013; Whittaker, 2011). In general, it appears that the body of literature on reference management systems can be broadly divided into four areas (see also Emanuel, 2013; Fourie, 2011):

- Non-empirical, mostly narrative analyses and comparisons of reference management systems features, trends, and criteria of selection (e.g., Kali, 2016; Karavaev, 2016; Perkel, 2020; Steele, 2008; Vaidhyanathan et al., 2012; Zhang, 2012).
- Empirical studies on the accuracy of automatic citation information (e.g., Fitzgibbons & Meert, 2010; Homol, 2014; Wyles, 2004).
- Empirical, mostly survey-based, studies on user perceptions of reference management systems and behavior related to collecting and managing sources (e.g., Chen et al., 2018; Nitsos et al., 2021; Speare, 2018).
- Best practices on training and support (e.g., Childress, 2011; Dovey, 2010; Mead & Berryman, 2010).

From this list, it becomes evident that as far as the impact of reference management systems on the theory and practice of writing in higher education is concerned, there is clearly a need for further research. Knowing what and how writers use functionalities of reference management systems can have a significant impact on the development of instructional strategies for writing with sources. However, there is virtually no research on how the use of reference management systems affects writers' activities and/or quality, productivity, or creativity (e.g., Melles & Unsworth, 2015; Vaidhyanathan et al., 2012). One exception, for example, is the study by Rokni et al. (2010), whose study compared inserting and reformatting references in a paper manually with inserting and reformatting references using EndNote software. The study showed that significantly more time was required for manually editing and reformatting citation information. Lorenzetti and Ghali (2013) surveyed authors of clinical reviews and meta-analyses on the frequency and ease of use of reference management systems. Their study revealed that the majority of authors of systematic reviews use reference management systems, but do not report this in their articles. Furthermore, Lorenzetti and Ghali (2013) found no clear links to exist between the choice of a reference management system and its perceived functionality or ease of use. On the contrary, empirical, survey-based studies consistently show that users value many of the functionalities of reference management systems (e.g., Salem & Fehrmann, 2013; Setiani et al., 2020, 2021).

McMinn (2011) systematically analyzed the Association for Research Libraries (ARL) academic library websites for information on reference management system support. It was shown that support for reference management systems in the major academic libraries is substantial. He concludes significant time savings could be achieved if the staff responsible for supporting these reference management systems could share their expertise, possibly by establishing a central repository for training and instructional materials. Essentially, however, this study raises the question of how libraries, perhaps in cooperation with other institutions such as writing centers, can most effectively provide support. Even more than 10 years later, the current state of research makes it difficult to propose recommendations on this issue. Much of the literature on reference management instruction is exploratory or descriptive. More research, including experimental studies, is needed to understand effective instructional methods for utilizing reference management systems in academic writing.

In this regard, there appears to be a positive development for survey-based studies. Recent studies are using more focused methods and study designs, for example by adopting established frameworks such as the UTAUT model (Venkatesh et al., 2003) to examine the use and acceptance of reference management systems (e.g., Nurkhin et al., 2019; Rempel & Mellinger, 2015; Setiani et al., 2020). Other studies systematically examine user characteristics to better understand indicators of referencing in the scientific community such as citation counts (e.g., Chen et al., 2018). If this trend continues, the results of survey-based studies may also help shed light on the specific conditions under which reference management systems support academic writing.

The discussion so far indicates that reference management systems can support and optimize the utilization of sources in writing projects. However, few writers use the core features of reference management systems for their writing activities (Melles & Unsworth, 2015). Thus, how exactly, and to what extent reference management systems influence writing with sources is not well understood (e.g., Drake, 2013). An important goal of university education and training should be to raise awareness among writers (i.e. lecturers, theses supervisors, students, etc.) for reference management systems and their functionalities to support writing. In addition, further research is needed, for example, to examine how reference management systems can support writers' alternate reading and writing activities during text production (e.g., Drake, 2013; McGinley, 1992). In addition, it is necessary to understand how specific features of reference management systems help to distribute writing activities between writers and tools in a beneficial way, and which features are suitable to support which activities of a writing project (e.g., O'Hara et al., 2002). To this end, it is necessary to adopt a writer's perspective rather than searching for the perfect bibliographic software.

Within their current state of functionality, reference management systems can assist in source reading and writing activities, but their use can also have risks. For example, using reference management systems may also weaken writers' knowledge and understanding about referencing (Kali, 2016). Furthermore, the accuracy of reference management systems and/or the meta-data automatically imported from journal websites or other online sources can be a concern (Salem & Fehrmann, 2013). Therefore, it is important for writers to be aware of both the power and the limits of reference management systems.

Looking back to the beginning, reference management has become easier, faster and more social over the years (Fenner et al., 2014). Collecting sources and automatically updating citation information has become more comfortable. In the near future, reference management systems will increasingly have to deal with alternative scientific content such as presentation slides, blog posts, or web links. Standards of open science will play an increasingly important role. From a technical point of view, issues of portability of reference libraries, interaction possibilities with co-writers, opportunities to share annotated libraries with the academic community, as well as the integration of reference management systems into writing-to-learn, as well as learning-to-write environments, for example by using AI technologies, will be significant.

At present, only advanced users can take advantage of the support that most reference management systems provide for writing. Moreover, this support is not completely aligned to the demands of academic writing. For this reason, many authors use a wide variety of tools (e.g., note-taking tools, mind-mapping tools, etc.) for the different stages of their writing project. Thus, for future research and development, it would be valuable to bridge tools for reference collection, analysis, and annotation to tools that focus on knowledge management, processing, and production in the writing process. As a result, applications and tools that facilitate academic writing with sources can be developed evidence-based. First promising approaches in this regard are, for example, commercial software-as-a-service solutions such as Auratikum (https://auratikum.com/), Sciflow (https://www.sciflow.net/), or raxter (https://www.raxter.io/). Such solutions allow academic writers to have the most important functionalities for their writing conveniently in one place.

5 Implications of this Technology for Writing Theory and Practice

More research is needed to understand the exact nature of the relationships between searching, reading, and analyzing sources and using reference management systems in the context of academic writing. Moreover, the functionalities of reference management systems are not fully aligned with the writing process (Vaidhyanathan et al., 2012). More advanced reference management systems might even provide more support for writing projects. We would like to illustrate this with three examples below.

First, writers—particularly inexperienced writers—often pay limited attention to evaluating the trustworthiness of a source by examining the author, the publisher, or the type of publication (e.g., Britt & Aglinskas, 2002; Drake, 2013; Goldman et al., 2012). Using more and better evaluation strategies is associated with less reliance on unreliable sources in one's own text (e.g., Anmarkrud et al., 2014; Britt & Aglinskas, 2002; Goldman et al., 2012). Thus, reference management systems could more explicitly support writers in paying attention to such information (e.g., by color-coding). Currently, for example, different publication types, are difficult to distinguish from each other at first glance in reference management systems.

Second, writers rarely follow a linear sequence of systematically searching databases, downloading and entering references into their libraries, saving and analyzing the full texts of selected sources, and then producing their text including citations in the correct style (Drake, 2013; McGinley, 1992; Mead & Berryman, 2010). Rather, writing activities interact in a recursive way as the writing process unfolds. This requires the writer to keep track of what they have already studied, what sources are relevant, and how these sources relate to their text and/or the overall topic. Functions that facilitate this integration process are hardly offered in reference management systems so far (Vaidhyanathan et al., 2012). For example, it seems to be important for writers to be able to view, annotate, and use multiple documents at the same time (O'Hara et al., 2002). Graphical overviews or perhaps creativity software and idea mapping technology could also make connections between different sources more visible (Goldman et al., 2012, see https://docear.org/ how such a graphical organizer could look like). Including such functions into reference management systems or combining reference management systems with such tools would make cognitive resources available for the writer to focus on integration processes across the source material that should be beneficial for quality of one's own text (Goldman et al., 2012; O'Hara et al., 2002; Proske & Kapp, 2013).

Third, in particular inexperienced writers have difficulty comprehending and summarizing multiple sources and integrating this source into their own line of writing (Cumming et al., 2016; Wette, 2010). Thus, there is a great deal of variability in how writers incorporate sources into their text (e.g., Goldman et al., 2012). Many reference management systems provide the option to copy verbatim citations from the full texts (i.e. quotations). Doing so encourages writers to repeat the content of a single source, but not to summarize sources in one's own text, and certainly not to develop an integrated argumentation. Moreover, copying and reusing quotations in this way might even promote instances of plagiarism. Here, at least, a functionality would be desirable that not only automatically extracts the selected passages from the full text, but simultaneously also the corresponding citation information.

6 List of Tools

Citavi	Description: Citavi is a proprietary software. The desktop applications "Citavi for Windows" and "Citavi for DB Server" are originally only compatible with MS Windows. Citavi Web closes this gap, as Citavi Web is browser-based and thus operating system independent. In addition to literature management, Citavi also offers areas for knowledge management and task planning	Developer: QSR International; previously Swiss Academic Software URL: https://www.citavi.com/

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EndNote	Description: Endnote is a proprietary software that is widely used. Endnote is available for MS Windows and MAC. It is complemented by a free web version. Endnote offers a wide range of functions that support reference management	Developer: Clarivate; previously Thomson Reuters URL: https://endnote.com/
Mendeley	Description: Mendeley is a free software, but not open source. In addition to the free version, a paid variant is available which offers additional features, such as increased storage space for (group) projects outsourced to the cloud. Mendeley is available for the operating systems Windows, MAC and Linux and is supplemented by a web version. In addition to the typical functions of a reference management system, Mendeley offers the best conditions for a comprehensive collaborative exchange. The user interface of Mendeley is only available in English	Developer: Elsevier URL: https://www.mendeley.com/
RefWorks	Description: RefWorks is a proprietary, web-based reference manager. Both the meta data and the collected full texts are stored in the web cloud. Thus, location-independent use is possible and no local updates are necessary Use of RefWorks requires an institutional subscription; individual user accounts are not offered	Developer: ExLibris, a Part of Clarivate; previously ProQuest URL: https://refworks.proquest.com/
Zotero	Description: Zotero is a free and open source reference management system. In addition to versions for the MS Windows, MAC and Linux, Zotero is also available as a web-based tool. Starting as a simple browser extension for Firefox, Zotero has evolved into a comprehensive reference management software. Due to its open source character, numerous extension are offered for Zotero. The Zotero interface is available in more than 30 languages	Developer: Corporation for Digital Scholarship; previously Roy Rosenzweig Center for History and New Media, George Mason University, Virginia URL: https://www.zotero.org/

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Plagiarism Detection and Intertextuality Software

Chris M. Anson and Otto Kruse

Abstract Software for plagiarism detection was developed in the early 2000s when powerful search engines offered writers opportunities for unattributed copy-and-pasting from other sources. Many algorithms were developed to reveal overlaps between original and source text. Although the software was imperfect, its use has spread across higher education, precipitating intense debates about its application to the teaching of writing. Because of instructors' fear of false accusation and the effects on students' anxiety, many educators have eschewed plagiarism detection systems. Others, however, have adopted plagiarism detection for formative and developmental reasons, such as helping students to understand intertextuality and making referencing a manageable skill. This chapter will briefly historicize the effects of the internet on the practice of plagiarism; describe the technology behind digital programs for plagiarism detection and its functional specifications; summarize some of the research on plagiarism detection programs; describe a few of the more popular programs; and conclude with implications.

Keywords Plagiarism detection programs · Misuse of sources · Formative vs. summative evaluation

1 Overview

Plagiarism is far older than the internet. Its roots can be traced to ancient Roman practices and to the onset of modern sciences in the Enlightenment era. One of the most common interpretations is tied to individual authorship and the need to protect original contributions to society or research (see Sutherland-Smith, 2015) and to ensure the economic consequences of original text production for its "owners."

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_15

From this perspective, plagiarism is considered a kind of intellectual theft (the word "plagiarism" comes from Latin *plagiarius,* or "kidnapper")—an offence against the legal protection of proprietary rights. Although plagiarism is not a criminal offense, it often leads to civil litigation because of copyright violation, or to personnel actions because of ethical standards.

With the establishment of the Web in the 1990s and its introduction into homes, schools, and universities, the threat of plagiarism took on new urgency. The immediate culprit was the new opportunity for writers to copy and paste other authors' work from the Internet into their own texts. This opportunity increased as the availability of texts from online sources increased exponentially and new, powerful search engines such as Google made those texts readily accessible. In addition, paper mills (Bartlett, 2009) as a form of contract cheating (Lancaster & Clarke, 2015) also increased as internet platforms offered the risk-free transfer of texts for money. To cope with these new digital circumstances, universities developed integrity divisions and codes of ethical conduct for students (Anson, 2008). Also, a new interest in plagiarism theory appeared, revealing nuances of student source use such as "patchwriting" (Howard, 1999), spawning studies of student research and referencing practices (see Jamieson & Howard, 2011; Citation Project) and distinguishing between the uninformed misuse of sources by students and the deliberate appropriation of other writers' text without attribution (WPA Council, 2019).

Theories of plagiarism also explore its meaning and range of application. As Weber-Wulff (2014) points out, there is no valid definition of plagiarism. In part, the lack of certainty about plagiarism comes from varying practices and beliefs in different discourse communities about the processes of acknowledging others' work (see Anson, 2011, and Anson & Neely, 2010 for specific cases; see also Maxwell, et al., 2008). To complicate matters, plagiarism applies not only to text but also to data, source code, pictures, tables, and patents, all of which need different kinds of tracking and detection technology. Weber-Wulff (2014) offers an even wider list of plagiarism activities, including translation plagiarism, plagiarism of structures, self-plagiarism, patchwork referencing, and others. In addition, plagiarism is often conflated with other forms of textual deception such as "contract cheating" (when someone produces the writing for the person claiming authorship, which plagiarism software is usually unable to detect—see Curtis & Clare, 2017; Lancaster & Clarke, 2015; for data on contract cheating, see Newton, 2018).

In educational contexts, student plagiarism usually does not violate property rights but violates the rules of disclosing the origin of ideas and text. In academic fields, most published text may be used and at least partly reproduced, provided it is properly cited or, in some cases, that the original author is compensated for the rights of reproduction (Hyland, 1999). In classroom contexts, concerns are less focused on copyright violations than on ensuring that the work students submit is their own. The reasons include the purposes of their learning, the need to evaluate the quality of the texts they write, and the importance of teaching them proper academic citation processes for future work. For these reasons, most educational institutions view student plagiarism as a violation of a contract-like agreement that the work is original and that all others' text is properly cited. Violations are not treated in legal terms but as a breach of an honor code, with punishments (if caught) of failing a specific paper or the entire course, being put on academic probation, receiving a "scarlet letter" on one's graduation transcript (or the metaphorical equivalent; see Swagerman, 2008), or being expelled from the institution.

Plagiarism is not a marginal issue; substantial numbers of students are willing to cheat with their assignments, as shown in several large-scale questionnaire and survey studies of academic integrity (McCabe, 2005; McCabe et al., 2001). A survey carried out between 2003 and 2005, with 63,700 responses from undergraduate students and 9,250 from graduate students, showed the following percentages of students who have engaged in the respective behavior at least once in the past year (McCabe, 2005; percentages are listed for undergraduates first and graduates second):

Behavior	UG's (%)	Grads (%)
Working with others on an assignment when asked for individual work	42	26
Paraphrasing/copying a few sentences from written source without footnoting	38	25
Paraphrasing/copying a few sentences from Internet source without footnoting	36	24
Receiving unpermitted help from someone on an assignment	24	13
Fabricating/falsifying a bibliography	14	7
Turning in work copied from another	8	4
Copying material almost word for word from a written source without citation	7	4
Turning in work done by another	7	3
Obtaining a paper from a term paper mill	3	2

These data, however, are not longitudinal. Even though internet use has increased exponentially, it is not clear whether it has caused an increase in plagiarism, as Harris et al. (2020) showed in a large sample of adult learners in an online teaching context. The McCabe study even showed a decrease in copying from internet sources compared to print material (see also Walker, 2010.)

Other research on cheating shows that a relatively small group of students tend to engage in serious types of plagiarism (in contrast to the unknowing misuse of sources because of lack of training), but most students today are or have been affected by the practice of plagiarism detection introduced since the early 2000s. In the teaching of writing, plagiarism detection has an additional consequence which is alternatively called plagiarism anxiety, plagiarism phobia, or plagiarism paranoia. All three refer to the fear of being punished for incidentally and unknowingly plagiarizing. The reasons are twofold: first, when rules for referencing are not clear, and second, when instructional discourse moves plagiarism into the domain of misconduct and academic punishment. For the teaching of writing and referencing, it is essential to give students the opportunity to make mistakes. A differentiation between errors and misconduct is necessary, and referencing skills should not be learned in a climate of punishment and pseudo-criminal charges, as the use of plagiarism detectors often implies, but rather in a context of critical thinking (Vardi, 2012). When plagiarism software is mistakenly assumed to unerringly detect plagiarism, as Silvey et al. (2016) claim is the problematic case at Australian universities, the learning of intertextuality is prevented rather than fostered. In addition, students need to be acquainted with the nature of plagiarism detection so that if and when they are in a context that uses detection programs, they are well informed about how these programs work.

2 Core Idea of the Technology

Since roughly 2000, a constant stream of new tools and technologies has emerged to identify plagiarism in students' and professionals' documents. Plagiarism detection software became a matter of public interest and a great concern in higher education policy even though the real numbers, as the data above show, never reached the imagined dimensions of internet plagiarism. Reduced to its core operations, the technology indicates the similarity of a given text to already published texts or texts held in the system's database. The critical requisites of this software are (a) the access it has to a database of published texts and the size of this database, and (b) the algorithm that calculates the similarity.

However, existing tools cannot unerringly identify plagiarism; the software can only indicate cases of possible plagiarism through text matching, but cannot identify plagiarism itself. It cannot, for example, differentiate between well-referenced similarities and plagiarized ones. They all are included in the index of similarity. These facts have called into question the use of the terms "plagiarism detection software" or "plagiarism checkers." Foltýnek et al. (2020) suggest the alternative terms "text-matching software" or "software supporting plagiarism detection," while Wikipedia prefers "content similarity detection." Weber-Wulff (2019) calls the software "a crutch and a problem," and does not see it as a solution for the plagiarism problem. From her experience of annually testing several publicly available tools, she writes that

> The results are often hard to interpret, difficult to navigate, and sometimes just wrong. Many systems report false positives for common phrases, long names of institutions or even reference information. Software also produces false negatives. A system might fail to find plagiarism if the source of the plagiarized text has not been digitized, contains spelling errors or is otherwise not available to the software system. Many cases of plagiarism slip through undetected when material is translated or taken from multiple sources. Assessments depend on both the algorithms used and on the corpus of work available for comparison. On the other hand, they can do more than detect plagiarism as they are able to indicate all parts of a text that matches sources texts on the internet. This may also be used to learn, control, discuss, or study referencing.

Weber-Wulff further discusses the intention of the devices, the processes of detection, and the ways the systems have been used. She concludes that "Academic integrity is a social problem; due diligence cannot be left to unknown algorithms." Still, the comparisons show that the quality of the tools differs markedly; her conclusion is not to abandon the technology but use it differently.

While one area of plagiarism research and development still aims to improve plagiarism detection and invest pseudo-criminological interest in detecting more subtle kinds of plagiarism and obfuscation, many practitioners in this field move in another direction, using the software as a tool for learning about the practice of drawing on the work of others and appropriately acknowledging the source of that work.

Grammarly, for example, originally designed as an editing tool, also offers a plagiarism checker for writers with a much gentler assumption about the reasons of copying from other papers than the usual plagiarism definitions suggest:

> You're working on a paper and you've just written a line that seems kind of familiar. Did you read it somewhere while you were researching the topic? If you did, does that count as plagiarism? Now that you're looking at it, there are a couple of other lines that you know you borrowed from somewhere. You didn't bother with a citation at the time because you weren't planning to keep them. But now they're an important part of your paper. Is it still plagiarism if you're using less than a paragraph? (Grammarly).

Here, Grammarly points to inattentiveness or unintended errors as causes of plagiarism rather than as collusion or cheating, or intentional copying. Its intent is to offer its services to prevent plagiarism.

Other plagiarism detection tools are aimed at professional communities, particularly academics. iThenticate, for example, is a platform used by many journal editors and researchers to detect plagiarism and text replicated across articles by the same author(s) (see www.textrecycling.org). The database is populated by 93% of top-cited journal content and over 70 billion current and archived web pages. The tool is used both formatively by researchers (to ensure they have made no errors of citation or attribution) and as a tool to detect plagiarism or text recycling.

3 Functional Specifications

Plagiarism software contains several functionalities that interact to analyse text input:

- a field to insert text;
- a function to pre-process text that typically includes document format conversions and information extraction (Foltýnek et al., 2019);
- a corpus of texts used as a reference field for the text in question or access to a search engine (often including but not limited to Google);
- an algorithm comparing the indicated text with the ones from the corpus or the internet;

- a control panel indicating text similarity (alternatively, text originality) as a percentage or the number of matches with existing texts;
- a way of marking all text that is identical to any of the originals in the corpus, including references to the source and indicating the original text.

Plagiarism software may also contain features to detect obfuscations such as altering copied texts or filling in letters made invisible (by using white color) into the spaces between words. Plagiarism software such as Turnitin does not indicate "whether plagiarism has occurred as it does not identify whether a student has appropriately referenced, quoted, and/or paraphrased" (Silvey et al., 2016).

Algorithms for intertextuality software may work on different principles that may be combined but usually are not disclosed to their users. For a further explanation of how plagiarism detection software works, see Bailey (2016) and Eisa et al. (2015).

4 Main Products

The prototype for plagiarism software is Turnitin, simply because it has been the most successful at selling its products to institutions and is used in over 100 countries. Originally developed by iParadigms, an educational technology company founded by researchers at the University of California at Berkley, it was then sold to investors in 2014. Silvey et al. (2016) note that Turnitin is used by 90% of Australian universities in one or form or another, and Barrie (2008) claims that 95% of UK institutions use Turnitin. In the US, where plagiarism detection tools are controversial and have met with significant resistance among many writing-studies specialists, the number may be smaller. iParadigms also created an informational web site for plagiarism, www.plagiarism.org, which is sponsored by Turnitin and addresses students as well as faculty.

Turnitin.com has changed its web emphasis from plagiarism detection to support for student creativity and for upholding academic integrity. As of this writing, its services are currently split into five areas:

- *Originality:* This tool is a plagiarism detector indicating similarities of papers with web-based texts; it includes the teaching of referencing and may be offered to students for self-checks of plagiarism.
- *Gradescope:* This tool offers grading services in collaboration with teachers who indicate criteria for evaluation.
- *iThenticate:* As mentioned, this tool compares content against existing literature but focuses on published work and is therefore often used by academics and professionals. It supports the development of focus, the detection of similarities to other papers, manuscript development, and collaboration.
- *Similarity*: This tool is a pure plagiarism checker that shows similarities to existing papers, displays the original literature, and is sensitive to manipulations and attempts to hide plagiarism.

- *Revision assistant:* This tool offers feedback to students about intertextuality but also about various other issues (see Mayfield & Adamson, 2016).

Turnitin compares submissions with all internet material available and with all student papers ever submitted to Turnitin (so that students cannot "reuse" material from their peers' previously submitted papers). It cannot access internet materials stored behind paywalls and print-only materials but in some versions, it seems to have access to books issued by a large number of publishers. When it started, Turnitin relied mainly on a corpus of all submitted student papers; however, forcing students to submit their work for permanent "ownership" by a for-profit corporation met with considerable concern among some educators. Today, it maintains web crawlers to access all relevant internet materials.

The exact number of currently existing plagiarism detectors is unknown; many are somewhat more primitive versions of Turnitin or Grammarly. There are many local developments in various languages which are hard to access. Based on research into their effectiveness, Plagiat Portal classified 26 plagiarism detection tools into three categories: "partially useful systems" (Plagaware, Turnitin, etc.); "barely useful systems for education" (Plagiarism Finder, Docoloc, etc.), and "useless systems for education" (iPlagiarismCheck, Catch It First, etc.). A number of learning management systems, such as Moodle, allow for the addition of plagiarism detection tools into their platforms for easy access.

5 Research

It is beyond the scope of this chapter to refer to all the abundant research on plagiarism detection (see Bretag, 2016, for international perspectives). Foltýnek et al. (2020) offer an extended review of plagiarism literature that differentiates three levels:

Plagiarism detection methods refer to the automated identification of intertextual elements by varying algorithms.
Plagiarism detection systems refer to tools ready for use, including commercial offers such as Turnitin.
Plagiarism policies refer to research on "the prevention, detection, prosecution, and punishment of plagiarism at educational institutions" or to publications analysing the occurrence or forms of plagiarism and the institutional reactions to it.

For an understanding of plagiarism software, comparative research is essential. Comparisons can be done for different tools, for different types of plagiarism, and for uses in different languages. As developmental processes vary and some tools are continuously updated while others disappear and a third kind is newly launched, such comparisons are continuously necessary but their results don't last long. They help develop the field and the tools more than they produce cumulative results.

The most thorough comparison of available software has been carried out by a group of nine members of the European Network for Academic Integrity (Foltýnek et al., 2020) in which 15 text-matching systems were compared. A large number of languages from the Germanic, Romanic, and Slavic language families were included and a differentiated set of texts with varying kinds of plagiarisms (including obfuscation, translation, and paraphrasing) was used.

Many studies of plagiarism detection have focused on their pedagogical implications (Anson, 2011), the way they define plagiarism or students committing it (Canzonetta & Kannan, 2016), or the sources of resistance toward detection tools (Vie, 2013). Studies of student and faculty attitudes toward plagiarism detection software show mixed results; Atkinson and Yeoh (2008), for example, found some positive attitudes by both instructors and students toward the software, but just as many concerns, including (for students) worrying that too much emphasis could be placed on detection and not the quality of their writing, and (for instructors) the extra work involved in the process of detection and the process of pursuing academic misconduct—results found similarly by Savage (2004). Dahl (2007) found that postgraduate students looked upon Turnitin mostly favorably, but a few were less certain perhaps because of their concerns about their ability to cite sources correctly. In a study of instructors' attitudes toward plagiarism and Turnitin, Bruton and Childers (2016) found varying attitudes toward the software, as well as contradictions between instructors' sense that much plagiarism is a forgivable lack of skill and the strict policies on their syllabi.

It is not clear whether knowing that their papers will be submitted to a plagiarism detection system will deter students from plagiarizing. In one study (Youmans, 2011), half the students in two sections of a psychology course were informed that their papers would be submitted to Turnitin.com and half were not. However, the forewarned students did not plagiarize to a lesser extent than those who were not informed. To test the possibility that students did not know the effectiveness of Turnitin or how it works, a follow-up study reported in the same article controlled for this knowledge. However, students who were informed about Turnitin's mechanisms did not plagiarize to a lesser extent than those who were not informed. The author speculated that the challenges of source use may have overridden students' abilities to avoid unintentionally borrowing material they consulted.

Research on plagiarism detection software used instructionally rather than punitively has shown generally positive results. A comparative study of students receiving conventional anti-plagiarism instruction and others using the software as a learning tool resulted in significant reductions in plagiarism among the latter group (Stappenbelt & Rowles, 2009). Halgamuge (2017) found that formative uses of plagiarism detection software yielded "a substantial benefit in using Turnitin as an educational writing tool rather than a punitive tool." Rolfe (2011) found that both instructors and students had positive impressions after using plagiarism detection software formatively. And Davis and Carroll (2009) found that when used together with tutorial-like questions, Turnitin originality reports "appeared to have a positive effect on students' understanding of academic integrity reflected in improved drafts."

Analyses of the accuracy of plagiarism detection tools have revealed their limitations; Plagiats Portal (cited above) found that, using rigorous standards, the "best" systems were no more than 60–70% accurate. Perhaps the most extensive research on the accuracy of plagiarism detection tools is a series of studies by Weber-Wulff conducted between 2004 and 2013 and summarized in Weber-Wulff (2015), who concludes that although some systems "can identify some text parallels that could constitute plagiarism … the reports are often not easy to interpret correctly, software can flag correctly referenced material as non-original content, and there are cases in which systems report no problems at all for heavily plagiarized texts" (p. 625). A study by Purdy (2003) confirmed these findings. Mosgovoy et al. (2010) analyze the most promising detection systems and offer a roadmap for further developments.

6 Implications

It is not known fully what effect plagiarism detection tools have on novice or experts' composing processes. Typically, the software operates either on whole texts in draft form, which are submitted so that any questionable material can be appropriate revised or so that unattributed material can be appropriately cited; or on finished (submitted) text as a way to detect plagiarism and remediate or punish the writer. However, as mentioned, students' awareness that their writing may be submitted for plagiarism detection could create anxiety or lead to "safe" writing that does not rise to standards of complexity required of academic writers.

One possible application of plagiarism detection tools would require students to study the results of their paper's submission and then analyze any false positive or false negative matches and write a parallel paper or reflection explaining what should or should not be changed or what should be retained because of limitations in the software.

It is also not clear whether plagiarism detection tools result in stronger writing quality, since they focus only on text attribution—unless this is included as a feature in primary trait scoring of students' writing (see Howard, 2007). However, if instructors respond to students' drafts in progress after submitting them to a plagiarism detection system, and then offer advice based on the results, we might predict that the quality of writing will improve.

Further implications include ethical concerns that commercial interests such as Turnitin.com acquire some level of "ownership" of the work students are forced to submit as a course requirement. In addition, teacher-student relationships can be affected when students are suspected of possible plagiarism (by having their work screened) before they have done anything wrong.

7 List of Tools

Only current products previously rated as "partially useful" by Plagiat Portal are included:

Software	Description	URL
Turnitin	Plagiarism detection; proprietary; Web-based; can be incorporated into LMSs; text matching; includes other products such as assessment and feedback support	Turnitin.com
Plagaware	Plagiarism detection; freemium; Web-based; text matching; texts must be uploaded individually	http://plagaware.com
Plagscan	Plagiarism detection; proprietary; Web-based; text matching; three types of reports; includes source links	http://www.plagscan.com
Urkund	Plagiarism detection; freemium; Web-based; can be incorporated into some LMSs; text matching; "detects ghostwriting"; includes writing style analysis	http://www.urkund.com

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The Electronic Portfolio: Self-Regulation and Reflective Practice

Gerd Bräuer and Christine Ziegelbauer

Abstract This chapter focuses on the potential of ePortfolios as a tool for self-regulated learning and writing. What changes in the practice of academic writers when they include ePortfolios and reflective writing into their daily routines as students? Portfolios have been known for a long time as a complex modality in the construction of knowledge. Since the emergence of digital platforms (CMS/LMS) in education in the early 1990's portfolio work transferred into the digital space being used for multiple purposes and audiences. As a consequence, ePortfolios became both mode and medium for adjusting the author's intention toward the addressees' expectations. This chapter will provide an overview of different ePortfolio designs and tools that have the potential to relieve the mental stress created by the complex nature of writing and reflection. ePortfolio work will be shown as a construct being organized and designed around both the different phases of mental recognition and the rhetorical steps in putting reflection into language. The chapter closes with some recommendations how to start, maintain, and reflect upon ePortfolio work in teaching as well as in institutional development.

Keywords ePortfolio · Self-regulated learning · Reflective writing · Reflective practice · Institutional development

1 Overview

Portfolios have been known at least since the Renaissance as a mode of learning and reflection but also as a medium for presenting the outcomes of work processes. The Italian polymath Leonardo da Vinci (1452–1519) kept multimodal maps, journals

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_16

and logs that all followed one goal: to document and reflect through texts, pictures, numbers, and a variety of other symbols on his practices as an artist, engineer, scientist and architect in order to gain new insights from this interweaving of information for his further work and the optimization thereof. Da Vinci's artifacts and collections represent "both faces of reflection"—process and product of learning and writing—to quote Helen Barrett (2011), one of the early pioneers of the portfolio discourse that started in the 1980s in North America (Belanoff & Dickson, 1991). Most of the twentieth century portfolios were still paper-based and as such were often used for presentations in finances (e.g., stock market performance portfolios), the Arts (e.g., exhibition catalogues), and job applications (including CVs career development, and best practices).

Nevertheless, since the emergence of digital platforms (CMS/LMS) in education in the early 1990's portfolio work slowly but steadily transferred into the digital space being used for multiple purposes and audiences, e.g., a project portfolio in the professions turns into an application portfolio or becomes part of it in order to secure third-party funding for a follow-up project.

This medial transfer and functional adaptation emerged at first in English-speaking countries (e.g., Yancey & Weiser, 1997) and, about ten years later, in additional parts of the world (Baris & Tosun, 2011; Cambridge, 2012). Since then, national and international portfolio initiatives (e.g., EUROPORTFOLIO), and organizations (e.g., AAEEBL) evolved and private IT enterprises (e.g., PebblePad, Scorion, Foliotek) started to pick up upon a growing expectation in education and some professions with regard to strengthening reflective practice through electronic portfolios. In this article, we therefore want to examine what changed for reflective writers and their academic writing practice in the transition from paper-based to digital portfolios.

Probably the most significant change that happened for writers in this transition is the following: the two former basic functionalities of paper-based portfolio work—process-oriented in so-called learning portfolios and product-oriented in so-called presentation portfolios—can nowadays exist all in one digital place and be focused on individually in different pages.

Despite this change, the procedure of portfolio work remains the same due to the overall procedure of systematic reflective practice as developed by Donald Schön (1987). With whatever topic has been set for the portfolio, students:

a. collect the traces of their work;
b. select the most important artifacts from the collection with regard to their learning process;
c. combine and interweave the selected artifacts in order to tell the story of their learning and its outcomes;
d. shape and share/present these outcomes with both the audience and the final purpose of the portfolio in mind (Himpsl, 2008), e.g. through a reflective introduction.

Nevertheless, the approach in which artifacts are collected in a single digital space triggers profound changes in the procedures that reflective writers now use. Here are just a few of these procedural changes (Table 1).

Table 1 Procedural changes from paper-based to digital ePortfolios

Phase	Paper-based	Digital	Modal/medial change
Collect	Place outside the portfolio	Place in the portfolio	Text-based vs. photo, video, audio, hyperlinks
Select	Eliminate material	Shift material	Scissors/throw-away vs. cut/paste functions (to keep sorted-out materials someplace else)
Interweave	Arrange and glue	Drag/drop, interlink	Static vs. dynamic connections
Shape & share/ present	Create, one-time shot (draft)	Continue to work on existing drafts	One addressee—one portfolio vs. same portfolio with different "faces" for different readers

In addition, there exists a difference within the digital realm that seems to have an influence on the writers' performance strategies, namely between portfolio platforms (mostly CMS-based) and learning platforms (LMS-based): While learning platforms are structured around the fabric of a seminar or even depict the latter directly, portfolio management systems are in use to initiate learner communities where peers with similar goals in their portfolio work are connected with each other.

On a learning platform, the instructor sets up a "classroom" in which course participants follow a syllabus imprinted to the structure of the platform (e.g. through weekly tasks and discussion forums). In contrast, portfolio hubs offer a flexible personal learning environment that can also include tools on demand from a cloud. Here, it is always the creator/owner of the portfolio who makes the decision on how he/she wants to work, all within the restrictions and expectations of a specific portfolio task. Students, through their ePortfolios, connect with each other whenever needed in their own workflow and, as such, create a community of practice. With regard to writing, peer feedback in portfolio work often focuses on the quality of reflective writing in general and the focus on certain levels of reflection in specific. Feedback seems also important on the appropriate multimodal design of ePortfolios with regard to a specific audience.

In order to relieve the mental stress created by the complex nature of writing and reflection—no matter what format of portfolio is being aimed for—portfolio work will often be organized and designed around the different phases of mental recognition (Schön, 1987) and/or rhetorical steps in putting reflection into language and discourse (Bräuer, 2016). Schön (1987) speaks of "reflection-in-action" and "reflection-on-action", assuming the person will find the right words to differentiate between (a) what he/she is experiencing in the moment of action and (b) what this experience means to the person later on.

Considering the differences of mental quality between Schön's two phases of reflection, this may be a great challenge for many students' writing abilities. Already Hatton and Smith (1995) identify plain description in early-stage reflection, but discourse with one's self, including critical reflection later on. Not to mention that language practice, especially writing (e.g., in a diary and/or journal) can further enhance mental operations and trigger deeper insights (e.g., Nückles et al., 2020). If portfolio work is done on paper, students tend to focus much more quickly on the product since changes to the portfolio are difficult to integrate without damaging the existing draft. In contrast, the two phases of reflective practice by Schön (1987) can be used as a mode of scaffolding writing much more diverse in a digital setting of ePortfolios. Here are some possible writing tasks and digital tools to meet the different levels of reflection (Bräuer, 2016, p. 37) rhetorically:

"reflection-in-action"

- *Document* and *describe* what you experience in the moment of action (e.g., through cellphone videos posted to a video annotation platform).
- *Analyse* the circumstances of your action and *interpret* your feelings while you are being active (e.g., through comments written directly onto the video annotation platform).

While "reflection-in-action" is happening directly in the moment of action, this reflection needs to be carried out quickly and easily, with as little effort as possible, e.g., through video, photo, audio recordings, quick notes and/or voice messages to oneself, all done with hand-held devices.

"**reflection-on-action"**

- *Assess* your reflections so far in the context of your previous experiences with similar actions and in the light of evaluation guidelines on both quality and result(s) of action (e.g., by adding still photos to the portfolio and commenting on them with regard to what happened and how/why it happened with what results).
- *Conclude* from what you assessed and evaluated (e.g., in the light of institutional/professional criteria and standards) and *plan* accordingly for a more efficient action and high-quality outcome in the future.

Since not all students possess the appropriate linguistic resources for the above highlighted rhetorical patterns, additional (scaffolding) tasks, material (sample texts, text patterns) and feedback on early drafts should be offered to the students as a means of writing process facilitation.

2 Core Idea of the Technology

The technology of ePortfolios pushes the idea of networked thinking and learning. Through reflective tools as part of the ePortfolio platform or as an outlet in the cloud, both solo and network writing are possible at any time—if done asynchronously—and for any reason, e.g. developing and swapping ideas, collaborative drafting and formulating, and providing feedback.

Using ePortfolios to collect, shape and share artifacts as a proof of a certain activity necessary to fulfill a requirement or reach a certain qualitative standard can be done by combining digital *tools* toward a personal learning environment (Attwell, 2007) in two generally different ways of structure and setup: (a) maintained on a digital platform more or less streamlined for electronic portfolios—Ravet (2007) calls this approach ePortfolio management systems; or (b) through individual use of an application managing different share points with a cloud—Ravet (ibid.) calls this ePortfolio organizer. While these share points in (b) are defined by the individual user and therefore create a personally shaped learning environment, the digital platform (either as learning management system or ePortfolio platform) is provided more or less by the institution and therefore predefines a standardized learning environment that is only personal by the means of surface design (e.g., layout) but not the selection and/or combination of tools and tool functionality.

Software used for ePortfolios includes the following:

- **learning management systems** (e.g., ILIAS, OLAT, MOODLE): restricted functionalities of ePortfolios (e.g., for individual design, sharing, commenting). Here portfolios are mostly seen as the endpoint of a learning process that happened during interaction on the learning platform. The creation of individual portfolio pages and collections will follow as a second step. This architecture supports a task design where content learning in the course work is more or less separated from individual reflective practice mostly carried out at the end or after the end of the semester;
- **social networking systems** (e.g., ELGG): restricted functionalities of ePortfolios (e.g., for individual design and commenting). Here portfolios are mostly seen as the endpoint of a longer process in social interaction. Again, the portfolio will be created as a result of social interaction, but not integrated into social networking;
- **weblog publishing systems** (e.g., WORDPRESS): restricted functionalities of ePortfolios (e.g., for individual design, commenting, presenting). Here portfolios are seen as a continuous (chronological), journal-like string of posts where individual posts can be commented on but not overall presentations;
- **eJournal software** (e.g. EVERNOTE, ONENOTE): restricted functionalities of ePortfolios (e.g. for individual design, social interaction, presentation). Here, portfolios are seen as a long-term collection of individual note-taking, including little or no final design for presentation;
- **ePortfolio management software** (e.g., MAHARA, PEBBLEPAD, SAKAI): provides all functionalities of reflective practice including collecting, selecting, combining, designing/shaping, sharing/presenting artifacts as a proof of a required quality of action/competence.

The consequences for individual users in balancing the two faces of portfolio (process vs. product) are clearly visible: ePortfolio management systems are structured in a way that makes it easy for the institution (in education, business, etc.) to initiate a certain focus on either "process" or "product" and/or prescribe the transfer process from "process" to "product" whenever necessary. In this scenario, users will be guided how to interact with their portfolio. This does not exclude individual design and content work but the direct experience of ownership and self-directed learning may be limited. With regard to the tools being involved in the reflective practice, the owner of the portfolio can only use whatever tools are made available through the platform.

In contrast, ePortfolio work via a cloud solution brings much more direct ownership and independence, but also the danger of overestimating the power of either "process"- or "product"-focus for whatever the reason of the individual portfolio may be. In other words: the chance to fail as a learner seems larger by using the cloud-based ePortfolio, including the prospect of learning as a result of failure.

Interaction within larger communities of portfolio users is possible in both cases but more forced upon the individual participant in a platform-based environment. That approach can also force scaffolding through small tasks as a basis to reach in-depth reflection. Cloud-based users may also receive multi-step task arrangements from their facilitators but it is only on a platform where the processing of small-step tasks can be forced by a certain technological setup. The same is true for peer feedback, an important element of reflective practice when "reflection-in-action" should be pushed toward "reflection-on-action" (Schön, 1987). It could well be that users of cloud-based portfolios quit reflecting at an early stage of their work and, therefore, do not really go beyond documenting and reporting whatever they reflect on.

With regard to the audience, access to other people's ePortfolios is manageable by the creator/owner in both scenarios in similar ways. Nevertheless, in the cloud-based scenario, the audience can be defined more freely, including the danger of failing to choose the right people for feedback on the outcome of reflective practice. While the owners of ePortfolios in institutionalized platforms also could choose their feedback partner freely, they rarely involve people from outside the institutional set-up but most often prefer peers from their class. This creates the danger of unconsciously setting up mutual "feel-good feedback" that is often not very helpful for revision.

3 Main Products and Functional Specifications

In the following, two examples of common software solutions will be introduced and further discussed: (3.1.) Mahara as an example of platform-based technology and (3.2.) OneNote as an example of cloud-based applications.

3.1 Mahara

One of the most common ePortfolio platforms is Mahara, which started as a collaborative venture funded by New Zealand's Tertiary Education Commission's e-learning Collaborative Development Fund (eCDF) involving New Zealand Universities in 2006. The project is supported by Catalyst IT, which engages the lead developers and maintainers of the platform (Mahara, 2021). Until 2023 Mahara was an open source but still is a stand-alone system. However, Mahara can easily be connected to learning management systems like Moodle via LTI to support single sign-on. It is browser-based, so no extra application must be installed. In addition to the browser version, there is also an app for mobile devices, which supports quick recording of ideas and impressions with the help of data uploads, audio memos, photos and journal entries. These memos can be processed later in the ePortfolio. That being said, Mahara can not yet be used offline due to its overall browser-based technology.

Mahara is the leading ePortfolio system worldwide. It is used in schools, vocational training, universities and further education all over the world. There is also a large developer community working continuously with Catalyst to improve the system. Every half a year, Catalyst publishes a new version with new features to make sure that Mahara stays current. Because Mahara can be hosted by every institution itself (since 2023 license-based), there are no major problems with data security.

A main feature of Mahara is the focus on the learner. Therefore, it is the learner who is responsible for providing the content that is important to him or her. There are three functional areas in Mahara, which allows the learner to *create* content, to *share* content, and to *engage* with other community members.

3.1.1 Create

This is the learner's private area within the system. Here, the learner can collect all kinds of artifacts that he or she thinks are important for personal development. Quick notes can be taken in a journal. The artifacts can be arranged or rearranged on so-called pages to show and reflect the learning process. To support diversity and creativity Mahara offers a wide variety of different content types, which can be used to create content (e.g., text, image, external media, open badges, Google apps). There is no predefined layout. The learner can adjust the size of the content and place it anywhere on the page. If there are several pages with content relevant to the learning process, these can be combined into a so-called collection. Learners can also create to-do-lists with goals and tasks to manage their learning journey and be reminded by a system-built schedule.

3.1.2 Share

Because feedback is important to improve one's reflective writing skills, learners can share their ePortfolio within the Mahara system. Here, learners have full control over who they share their ePortfolio with and for how long. While sharing the ePortfolio the learner can continue working on it. The person who provides feedback can follow the learner's progression and adjust her or his feedback throughout the learning process. If the ePortfolio is being set up as required by the institution, it can also be submitted in the end. When the ePortfolio is submitted, the learner isn't able to do further editing. Accordingly, Mahara can be used for both formative and summative assessment.

Due to the many design possibilities, it is important not to be blinded by the visual appearance of a page during the feedback process, but to always read the content critically. On the other hand, the many possible multimodal design options provide a powerful learning opportunity with regard to reader-based layout. One restriction of Mahara, though, is that feedback can only be given in a comment field which is located at the bottom of every page. Commenting within the text is not possible and therefore persons providing the feedback need to be able to clearly describe and explain why and how they want the writer/owner of the portfolio to revise.

The sharing of the ePortfolio does not have to be limited to Mahara users. Creators/owners can also make their ePortfolio accessible to people outside the platform, for example by using a secret URL. This way, the ePortfolio can also be used for bridging the gap between education and profession, e.g., through portfolios as job applications.

3.1.3 Engage

Within the Mahara system users can engage in groups:

1. Learners can create their own tandems and teams for working together on specific topics. Here they can create pages and collections collaboratively and further discuss and develop them.
2. Classes can be organized by using the "Groups" function of Mahara. This way, the teacher can provide templates for reflective writing either through "best practice" portfolios or text patterns for certain levels of reflection.

Both methods can help the students to improve their reflective writing skills based on their individual skill level. A useful feature here is the "Plans" function, which was released with version 19.10. Here, the teacher can design and publish various tasks for different skills levels. This way, the student can choose the task that suits his or her level of skills. Each task can be provided with a deadline of completion which often helps students to monitor their progress. Furthermore, instructions and literature on reflective writing can also be provided within the group setting. Open questions or problems with reflective writing can be discussed in the group forum.

Reflecting on and developing one's learning process should be a lifelong commitment. Therefore, it is important that the ePortfolio, which was created during the study at the university, can still be accessed and continued after graduation. Mahara offers the possibility to export one's data in the formats HTML and LEAP2A. In order to continue working on the ePortfolio outside Mahara, it is necessary to import the LEAP2A file into another ePortfolio system (e.g., within the profession).

Based on classroom observations and coaching reflective writers in writing centers, the following research on Mahara ePortfolios can be provided with regard to task design and writers' motivation:

Small writing tasks focusing on individual aspects of reflection seem to help writers to come to grips with the complex task of reflective practice (Arimond, 2020). If those smaller reflective tasks will not just be prescribed isolated from each other but with strong interconnections, the quality of reflective writing can be bolstered even more (ibid.). If both single tasks and task arrangement lead to an experience of fulfilled learning, students will be intrinsically motivated to work on their portfolios for a long period of time, including portfolios that bridge several semesters or perhaps facilitate the entire course of study and even reach into the profession in form of application portfolios and portfolios of continuing education. In other words, writing for changing purposes and audiences can be highly motivating since the authors experience purposeful, authentic communication (Arimond et al., 2018).

3.2 *OneNote*

Even though the tool that will be focused on in the following paragraph is not an ePortfolio technology per se but a tool for note-taking, the emergence of OneNote in the portfolio practice of students is a striking example for the powerful influence of digital technology on the decision-making process of present learners. While institutions of higher education currently prefer ePortfolio platforms such as Mahara, stakeholders should, at the same time, haven an eye on their students' needs and choices when making decisions on the future direction in the development of personal learning environments, ePortfolios included.

In our experience, attention to OneNote by students in higher education has been growing steadily in recent years. Nevertheless, the so-called early adopters to IT solutions seem to have used it from early on and experimented with the different features often in connection with MS Teams. Some may ask themselves here what OneNote has to do with portfolios since it seems comparable in its features with Word or Google Docs. Would we want to suggest Word and Google Docs for portfolio work? Probably not, but on a closer inspection, OneNote is different and therefore has some specific potential for reflective practice as seen further below.

This cloud-based software, often also described as "digital journal" or after the existence of smart/ digital pens also as "scratchpad", appeared in 2003 as a MS Windows application included in MS Word (until 2019). Later on it was also available for macOS. Since 2020 OneNote can be installed through Office 365 as a stand-alone app for any portable device and can be connected as needed with Word, Excel, or Outlook. Sharing, feedback and any other forms of collaboration with individual peers or communities of practice may be best realized through MS TEAMS while the journal in parts or as a whole can now also be saved on a local hard drive and worked on off-line as needed. Therefore, it is now also possible for an instructor to download performance records once these documents have been submitted by the students. Nevertheless, this doesn't mean that the students will keep track of these submissions themselves and use this documentation for making visible the unfolding of their learning path. The nature of OneNote as a journal or scratchpad makes it easy to delete things done.

In another user scenario, OneNote may lure the student into ongoing changes of individual documents which, on the one hand, could encourage continuous learning but, on the other hand, over-emphasize the process over the product. Since there seems to be no rhetorical and practical use in a personal journal to integrate or merge individual pieces of work into a larger context, the ongoing fiddling with individual sketches may turn into repeating emty activity cycles and delaying (or preventing) new insights written down as text.

Since the use of OneNote as a cloud-based portfolio is fairly new, no research can be presented at this point. Nevertheless, a number of practice reports can be found instead, e.g., on interaction between product designers (Noessel, 2015). In this example, sketches will be collaboratively modified by copy/paste, or they can be scaled, shared and/or exported into more elaborate design programs as needed. This demonstrates the potential of OneNote for document-based collaboration, a quality that is not easy to reach at the same level with Mahara.

Another resource (Teaching Hub, 2021) shows a detailed feature comparison between OneNote and Mahara in order to make ePortfolio work more efficient for both students and instructors. OneNote provides less flexibility to design page templates, a feature that seems important for users to make the ePortfolio their own, to create ownership and meaning of their reflective practice. On the other hand, as already mentioned above through the integration of OneNote into MS Teams, individual documents can be used in synchronous meetings for both presentation and collaborative document editing (ibid.). For more detailed information on this system comparison a table (Excel) provided on Teaching Hub (ibid.) can be consulted.

4 Research and Practical Implications

ePortfolios seen as bundles of digital communication tools, either presented on a platform or individually selected in a cloud, seem to provide specific potential for students' multimodal writing and learning. As described in detail in various chapters of this book, changing digital tools while moving between single writing tasks and combining those tools while working on entire task arrangements enable writers in various competencies (skills) that are all necessary for producing texts and especially high-end portfolios. In addition, ePortfolio should also be seen as "a curated repository that is (…) mediated through interaction with instructors and peers" (Prokopetz, 2021, p. 25) where all actors in using ePortfolios negotiate the meaning of whatever topic they are working on. Due to the limited scope of this chapter, here is a list of references on most recent research topics with regard to reflective writing and portfolio in higher education:

- Improving independent learning (Madden, Collins, & Lander, 2019).
- Creating and maintaining independent learning spaces (Mihai et al., 2021).
- Monitoring different learning/workspaces and the moving between them (Prokopetz, 2021).
- Team-based transformational learning in shared online workspaces (Whitmore & Thacker, 2021).

- Collective knowledge building (Mihai et al., 2021).
- Motivation and higher order thinking (Chittum, 2018).
- Design thinking made visible and meaningful (Doren & Millington, 2019).

It must be said, though, that the insight provided by the studies mentioned above is less specific for enhancing academic writing and writers but more concerned with general consequences of portfolio work for teaching and learning in higher education. Nevertheless, the specific educational value of hypertextuality as a concrete means of multimodality (Kress, 2010) in the process of meaning-making on the writers' side and decoding and co-creating meaning on the reader's side becomes strikingly clear throughout many of these studies. In addition, whenever not only students but also instructors work on their portfolios and share those, there is a great opportunity to create strong communities of practice and vital knowledge communities across institutional hierarchies. Here, both students and instructors alike engage in shared digital composition and communication about their choices on digital modes and design based upon their audience' ability and expectations.

5 Conclusion

This final part will be used for some exemplary recommendations to start and maintain ePortfolio work and to reflect upon it in individual teaching as well as in institutional development (see also Yancey, 2019):

1. No matter what digital applications and tools will be used for creating and maintaining ePortfolios, they should trigger different modes of reflection and, as such, lead to a multiple perspective on whatever activity is being observed. This multiple perspective should be initiated by an adequate task design and supported by appropriate technological structures that stage existing tools toward diverse reflective strategies and the creation and strengthening of a community of practice. Teaching staff (faculty) often need additional training and support for the above mentioned design activities on both pedagogical and technological levels. Opportunities for the latter should be provided by the institution.
2. In order to secure continuous and high-quality participation by the students in the multiple steps of long-term ePortfolio work, multimodal feedback by peers and experts (KI tools included), is needed. This feedback and the consequences thereof should be included in the ePortfolio as a means of (self-) assessment and become the basis for final evaluation and acknowledgement by the institution. Criteria for feedback and assessment, sanctioned by the institution, need to be conveyed to teachers and students (White, 2005).
3. ePortfolios should not only provide artifacts for a currently performed practice but also demonstrate appropriate alternatives for future action. In addition, portfolios should also include proof of an already changing practice no matter what outcome this may have brought about. In order to be able to really demonstrate changing patterns of action, students need to be provided with enough time and

opportunities within the curriculum, technology and organizational aspects of the institutional framework.

4. Based on a close monitoring of ePortfolio work “in-action” and “on-action”, teaching staff (faculty) should gather evidence of the existing quality of task design, curriculum and technology. Ideally, this reflection should be carried out with help of a teaching portfolio and would eventually lead to insights with regard to necessary curricular, technological and institutional change. These opportunities for a “learning organization” (Peter Senge) should be coordinated by a steering group which has been assigned by the institution’s directorship. Such a steering group should also be in close contact to the students to further analyze and interpret their unique portfolio-based insights in learning and instruction.

6 Tools List

Tool	Description	References
Cloud-based portfolio (e.g., OneNote)	Portfolio management systems are in use to initiate learner communities where peers with similar goals in their portfolio work are connected with each other	https://www.microsoft.com/de-de/microsoft-365/onenote/digital-note-taking-app
CMS-based portfolio platforms (e.g., Mahara)	Portfolio management systems are in use to initiate learner communities where peers with similar goals in their portfolio work are connected with each other	https://mahara.org
Edubreak	Video annotation platform which can be used for blended learning arrangements: activities being video-taped, posted, peer-commented on and linked with theory and practice. Both process and results of this effort can be arranged and presented in digital portfolios	https://edubreak.de
Foliotek	Student and program assessment tool for monitoring student and faculty activity (competency-based assessment) and for program performance analysis with the longterm goal of accreditation management	https://www.foliotek.com
LMS-based platforms with portfolio feature (e.g., Ilias)	Learning platform is structured around the fabric of a seminar and parallel to that also provide a site for portfolios	https://www.ilias.de
Mahara	Started as a collaborative venture funded by New Zealand’s Tertiary Education Commission’s e-learning Collaborative Development Fund (eCDF) involving New Zealand Universities in 2006. The project is supported by Catalyst IT which engages the lead developers and maintainers of Mahara	https://mahara.org https://www.catalyst.net.nz

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Tool	Description	References
OneNote	Digital notebook allowing to collect and develop ideas, share these with others and collaborate further on	https://www.onenote.com
Pebble Pad	Student-centered learning portfolio focusing on individual learning design, the scaffolding of long-term learning journeys, and on authentic assessment	https://www.pebblepad.co.uk
Scorion	Focusing on programmatic assessment. With the Scorion E-Portfolio, students and supervisors can provide each other feedback within one app. Based on the data entered, the Scorion dashboard provides a precise picture of the progress and performance of a student at any time	https://scorion.de/scorion/

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Content Management System 3.0: Emerging Digital Writing Workspaces

Lance Cummings

Abstract In recent years, content creators and academics in online creator culture have re-imagined how we take notes using digital spaces like Roam Research, Notion, Obsidian, and Craft Docs. Though developers and users refer to these spaces as project or personal knowledge management systems, these digital spaces are a new kind of Content Management System (CMS), or wiki, at their core. These tools are no longer just about collecting and organizing information but cultivating new connections for ideation and content creation, both personally and collaboratively. This means downplaying or ridding these spaces of the folder interface and actively hyperlinking individual notes to be fluidly rearranged and connected in new ways. New CMS writing spaces like Roam Research, Notion, Obsidian, and Craft Docs have taken this strategy to a new level by incorporating more hypertext tools, like backlinks and knowledge graphs. This not only allows researchers and writers to cultivate new ideas but enhances content generation, helping researchers and writers renew the process of coming up with new ideas and manage the massive amount of information flow in the twenty-first century.

Keywords Content management systems · Knowledge management · Workspaces · Wikis · Project management

1 Introduction

Understanding the twenty-first-century digital workspace requires some knowledge of content management systems (CMS). As discussed in Heilmann "The Beginnings of Word Processing: A Historical Account", we have historically managed digital content through the structural metaphor of the office, like books, filing cabinets, and desks. In these environments, publishing clearly delineates the role of writing and publishing tools. Writers worked in their own space, like Microsoft Word, and publishers worked with a whole different set of tools, making both roles distinct. The

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_17

rise of online content creation and collaboration has made the two spaces increasingly similar, where content can be shared and used across multiple networks. For writers, this means that we no longer work alone but in a community. CMSs are now being collaboratively built as digital workspaces to accommodate more networked conceptions of text and content. Though built on the core idea of a wiki, these CMS platforms are quickly expanding beyond being simply a collaborative writing tool.

The rise of the wiki as a web application made content management a more accessible and collaborative process that emphasized the co-construction of digital content. Writers can all work together to create content and then publish it on the web. There is no need for an editor or a publisher, and content can be updated by any user. While the first wiki tools were designed to support the co-construction of knowledge, new CMS technologies have since focused on knowledge management and the connection of information and ideas.

Most of the research in wiki-technologies has focused on student and professional collaboration in online spaces, emphasizing the social aspects of knowledge creation. Wikis provide a more flexible space where writers can co-author and discuss the creation of content. For example, in a cross-campus study on student use of writing technologies, students mostly understood wikis as a classroom technology for writing papers (Moore et al., 2016). Though the power of wikis lies in the affordances for networked interactions, we often approach these spaces statically, using the traditional page as our working metaphor. But the core of this technology is networked thought. As a collaborative tool, wikis enable multiple authors to connect ideas in generative ways that create new knowledge. The new CMS platforms emerging on the market foreground this core idea.

This chapter will look at a range of CMS digital workspaces that are used to manage digital content. Though these workspaces have evolved from the more traditional wiki environment, the networked nature of these new platforms emphasizes the co-construction of knowledge in the ideation phase of writing, not just in the composing stage. Rhetorical theorists often call this phase invention—or the activity that generates ideas for writing or discourse (Atwill & Lauer, 2002; Lauer, 2003). While these CMS workspaces have grown beyond their original purpose, they remain a useful way of thinking about writing as the activity of making connections and generating new ideas both personally and collaboratively.

This chapter will also discuss how these new platforms are changing the way we manage content and how they change the role of digital workspaces in the writing process. By understanding this context, we can better understand the implications of its use in the twenty-first-century writer's workspace.

2 Overview

The invention of the internet continues to change the way we think about text, particularly as our systems for content management become more flexible and accessible to writers. Content Management Systems (CMS) are computer programs that allow creators to publish, edit, and change their own web content without code (Burgy, 2020). The history of the CMS really begins with the website, which is itself a content management space. At first, CMS products were static documents, like a book. Both content and code were closed source. But by early 2000s, several open-source CMS alternatives rose with Web 2.0 technologies, allowing users to both create and modify their own content and customize the CMS itself. WordPress is the most well-known CMS product and is still used today in the classroom and academia to easily manage websites, blogs, and portfolios.

Wikis are content management systems centered on collaboration and the organic development of knowledge, allowing users to create and modify web content through a simple interface. This CMS technology allows both readers and writers to change content without any special technical knowledge. Ward Cunningham developed the first wiki in 1994, calling it WikiWikiWeb, which is still accessible online (WikiWikiWeb). Using an Apple programming app called HyperCard, Cunningham designed composing spaces where users could create new links without looking through the page index to see if it already existed (Rothman, 2016). New pages could be more easily generated, edited, and connected. The welcome page describes this first content as the "informal history of programming ideas," but the community quickly evolved into its own culture and identity. Though we often think of Wikis' core feature as collaborative writing, wikis defining activity is the organic development of new ideas and content through connectivity.

Wikis are now common across many suites of tools, including Learning Management Systems (like Blackboard and Canvas). New project management systems like Microsoft Teams and Slack now allow users to enable wiki pages or install wiki add-ons. Three core features define Wikis and set the tone for new CMS platforms which expand on these affordances to leverage more networked and flexible workspaces, as discussed later in this chapter.

Collaborative writing. Users post ideas and content, which gets stored in this digital workspace. Then, other users can edit and add to this content, either collaboratively or independently.

Easy page generation. Wiki users can generate new pages from the pages they are composing, making the addition of content easy.

Revision history. All the changes and contributions are connected in some way. The wiki software also tracks the history of each page, so users can see who originally posted an idea and when it was modified. This helps users understand the context of each contribution.

In these ways, wikis are very different from the linear flow of Web 1.0 spaces. They are hypertextual, organic, and collaborative, focused on the development of new ideas and content. Wikis are very useful when you need to create or update large amounts of content in an organic way. The wiki software does not require an editor. Instead, multiple users can work on the same wiki page simultaneously and make changes to the content without overwriting each other's work.

Wiki technology's original purpose was to crowdsource knowledge. The most famous example is Wikipedia, which started in 2001. Wikipedia opens up knowledge production to the public, allowing writers and readers to easily add and review content. Now Wikipedia is one of the primary resources for initial research into any subject. Though the crowd-sourcing of knowledge has changed the way we think about content, this idea of a wiki has remained static for at least a decade. Professionals use wikis to develop a knowledge base for their business or create help sites for their technology. Writing teachers use wikis in the classroom to help students generate their own knowledge. Academics even use wikis to track the job market.

CMS technologies are moving through the same cycle Heilman notes within our chapter "The Beginnings of Word Processing: A Historical Account" (Heilmann). These new CMS workspaces started out as a fairly simple tool for productivity enthusiasts, but as the developers raise investment capital, the features become more sophisticated and the user base is growing, as are the use cases. Like word processors, wikis did not turn out to be all that revolutionary beyond the co-construction of text or pages, but more of a re-implementation of the known. Now these technologies are taking more of a revolutionary approach to text, intertextuality, and collaboration.

3 Core Idea of the Emerging CMS 3.0 Technology

Emerging CMS platforms like Roam, Craft, and Notion focus the digital workspace around *networktivity*, while also integrating flexible project management interfaces that encourage a more reflective approach to invention in the writing process, whether it is collaborative or not. Networked environments focus on the multi-directional and fluid relationships with the CMS ecosystem, rather than static unidirectional organization. Instead of just focusing on the development of content, emerging CMS workspaces create space for exploring new ideas through dynamic content, bidirectional links, and customizable interfaces. Much like index cards, they allow scholars and writers to maintain a fluid knowledge base that connects new ideas and generates content faster and deeper by simulating the associative and juxtaposing structures of the mind.

These new CMS spaces expand our ideas about text to what Ted Nelson called a Xanadu, or "docuverse" in 1982. This hyperspace is where all texts are interconnected, including all literature—high and low, formal and informal, scientific and cultural (Nelson, 1982). Vannevar Bush first dreamed up the Memex machine—a digital library like the human mind with "associative indexing… whereby any item may be caused at will to select immediately and automatically another… [so that] numerous items have been thus joined together to form a trail" (Bush, 1945). At an individual or group level, this means all our texts from grocery lists to journals to research notes exist in the same space, because you never know what new connection you might discover. Early wikis never really lived up to this idea, but emerging CMS platforms create new ways for writers to store information and generate ideas.

These new CMS spaces are not just a re-implementation of the wiki, but a more networked way of thinking about hypertext. The core idea of new CMS platforms is not about collaboration or even content generation, but the ability to connect ideas and rearrange them at any time. Unlike a traditional notebook, you don't have to stop and write down the idea; you can link it to other ideas and ideas that you have already noted. In this way, these new CMS spaces are not just about knowledge or collaboration, but about creating connections. Whereas the original wiki was designed to be a collaborative tool, these wikis are designed to be personal and highly fluid, with the potential for multiple authors to contribute to a single note. Instead of creating static and linear texts represented by pages, new CMS spaces focus on microcontent that can be manipulated in many ways during the invention process. The focus is on bits and pieces of information that can be composed in many ways, rather than the compositions themselves.

As argued by Rice (2007), hypertext changed our linear ideas of writing early on in the 1990s, but never situated itself within our conceptions of the composition process. Rice points out that hypertext opens up the writing process to a vast amount of "information, connections, and applications" that counteract the academic focus on curated and concise content. Though Rice uses hypertext to argue for non-digital modes of new media, he highlights an aspect of digital writing that has yet to be accounted for in the invention stage of academic writing where scholars manage notes and information for the generation of new ideas:

> For me, these definitions of how information comes together and breaks apart, of how information works with other information in order to transform, displace, or move along ideas, aptly describe the new media experience composing. (p. 307)

Johnson-Eilola and Selber's (1996) early research argues that hypertext can be either contractive or expansive. If we approach hypertext through print metaphors, hypertext will reinforce more conservative ideas of text, seeking to make information more accurate and accessible. Hypertext can also be seen as a form of thinking that involves constructing and deconstructing information. Traditional workspaces rely mostly on convergence helping us collect, index, and retrieve information quickly. But this convergence does not necessarily help us make new connections or create new ideas–just find old ones. Hypertext allows us to think in a new way. As we are writing, we constantly build new connections, which leads to new ways of thinking about information. In hypertext, you can create new connections by entering new ideas into existing networks.

Understanding writing as the act of combination and juxtaposition is key to understanding these new wikis. In his "Second Brain Manifesto," Forte (2020) argues for a mindset shift from scarcity to abundance in how we deal with information (also see Pitura, "Digital Note-Taking for Writing"). Ideas should be shared freely, easy to access, and readily connected. Managing information is not about collecting as much as possible, but about organizing and connecting ideas in innovative ways. Programs like Roam, Obsidian, and Notion are built on these new ways of understanding text and knowledge.

4 Functional Specifications

In new CMS spaces, the way to get an idea from one person to another is not through folders or file structures, but through connections. The act of making connections and moving ideas around in this way is the essence of writing. Writing is no longer a thing that happens inside a head, but is rather a process of combining and juxtaposing information or microcontent. These technologies highlight the *infomating* view of hypertext that foreground the breaking apart and coming together of information, rather than a more fundamental view that sees text as more static. For example, one of the most popular emerging CMSs, Roam, flattens the relationships between text, ideas, and other assets, allowing for easier connections by doing away with any sort of file hierarchy. Whereas most traditional wikis have a static index, Roam allows users to either create (and revise) indexes, use a graph instead, or dispense of the index altogether. These kinds of CMSs offer no "unqualified answers" and lots of choices encouraging users to play with their knowledge and information (Johnson-Eilola & Selber, 1996).

These technologies flatten the relationships between text, ideas, and other assets, allowing for easier connections. For example, pages are made of blocks or micro-content, instead of paragraphs or words, and usually file hierarchies are either down-played or non-existent in these spaces. These new digital spaces function more like our brains by giving context to our content. True networks and their contexts are constantly changing. If a CMS platform is going to perform like our brain, then it needs to shift and change as we play around with different combinations, associations and juxtapositions. Though each of these new digital workspaces look different and approach writing in their own ways, the linking functionality behind these tools are the core features that help writers and creators redefine the process of inventing new ideas in academic writing.

Though these new CMS workspaces can look vastly different, allowing for diverse use cases, there are four key specifications that make them an infomating tool.

Bi-directional links. These emerging CMS platforms are built on what is often called "bi-directional links" that allow for wiki pages to be linked both ways. In a traditional wiki, links go only one way. You can easily create a new page, but to return to previous pages, you either have to click the back button or return to a home menu or index, creating a unidirectional branch structure. You can link across these structures, but this must be done manually by cutting and pasting links. Bidirectional links allow authors to link across branches and categories. For example, I might want to link all my notes to a master note on "hypertext." In most of these platforms, you simply embed the word within two brackets (Figs. 1 and 2).

Content blocks. The second unique attribute to these new CMS workspaces is the use of blocks. Instead of using paragraphs as the basic unit of content, most of these digital spaces allow blocks to be any kind of content from a bullet, to-do, paragraph, image, table cell, etc. This allows writers to easily organize and re-organize content in different ways. Entire blocks can also be linked bidirectionally

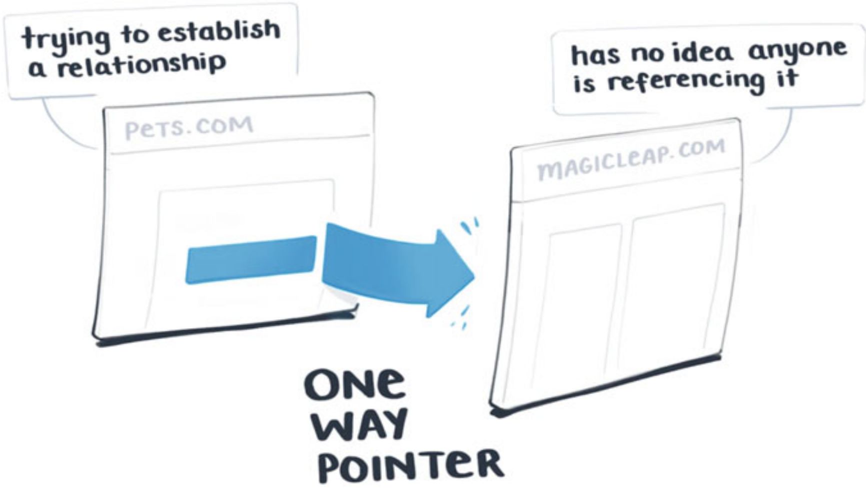

Fig. 1 Unidirectional links (Appleton, 2020a). Used with permission

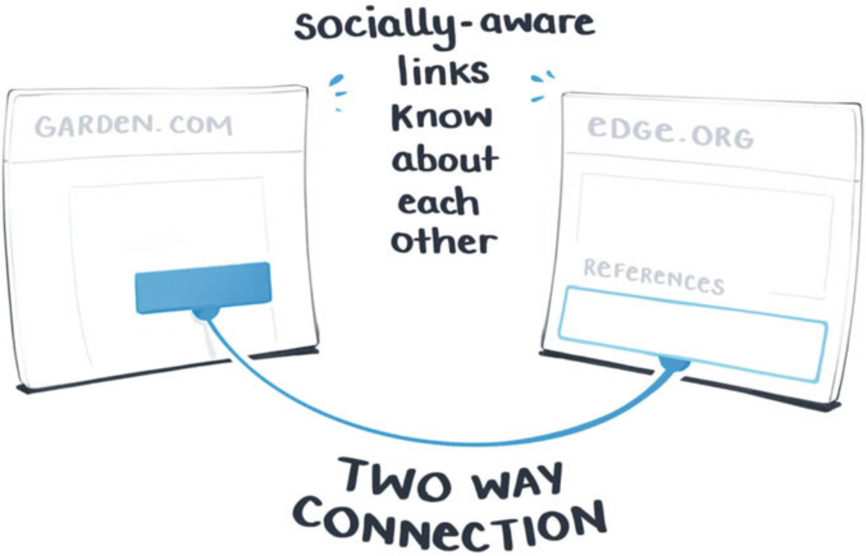

Fig. 2 Bidirectional links (Appleton, 2020b). Used with permission

(not just words). Microcontent can be reused in various ways, allowing for the reuse of smaller chunks, rather than simply reusing or copying an entire page.

Reuse. In addition to the enabling of new connections, these CMS workspaces allow writers to reuse other notes or text. For example, you can link an entire block of text into a new note without re-writing or copying and pasting.

Search. Though each of these platforms take a different approach to organization, all of them leverage more powerful searches, de-emphasizing hierarchical structures. Users are much more likely to search for the note or text that they want to work on, then dig through a folder hierarchy.

At the moment of writing this chapter, these tools are adding features at a rapid pace, defining themselves as they go. Though not core functionalities, the following four features are common throughout these technologies.

Knowledge visualization. Most emerging CMS workspaces have or are developing alternative ways to visualizing knowledge. The most popular is the knowledge graph that allows writers to see how key words and ideas are connected, much like a mind map.

Daily note. Daily notes are becoming a key feature which allows users to easily capture quick thoughts and notes, while also providing connections to specific days and events. For example, bi-directional linking allows you to see what other notes were written that day or what other notes relate to that day's key words.

Markdown. These technologies allow writers to use markdown, a stripped-down version of HTML. In general, this makes text version-proof and allows writers to focus on content rather than formatting.

Sharing and Publishing. Most of these digital workspaces provide several publishing and sharing options, allowing different authorship roles. Notes, texts, and ideas are meant to be shared. Anything in this workspace can be converted to a PDF, MS Word Doc, web page, or even a to-do item in a project management program.

5 Main Products

Though the wiki technology behind CMS platforms has not changed much since 2001, these new digital workspaces are exploding on the market, fueled mostly by content creators and productivity enthusiasts. They all have a slightly different focus and approach to organization, but the common thread is that they are flexible digital workspaces built around connectivity and knowledge management.

Perhaps the most revolutionary is Roam Research, which also looks the most like a traditional wiki. Since its creation in 2017, Roam has developed a user base exceeding 60,000 users and is growing daily (Bru, 2020). Conor White-Sullivan (2020), the co-founder of Roam, wanted to build a knowledge system that allows for both individual and collaborative thinking. Not only can you collaborate with others but also with your "past and future self." Roam will often bring up new associations with past notes that writers would not have remembered in any other way. For example, I may have written a note about hypertext two years. When I got to create another backlink to a new note about hypertext, the old note will pop up.

First launched in March 2019, Roam was the first space to leverage bi-directional linking and implement the daily note as the core workspace. Roam's specific approach does away with any default structure, focusing on a powerful search that can find pages or content blocks and a knowledge graph to organize information. Roam opens up with a daily note where users can capture anything, including text, images, links. Each page in Roam looks much like an outliner, where writers can post individual blocks of content that are bulleted on the blank page. When a writer wants to make a connection with a previous note or build a new note, they simply put double brackets around a word or phrase. For example, if I write down a thought or fact about wikis, I can create a new note for wikis that will be connected both ways.

Though you can add shortcuts to specific notes on the left-hand menu bar and switch to a table view of notes, Roam is meant to be organic, allowing users to search and link content while writing without using navigation. Most users simply search for notes they are working on or click a backlink when required to make a specific connection. Though many users use Roam research to "collaborate with themselves," these knowledge graphs can be shared collaboratively between users. When necessary, users customize their left-hand navigation window by self-selecting shortcuts to specific notes.

Though this initial view of Roam may seem overly simple, developers and users are creating plug-ins that add custom functionalities. For example, users developed a Readwise plugin that imports notes from various reading apps. Roam added the ability to create task boards and link individual blocks. Because apps like Roam Research are so customizable, use cases for these linking technologies are growing.

Notion is the CMS tool that is most distinct from Roam Research. First launched in March 2016, this CMS markets itself as an "all-in-one workspace," where users can take notes, draft, and manage projects with task lists and calendars. Notion has powerful tables that can be used to reorganize information easily into different views. Instead of dividing the digital office into different apps or spaces, Notion seeks to have all those apps in one functional space, but focuses on connectivity and customization to create flexibility for both users and collaborative groups.

Though these are the two main technologies in this field, several alternatives are moving into the market. Obsidian has many of the same features as Roam, but retains a file structure for organizing files into categories. Obsidian also focuses on keeping user data secure by housing all data on the user's own hard drive (rather than in the cloud). Craft Docs combines many of the features of other wikis, but focuses on providing more design choices and outward-facing uses. Microsoft is working on a product like Notion called Microsoft Loop, which has not been fully released at the time of this writing.

Though each of these CMS platforms rely on the same core functionalities, each focuses on its own niche, use cases. See the table below for some of these differences.

6 Research

Research in technical communication has focused on how technical and professional CMS platforms have made text more adaptable through small component management (Batova, 2018). These technical CMS platforms help corporations and software developers manage large amounts of content and documentation. In the technology sector, text is never static, but constantly evolving as software and technology changes. Working with blocks of content allows companies to reuse content and rearrange information for different contexts. These professional CMS platforms are not accessible to the everyday writer.

Emerging CMS platforms take this idea of text to the more general user by combining wiki technology with a small component mindset. For example, Lewis (2016) argues that CMS technologies shape user activity as a kind of a macroscopic genre that is typically invisible to users and writers. These new workspaces are CMS technologies that make these macroscopic genres more visible and allow users and writers to transform how these structures influence their writing and thinking.

Scholars are beginning to examine how new technologies shape writers' "workflow". Notably, Lockridge and Van Ittersum (2020) argue that "workflow thinking" is becoming a key feature in digital writing. Writers reflect on how ideas and information "flow" through various app stacks, sets of applications, so as to improve the quality and efficiency of their content generation, just like tech companies have had to re-think the publishing cycle of their user documentation. Very little in-depth research has been done on these new digital workspaces at this point, though scholars in writing have researched traditional wikis since their inception.

In the study of writing, researchers have mostly seen wikis as a technology that emphasizes networked and collaborative writing (Lundin, 2009). New media, like wikis, blur the roles of author and reader, default to collaborative writing, and are constantly changing–- or at least can be subject to change. In short, these spaces foreground the generation of text through networked interaction where the roles of reader and writer blur (Hunter, 2011). But how networked or innovative a wiki depends on the embedded use (Sura, 2015). For example, wikis have been used in L2 writing as a peer review tool, which retains important distinctions between writer and reader (Bradley, 2014; Elabdali & Arnold, 2020). In a political science course, students used wikis to mediate politically charged projects on weather (Carr et al., 2007). Many teachers even use Wikipedia to give students experience in collaboration and information literacy (Vetter et al., 2019).

Yet, most research on wikis has focused on their uses within the context of the writing classroom. Very little research has been done on the scholarly use of newer digital workspaces (Matysek & Tomaszczyk, 2020; Pyne & Stewart, 2022), though researchers have looked at how other kinds of applications play into the research and writing process (Given & Willson, 2018). Emerging CMS platforms are designed for authors to write, work, collaborate, and create new knowledge online. They also foreground how knowledge production is changing. Some of these features are designed around what are known as generative texts. These types of texts generate content through the relationships they form with other texts. They are built through networked interactions between users and writers (Moore et al., 2016). Although this may be true in many cases, most of the innovation in these spaces stems from the networked interactions between users and writers. Users can contribute new content, while the wiki software enforces peer review in real time. Most of the wikis emphasized this peer review process. What has changed is the emphasis is now on generating new knowledge through this networked environment (Lundin, 2009).

New CMS platforms that promote invention over collaboration, foregrounding the ideating phase of writing, making it more visible, but also requiring academic writers to be more mindful of how they are putting together content in new ways. These types of tools use features like tags, bidirectional links, content blocks, and powerful search options to create networked spaces for the creation of new content. These emerging workspaces create these generative text structures through different means, but the end result is the same. They generate content through the relationships they form with other text.

7 Implications

Though each version of this technology varies, the core features allow developers and users to create their own use cases. Also marketed as an all-on-one tool, writers can keep all their notes, writing, and project management in this one space. These platforms are highly versatile and writers can shape and mold these workspaces to different workflows and uses. In fact, they are now being called "no-code" applications, because users can build their own applications without code. For example, writers can create their own custom notes application using databases in Notion … or even design their own app or dashboard. This has implications in several important areas of writing.

7.1 Writing and Thinking

Emerging CMS platforms provide a new kind of thinking space for digital writing that can be networked, shaped, and transformed in different ways depending on contexts. Writers can generate new material through association, juxtaposition, and play simply by manipulating the workspace. For example, users can build their own indexes separate from any file hierarchy or visualize ideas in a graph. Because these are networked environments, writers can also shape the content and relationships they form with other writers and readers.

In these spaces, some aspects of our cognitive processes become visible through links and graphs. Because most of these digital workspaces allow users to shape and transform the space, cultivating these CMS workspaces becomes a form of thinking itself, often preceding the ideation phase of invention. As a result, our thinking can become much more visible by making it tangible. Instead of just thinking about our ideas, we can actually see the process of how our ideas came to be.

Writers can use this visibility of their own thinking to help them discover and explore new ideas, not just to confirm existing ones. For example, we might see a link from the keyword "time" to a concept like "crisis management." We then have an opportunity to play with that link in various ways. Perhaps we see a line of association going off in another direction: "Time Crisis = time management." From there, we might generate a whole new cluster of ideas. In the end, these kinds of CMSs can be extremely powerful tools for cultivating and accelerating both individual and group conceptual thinking.

Many writers now use the Zettelkasten method, or something like it, to collect more permanent notes that can be used to generate new connection and ideas over and over (Ahrens, 2022) (also see Pitura, "Digital Note-Taking for Writing"). For example, writers can bring up a topic or keyword and follow trails of connection on one screen or window and start piecing those notes together in a draft in another window or screen. Instead of just searching our minds in the invention phase, writers play around with items on the screen. These writing tools also offer more flexibility and choice in how we manage our writing projects. Instead of linear processes and milestones, we have more room for discovery and play during the research and writing process.

CMS platforms also support formulation at another level. When writers work in these spaces to network their thinking, they begin to see the process as organic. Formulation is not a goal; it is a byproduct of the process of discovery. As a result, these workspaces cultivate mindsets that affirm the best ideas and texts are not the ones that are fully formed but rather those that are most accessible to us as we move toward them.

7.2 *Collaborative Processes*

Networked writing environments also afford other kinds of writing workflows, especially when working collaboratively. One writer can take the lead and generate content, while another follows along and adds observations, comments, or questions. Writers can write in parallel, taking turns "pinging" each other with quick observations and questions. Writers can work together in series, drafting in real time as new content is generated. Writers can use these platforms to network the generation of content, not just the storage.

All emerging CMS platforms have collaborative capability. Notion specifically markets itself as team-based wiki, as well as a personal knowledge base. These wikis allow writers to share spaces, but also customize author settings depending on the use case. CMS tools not only help writers think together or develop a single document, but actually produce a system of content.

Though these wikis can be used much like Google docs, these spaces provide various degrees of access for feedback and co-authoring, including interactive comments and discussion spaces. Authors can tag each other in the text. Often, there are analytics that help collaborators see all the activity going on in the space.

New CMS workspaces can be used to help students develop more collaborative approaches to research and invention by allowing them to work together on a knowledge base, while also developing content in real time. Also, because these wikis can easily be shaped in customized ways and shared, they make a great portfolio or knowledge base. Teachers have also used these spaces to organize course material.

7.3 Conclusion and Recommendations

Emerging CMS workspaces expand and deepen the invention process, allowing writers to not only make new connections and generate material, but also helping them reflect on their invention process. Writers can cultivate these CMS for specific research writing tasks, and the visibility of the thinking process can give researchers more opportunity to observe how writers come up with ideas.

These platforms are great for complicating students' idea of the writing process, helping them explore what it truly means to research and develop content, either as individuals or classes. Too often students think of research as a simple seek and find. Online writers are even known to show their thinking process. These platforms can provide rich data for students to explore how writers come up with ideas. Students can also create dynamic portfolios or publish course content.

At this point, these tools are too new to have any significant research. Though they have made their way into the classroom, scholars could research how they are being used. Further research can also be done on the connection between creator culture, the writing process, and how that can change the way we think about writing in academia.

This is a growing market that is diversifying at a fast rate. Though new features are certainly on the horizon, the core functionalities and how they re-work our conception of text are what will fuel those new features.

Tool	Description	Reference links
Craft Docs	Craft Docs is a simple CMS intended to help with quick, organized note-taking in a variety of formats and uses. Functions include convenient links between notes, fast pasting of formatted text, and easy sharing. Free with premium options	https://www.craft.do/
Notion	Notion is a modern project management tool that includes files, tasks, calendars, and advanced databases. Users can link different calendars to each other, create advanced dashboards, and collaborate with other coworkers. Free with premium options	http://notion.so
Obsidian	Obsidian is a secure and private CMS that focuses on note-taking and drafting. Data is not stored on a remote server, and includes links between notes as well as sophisticated folder organization. Free with premium options	http://obsidian.md

(continued)

(continued)

Tool	Description	Reference links
Roam	Roam focuses on personal knowledge and task management, allowing for advanced bidirectional links, customizable plug-ins, and multiple users. Pay-for-service	http://roamresearch.com

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Writing Analytics and Language Technologies

Automated Text Generation and Summarization for Academic Writing

Fernando Benites, Alice Delorme Benites, and Chris M. Anson

Abstract In this chapter, we discuss the implications of automatic text generation for academic writing. We first review the current state of the technology and how it is being used. We then discuss the implications of using automatic text generators for academic writing, including the need for users to be aware of the limitations of the technology and how to use it effectively. We also discuss how the use of automatic text generation can change the traditional stages of writing, and how the content generated by these systems is not justified by semantic or extra-linguistic criteria. We finally argue that notions that have been useful for explaining, analyzing, and teaching academic writing will need to be re-examined in the light of human–machine-interaction. (This abstract has been automatically generated using OpenAI and slightly post-edited; see this article's Appendix for an explanation.)

Keywords Natural language generation · Machine learning · Human–machine interaction · Academic writing · Text production · Language modeling

1 Introduction

In the twenty-first century, academic writing mostly takes place with a minimal setup of at least a computer, a text processor, and an internet connection. In this context, computers are often used to relieve human writers of specific tasks like correcting spelling mistakes, providing the results of library or internet searches, and

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_18

organizing scientific references into standardized quotations. Yet the author, who actually performs the task of choosing the words and the order they will be presented in, is still human. Or is it? Automated text generation has undergone significant advances in the last few years and is likely to redefine human–machine writing interaction in the near future.

Procedural text generation is actually not a new concept: in the seventeenth century, the German poet Georg Philipp Harsdörffer had the idea of designing a *volvelle*—a contraption of several circles whose combination produced words and sentences according to their respective position (http://whitneyannetrettien.com/thesis/). Centuries later, in the era of computers, natural language generation (NLG) long relied on the same principles: combining words, very much like building blocks, using a set of rules in order to produce a text. For decades, automated systems have used templates, so that for each text to be produced, only some slots must be filled. These templates were very specific, as they gathered formulations designed for each language, for each domain, for each document type, and so on. As a result, maintaining such templates and keeping them up to date was a laborious and tedious task, and they performed better with highly standardized texts. This is why these text generation systems were employed mostly in domains such as weather reports (e.g. the *Pollen Forecast for Scotland* system [Turner et al., 2006]), sports news, and financial reports. The idea was to turn structured data, which was stored in databases, into text, hence automating the additional tedious work of organizing the data into a coherent text. The main goal of these NLG systems was to produce intelligible and relevant information only, regardless of the style or the repetitiveness of such texts. To that extent, such an approach might not seem compatible with the production of academic texts: academic writing is bound to language-specific and domain-specific conventions, but it also requires a certain amount of fluency and readability in order to engage readers. It works from the structure of the text up to the idiomaticity and how to express certain relations. Most importantly, the text should be written in a way to keep the reader interested and guide them through a discovery, or it should point attention towards key information. Even more, the ongoing competition for publication and acceptance of conference or even journal articles makes it unavoidable to consider questions such as style, rhetorical decisions, and even repetition (and its forbidden form, plagiarism—see Anson, 2022). This concern, and more generally the overall urge for intrinsic novelty in every academic publication, should discourage academic writers from using the aforementioned systems to produce their papers; however, it could be argued that such systems might act as "writing assistants" for more fluent, extended, and original text.

1.1 Core Idea of the Technology

To understand current developments in automatic text generational and natural language processing, it is helpful to trace their history in AI research. In the early 1980s, AI experimentation was partly designed to explore human language processing to inform computer-based processing. Work at Yale Artificial Intelligence Labs, particularly by Roger Schank and colleagues (see Schank & Abelson, 1977), succeeded in generating texts that appeared to be written by humans, with a level of acceptable structure, coherence and cohesion, and lexical accuracy. One program, "Talespin," was designed to create stereotypical "Aesop"-like stories with anthropomorphized characters and simple plots (Meehan, 1976, 1977). However, the errors generated in the automated story production process yielded insights into what information a computer needs to work effectively with natural language. In particular, the lack of sufficient world knowledge created significant problems, especially concerning plans, actions, preconditions, and logical outcomes. For example, early in the development of TaleSpin, the program produced stories such as the following:

> Joe bear was hungry. He asked Irving Bird where some honey was. Irving Bird refused to tell him, so Joe offered to bring him a worm if he'd tell him where some honey was. Irving agreed. But Joe didn't know where any worms were, so he asked Irving, who refused to say. So Joe offered to bring him a worm if he'd tell him where a worm was. Irving agreed, but Joe didn't know where any worms were, so he asked Irving, who refused to say. So Joe offered to bring him a worm if he'd tell him where a worm was …. (Meehan, 1977, p. 91)

Meehan explains the source of the problem: "Don't put a goal on the stack if it's already there. Try something else. If there isn't anything else, you can't achieve that goal."

The programming for these tales takes a traditional form of rule-codes called planboxes, linguistically instantiated, that include details about plans, goals, actions, what a character knows, etc., as illustrated in the following:

Planbox 1: X tries to move Y to Z

preconditions:

X is self-movable
If X is different from Y,
then DPROX (X, X, Y)
and DO-GRASP (X, Y)
DKNOW (X, where is Z?)
DKNOW (X, where is X?)
DLINK (X, loc (z))

act: DO-PTRANS (x, y, loc (z))
postcondition:

Is Y really at Z? (DKNOW could have goofed)

postact: If X is different from Y, then DO-NEG-GRASP (X, Y)

Through multiple trials and errors, these rule codes can be refined, each iteration showing what else is required for the production of even simple tales with logical plots.

Another important requirement for natural language production and interpretation involves the role of inferencing. Consider these pairs of sentences:

Paula's dog slipped its collar on a busy street. The veterinary bills were obscene.
René drank a fifth of vodka at the party. The morning was unpleasant.

To either interpret or produce these texts, a program first needs the semantic knowledge to understand the word "slip" in the context of a dog getting out of its collar (as opposed to "slip on the ice"). It then needs to infer that when a dog slips its collar, it can run from its owner and is likely to be injured in traffic on a busy street, and that such an injury will require the intervention of a veterinarian who bills the dog's owner. It also has to know that "obscene" can be used to describe not only something pornographic or grotesque but outrageous in a general and negative sense, and it must know that very high bills are unpleasant to most people. In the second pair, the program needs to know that a "fifth" is a liquor bottle size, and that drinking a fifth of vodka typically causes a highly displeasing physical reaction the next day. In both cases, this knowledge is not propositional in the statements but resides in world knowledge activated between the sentence pairs: it is *implied* in production and *inferred* in reception.

Schank and colleagues proposed categories of world knowledge required to understand and generate text. These included scripts (typical sets of actions, such as those that entail at a fast-food restaurant vs. an expensive fancy restaurant), props (such as menu boards vs. printed menus in leather folders), roles (such as order and cashier personnel vs. a maitre d', a head waiter, a bread waiter, and a sommelier), plans, and goals. By themselves, roles such as waiter, maid, carpenter, banker, etc., activate many assumptions that do not need to be stated in language but are inferred. Consider the following sentence:

The police officer held up her hand and stopped the car.

Any program working with natural language needs to know that the police officer has role-authority to cause driver to use the brakes to stop the car, not that she physically stopped it herself.

Schank and Abelson (1977) detail the kind of programming required to yield natural-language outputs that make sense. But the extent of knowledge required to generate or interpret text was, at the time, almost insurmountable for humans to program into a computer system. Consequently, this approach to NLG was replaced following the advent of artificial neural networks and modern natural language processing. Algorithms are now learning from textual data at a breathtaking pace, especially since the amounts of data being available on the Internet are increasing as quickly as the processing capacities of computers. Machine learning methods allow computers to observe the data and infer their own rules from it and, in essence, imitate what they have observed so far. In particular, self-supervised deep learning methods can not only extract word frequencies from large amounts of text, but also construct word correlations that allow the creation of very fluent texts. This technology is already widely developing for translation, and neural machine translation solutions like Google Translate or DeepL are now freely available to all Internet users, offering fluent, idiomatic, and often accurate translations. The quick rise of such machine translation engines that are now omnipresent on websites, social media, and handheld devices hints at a similar explosion of automated text generation solutions in the near future, especially because the underlying technology of machine translation is text generation. But just as the use of machine translation entails pitfalls and requires a specific set of skills and knowledge to avoid them, using automated text generators for academic writing purposes will require a basic understanding of their affordances and a heightened awareness of their risks and potential (see Anson & Straume, 2022). Therefore, a closer look into these machine learning approaches is justified.

Automatizing and standardizing writing processes is not new in academic writing. Numerous phrasebooks and collections of stereotypical formulations, templates, and writing guides have been published over the years in an attempt to speed up the writing process. Such ready-made formulaic blocs can seldom help with other writing issues, such as overcoming writing block or anxiety, citing related works more rapidly (e.g., turning citations into readable text), rephrasing and paraphrasing, and summarizing findings. These are areas of interest to AI-based programmers and AI-application users. In fact, several attempts have been made to create an algorithm that can write a scientific abstract or even a full paper on its own; one such paper was even submitted for publication (Thunström & Steingrimsson, 2022).[1]

Besides the creation of new content, academic writing also encompasses a variety of summarizing tasks: writing a literature review, for example, can be considered a multi-source text summarization activity. It is also quite usual to summarize one's own text in a short abstract that will help potential readers to decide whether a paper's content is relevant for their research or not. This type of single-source text summarization is particularly current in the academic context. Automatizing such tasks could prove useful, especially since summarization is less bound to novelty and originality than academic text production in general. Yet automatic text summarization presents other challenges: summing up facts, abstracting, and generalizing might require general, contextual information that the system does not possess. In the worst case, this could lead to the system stating new and inaccurate facts. Further, deciding which elements of a text are to be mentioned in a summary and which ones can be left out usually relies on our human understanding of the text's content, and could pose a problem for an automatic system.[2] To that extent, while summarization is an inherent part of academic writing, automatic text generation and automatic text summarization are usually considered two distinct yet related fields. Both are rather large fields, which is why we will provide only a brief overview in this chapter. There is, of course, already abundant research focusing on various related fields (such as

[1] https://www.scientificamerican.com/article/we-asked-gpt-3-to-write-an-academic-paper-about-itself-mdash-then-we-tried-to-get-it-published/, accessed 19.08.2022, remark: since the references are wrong it probably won't pass the first review. However, we recommend the reading of the paper, since it shows how a fluent text can hide such mistakes.

[2] When "supervised," of course, such systems can still benefit writers who spend a fraction of the time it would take to write an abstract simply ensuring that the output of the system is accurate.

chatbots, machine translation, question and answer generation, and next word prediction); for extended surveys and reviews, see Yu et al. (2022), Celikyilmaz et al. (2020), and El-Kassas et al. (2021).

2 Functional Specifications

2.1 Rule-Based Systems vs. Neural/Statistical Methods

A very early version of a text generation system can be seen in chatbots such as ELIZA, which was developed in the 1960s. Many generations since then, the systems employ different methods that can be divided into rule-based or neural/statistical-based. The rule-based methods are triggered by words found in a given sentence: they replace a variable (missing word) in the template with a value according to the context and return this filled template. Neural/statistical methods work differently: they learn correlations between words so that they can either find the right context (intent classification) or predict the words that should more likely come next. When using intent classification, they can find the right values to fill predefined templates or even generate a response directly. Statistical methods usually work with a set of rules extracted from a learning corpus, whereas neural methods rely on neural networks architectures, also trained on selected corpora. Neural networks generalize better to unseen input data, but they can also derail and create nonsensical content (Fyfe, 2022). They are the current state of the art, which is why a closer look at their inner workings will help to explain the stakes of automatic text generation.

2.2 Neural Networks

Artificial neural networks (ANNs) are inspired by biological neurons (McCulloch & Pitts, 1943). In that regard, they build an abstract representation of these: the signal from one neuron to another neuron can either be intensified or repressed. A popular base building block (neuron) of ANNs is the Perceptron (Rosenblatt, 1957), which sums the input signals and decides they should be repressed or passed through. Moreover, the connections between the neurons create a network; consequently, it is only with enough input strength of the connected neurons that a given neuron is activated and passes the input signal through. In that sense, each neuron acts as a gatekeeper. Each connection is also referred to as a parameter in ANNs (there are, in fact, generally two parameters for each connection, a weight and a bias). Each parameter is usually set to a random number and needs to be adjusted through training. By presenting examples with input values and output values, a neuron based on the input can produce an output; the difference between true and produced output (error/cost function) is used to adjust the parameter values and therefore learn. However, a neuron alone cannot differentiate complex problems, given the logic rule with two input parameters (Minsky & Papert, 1969). For example, let us imagine the following set of parameters:

a: = I am eating
b: = I am talking
c: = I am polite

Within the context of a formal dinner I am invited to, if both parameters a and b are true (I am eating, and I am talking), then parameter c is false, since it is usually considered not very polite to speak with a full mouth. On the other hand, one could usually expect that guests engage in conversations and that they at least try the food that is served to them. As a result, not eating and not talking (i.e., a and b being both false) will also make me impolite, and variable c would be false again. If I either eat or talk (a or b being true), then I am polite and c is true. A single neuron cannot solve problems like this, also called a non-linear separable problem.

In order to solve such problems, neural networks have to use multiple neurons, usually structured in layers (multilayer Perceptron). The more layers, the more complex the problems that can be solved. In general, there is no rule determining how many layers a problem of certain complexity needs. However, the more layers a network has, the more calculations it needs to adjust each parameter. Therefore, very large networks are expensive in terms of time, computing power, money, and ultimately their carbon footprint. Nevertheless, there are techniques to train large networks with fewer resources. One of them is to have the system not learn all samples at once, but in batches, where each batch encompasses a certain number of examples. A hyperparameter called the learning rate adjusts how much the new batch influences the network's parameters in order to accommodate the new examples, but also how many of the examples of the previous batches can be discarded (and thus partially forgotten by the network). It is very difficult to estimate how big a network needs to be and how to train such large networks so that they keep everything correct. The problem is aggravated when the data are not perfect, which is almost always the case. As humans tend to disagree quite quickly on many issues, large amounts of texts will yield contradictory claims about their quality or relevance. It is not clear how such varying claims are processed by the neural networks, since they cause a paradox for the learning algorithms.

Moreover, text cannot be processed in its raw state by neural networks; it first needs to be transformed into numerical values. Numbering all the words creates a huge amount of data (the English language is estimated to have between 400,000 and 600,000 words). This results in an enormous range of randomly assigned numbers without semantic or logical organization or connection between them. Neural networks cannot handle input data well in this form. The solution is to use so-called word-embeddings (Mikolov et al., 2013), in which the networks are trained to predict a word given the context it appeared in. Therefore, the network will learn which words are similar to each other and occur in the same context.

A common representation of word-embeddings resembles a basic algebra of words, or word analogies, with vectors; for example, the symbol $_v$ stands for a vector word-embedding representation of the word:

$$\text{Yen}_\text{v} - \text{Japan}_\text{v} + \text{U.S.}_\text{v} \approx \text{Dollar}_\text{v}$$

This representation allows us to understand how semantic relations between words are handled within the networks. By making the networks bigger (with more and deeper layers) and using a similar learning routine (predicting masked words), developers can allow the networks to effectively learn a given language, creating so-called language models.

However, this approach also has its limits: it does not fare well with context-dependent words such as the homonym *bank* (financial institution? park bank? river bank?). Newer approaches using recurrent neural networks (Hochreiter & Schmidhuber, 1997) take the order of the word in the input texts into account, but still cannot solve the issue completely. Thus, the sequential approach often leads to signal losses, especially for long sequences. In terms of text writing, this would, for example, lead to coreference and negation problems. This is why a progressive shift started in 2017, when such issues were overcome with the advent of so-called transformers, the current state of the art.

2.3 Transformers

A transformer is a neural network architecture introduced by Vaswani et al. (2017) and is composed of different neural networks, called an encoder and a decoder.[3] An input text is transformed into a prediction, in other words, an output text. More specifically, the input text is first encoded into a representation (in a so-called latent space), which is more independent of the source language and then can be decoded into the target language. Further, transformers use a method called attention, more specifically self-attention, which tries to put words into the overall context of the input text. A further aspect is that the original input signal is propagated throughout the neural network.[4] Therefore, the network is able to learn which word fits which context more quickly than other architectures, e.g. multilayer Perceptron, although transformers and other architectures rely on similar base building blocks.

Devlin et al. (2018) presented a method to train transformer architectures (Vaswani et al., 2017) so that the machine learning model would predict words within a partially incomplete sentence (usually 15% of the words are masked or removed) by using only the encoder side of a transformer. The model used a 3.3-billion-word corpus and went multiple times over this mass of textual data, and was able to perceive which words often occur in which context. This method, known as BERT, is very popular, especially for text summarization.

[3] When applied to text, such encoder-decoder architectures are also called sequence to sequence architectures.

[4] This is also called *skip connections.*

Contrary to BERT, another development, GPT**,** uses a decoding side of a transformer. This can be applied to next-word generation, where the words are "uncovered" from left to right, and the system guesses which word will best fit given the whole context provided on the left. Using this technique, the model can predict words and generate text. GPT's successor, GPT-3, massively increased the amount of processing data and the number of parameters to be adjusted by the model. This increase in training translates into a greater generalization of the model. The advent of GPT-3 also brought prompting, a new machine learning method that quickly gained popularity. Usually, learning and defining a new task—unknown to the machine—constitute a separate part of the machine learning process associated with great costs and large numbers of samples. GPT-3 allows this step to be performed with much lower resources and outside the actual machine learning process. This is why GPT (in versions GPT-3.5 and GPT-4) and its public-facing ChatGPT is currently one of the most popular models for text generation.

For summarization and translation, the transformer architecture here thus reads the text and transforms it into another text. However, the length of a single input text in Chat-GPT is somewhat limited to, around 3000 words (except for the GPT proprietary system, whose GPT-4 currently allows around 7,000 words but a model allowing 25,000 words is already announced). Larger models and models based on other techniques are being developed (see Beltagy et al., 2020; Zaheer et al., 2020), but it could take some time until their release for production, especially because the evaluation of large amounts of texts is very complex and requires high computing resources.

2.4 Evaluation

Whenever artificial intelligence is used to perform a task, the question of quality evaluation and metrics arises. There is an evident need for objective, measurable, and comparable evaluation scores to assess how well a given system performs. Manual evaluation is surely valuable but expensive; neural networks systems usually have many settings used for creating a model and assessing if it learned enough, so that at the end hundreds of model states need to be compared. Estimating the quality of the systems, and choosing the best among them, is preferably performed without human intervention. For that purpose, there exists a range of automatic evaluation metrics (AEMs). They are different from a key component in machine learning: loss or error/cost function, which allows the machine to learn what is correct and incorrect, and thus change the parameter values of the model accordingly. This is usually calculated based on a human-produced reference text collection. AEMs evaluate the quality not for single samples (texts) but at corpus level; thus, they can measure further aspects, such as the recurring types of errors, or which words are more often wrong.

For text generation, evaluation is carried out by removing parts of the reference sentences and having the system complete those sentences. A comparison between the system's suggestions and the original reference sentences will provide an evaluation score. For summarization, the system's output is compared with a human-produced summary of the same input text. There are usually several rounds of evaluation (called iterations), and each iteration can use a different reference text, which allows taking into account the diversity of human writing styles. A major issue regarding the choice of adequate reference texts for evaluation ultimately relies on subjective criteria, given that human text evaluation has long been subject to discussion and debate.

2.4.1 Perplexity

One popular way to estimate the quality of the language model underlying a text generation system is the called perplexity (Jelinek et al., 1977). This metric tells us if a model generates text very close to the training data, i.e., if it catches the essence of the language by identifying which words are more likely to follow which words. When a text is generated, if its perplexity is low, it will correlate with scores of fluency, i.e., human evaluators would consider the text fluent. This allows an estimation of quality without having to manually annotate an extra reference corpus. In contrast, other sets of measures rely on manually created and annotated source and target sets of texts. Such measures can help to assess more precisely word accuracy, for example, and will be presented in the following section.

2.4.2 BLEU, ROUGE, METEOR

Bleu, Rouge, and Meteor are the most popular metrics for summarization, although originally designed (and still extensively used) for machine translation evaluation. They measure the number of words and word sequences (n-grams) that are shared by the text produced by the machine and a reference text. As such, they can measure different types of overlap (ROUGE: Recall-Oriented Understudy for Gisting Evaluation—see Lin, 2004—and even take the text length (BLEU: BiLingual Evaluation Understudy—see Papineni et al., 2002) and word order (METEOR: Metric for Evaluation of Translation with Explicit ORdering,—see Banerjee & Lavie, 2005) into account.

Since the essence of translation is to produce a text equivalent to a source text, at least for simple and less creative translation tasks, the constraints given by the source text usually restrict the field of possibilities for formulations. In that regard, machine translation is a rather guided and homomorphic process (i.e., where the structure of the data is preserved), and it makes sense to evaluate the system by looking for matching text sequences between multiple human translations and the system's output. Nevertheless, these metrics do not evaluate whether the meaning of a text is correctly conveyed—they merely check if the right words have been used, sometimes not even considering if they are in the correct order.

This issue is even more problematic when these metrics are used to evaluate summarization systems. Summaries often imply a targeted rephrasing and restructuring of a text's contents, usually writing *in other words*, for example by using more hypernyms to replace several terms at once. In that sense, text summarization inherently contains a change in perspective, a zooming out of the depicted content, and hence is based on the fact that the same content can be described with various levels of details in very different ways. This difference in the level of abstraction can be a challenge for word-based automatic evaluation such as BLEU, ROUGE, or METEOR.

To solve this problem, other metrics related to information retrieval could be applied to text summarization evaluation in order to verify that the most important information has been kept. However, in the case of abstractive summarization, where an entirely new text is created, it is a difficult task to verify that the same information is present in the source text and in the summary. If the information was corrupted in the summarization process, it is not clear yet how automatic methods can detect and assess the quality of the produced summary.

Models that generate good summaries according to these automated metrics can then be evaluated by humans. Popular criteria for manual evaluation of automatic text summarization methods are coherence, consistency, fluency, and relevance (see Fabbri et al., 2021 for a detailed description). However, these evaluations are often very subjective and difficult to compare across studies, since they seldom use the same data set and evaluators.

As we can see, the question of quality evaluation is not resolved yet. It is important to bear these limitations in mind when working with automatic text generation and/or summarization systems, especially since industry's claims tend to give a more enthusiastic and less rational view. While comparing the different automatic evaluation scores of various systems might be helpful, one should not forget that automatic metrics are not bound to human evaluation logic (as we know it from the evaluation of school essays, for example) and should be interpreted within their respective scope only.

2.5 Text Generation

Neural network models are the latest turn in a long history of artificial intelligence methods that require enormous amounts of digitalized texts and processing power. In that sense, it is questionable whether this should really be called intelligence, and not brute force. Nevertheless, it is precisely the huge quantity of textual data that makes a decisive difference between neural approaches and older text generators: rule-based text generation systems simply did not cover enough of the target language to produce texts that appear natural or intelligent. Even large systems of simple rules could not grasp a word's context of use. Neural networks, on the contrary, showed even more capacity to generalize as thought was possible, with relatively simple architectures. Yet it is important to bear in mind that, while both rule-based and machine learning systems can somehow mimic human intelligence, they do not understand the words that they are processing.

However, systems based on neural networks can usually handle correlations. For example, if we put “Mr. President Barack” in a neural text generator, the system will most likely predict “Obama” as the next word. Such correlations, along with many others, might be interpreted as the machine’s knowledge. But unlike humans, the machine only has the knowledge and intelligence for the specific task it has been trained to perform: for example, it proved very difficult to train text processing systems to do basic arithmetic[5] (Hendrycks et al., 2021). Therefore, systems that provide next word predictions or paraphrasing might change the meaning of one’s writing or suggest something basically wrong for the writing task at hand. Yet because the next best word is predicted given the context calculated on a vast amount of document collections (billions of words), the system’s suggestion usually appears fluent and “intuitive” in light of the rest of the sentence, which makes it even more difficult to spot a possible inconsistency.

While the idea of knowledge and intelligence is to be taken with caution when related to the machine, there is an undisputable amount of information contained in the vast text collections that neural networks use to generate texts. To that extent, text generation could also be a means for human users to acquire the knowledge stored in the networks. For example, entering “the president of the United States in 2016 was Barrack Hussein Obama” triggered the following suggestion for continuation: “The current president of the United States is Donald Trump” (generated by open-GPT-3 on August 12th, 2022).[6] This shows how text generation not only produces written outputs to express ourselves, but also provides users with new knowledge, ideas, and inspiration.

One undisputable advantage of large language models is hence the enormous amount of information that is stored in them. However, extracting specific information relevant to a given writing task or topic can be challenging, and the systems can mix up different subjects or end up stating false facts. This issue also applies when these systems are used for rephrasing: they can be exact and convey the intended message correctly in other more fluent words, or they can corrupt the input information, but still sound very proficient (Fyfe, 2022). Finally, these language models might simply reproduce the content they were trained with, creating problems related to authorship or plagiarism, or replicating problematic assumptions generalized from large data sets (e.g., that all nurses are women or all pilots are men).

[5] A good example was presented in https://ai.googleblog.com/2020/06/pegasus-state-of-art-model-for.html, accessed 28.8.2022.

[6] The generated information is already outdated at the time the authors are writing this article (summer 2022).

2.6 Text Summarization

Summarization is a very important part of scientific writing, such as creating an abstract for a paper or reviewing a group of papers. Though at first, both tasks might seem similar, they differ to various extents: multi-source summarization requires normalizing different papers to the same vocabulary, ontology, and group of concepts; distilling a certain approach or perspective to the research questions targeted by that group of texts; establishing which of the research subject points were compatible and how to compare different methodologies; and so on. This is a highly complex task for experienced researchers, requiring not only contextual understanding, but also abstraction skills to compare and synthesize knowledge. As described in Benitez "Information Retrieval and Knowledge Extractionfor Academic Writing", identifying the important words in the individual documents of a collection is a more or less solved task. However, summarizing multiple documents for a given research question requires a different approach—often the question and answering type (Dimitrakis et al., 2020), which has not yet been solved for that context (Durmus et al., 2020). The current technology is not designed to summarize the actual *knowledge* contained in documents, but to extract the most important words or sentences according to what the machine has learned from an annotated corpus. Basic approaches use TF-IDF[7] or similar technologies (e.g. bm25), where the idea is to find words that are particularly frequent in a specific document within a collection and hence have a certain degree of uniqueness related to this document. This procedure can also be applied to full sentences. Such an approach is described as extractive summarization, as it mainly consists in extracting unique and frequent words or phrases *as is* and "glue" them together to fabricate a summary.

Extractive summarization is often opposed to abstractive summarization, where entirely new text is generated to capture the essence of the original text(s). State-of-the-art abstractive summarization methods apply large, pretrained language models. These language models are learned in a self-supervised way, i.e., they undergo a pretraining stage where they learn to predict words according to a given context or to identify which sentences tend to follow each other, and which do not. Although they can overcome many linguistic ambiguities (homographs, homonyms, etc.), their task remains more complex when multiple sources are involved.

Another form of summarization, although not directly producing a text, is called topic modelling: the content units of a document collection (i.e., the words) are grouped by co-occurrence. This allows hundreds of documents to be overviewed and give an impression of the topics covered by a specific collection or corpus. It is then possible, in another step, to transform the topic lists or graphs into fluent text. This method is currently mostly used by linguists and specialized researchers, and further research is required to understand how knowledge can be extracted efficiently through this procedure.

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[7] See chapter Information Retrieval and Knowledge Extraction for Academic Writing.

3 Main Products

There is currently a wide variety of automatic text generators emerging on the market, the majority of them mainly aiming at content creation and copywriting (for example, Zyro, Jasper, and Rytr, especially for e-mail writing). They usually offer AI-based generation of blog posts, social media posts, search engine optimized texts, and marketing content. A smaller proportion of those online tools explicitly focus on academic writing.

One of the oldest systems, SCIgen, explicitly aimed to amusingly critique the overgenerous acceptance rate of some conferences. The code shows that the generation is rule-based and uses many scientific idioms,[8] as it draws from the science repository CiteSeer. Although the developers claim that their system produces "nonsensical" articles,[9] the output complies with most formal requirements for scientific publications.

Beside SCIgen's satirical ambitions, many other "serious" systems are now emerging. We will name and describe a few of them as examples for what is currently available. However, at the moment, the market is constantly evolving, and it is not yet possible to identify major players.

https://web.writewise.io is a rule-based tool that offers more than 700 sentence and section templates. However, it also offers a wide range of writing assistance functionalities to "compose clear, coherent, structured, and mistake-free manuscripts."

https://myassignmenthelp.com/mah-bot-editor.html is a free tool that creates essays based on simple keywords, e.g., a given title. Interestingly, this tool relies heavily on human–machine interaction in each step: after entering a title for their essay, users are offered various outputs flagged as the beginning of the text. They can either choose one or decide to write the beginning of the text themselves. After that, users are presented with an editor, where they can type their own text or choose automatically generated paragraphs which they can edit at will. The user interaction also foresees a disclaimer whenever they choose to use a generated paragraph, informing them that the text has been generated out of online resources and can be used at their discretion.

https://www.essayailab.com/ presents a very similar interface (if not identical) and also provides several suggestions to start with. The provider, however, strongly emphasizes the issue of plagiarism, with disclaimers showing exactly how the generated output has been edited to pass plagiarism checks. The editor's interface is very similar to the one found on https://myassignmenthelp.com/mah-bot-editor.html, but it offers more prompts and pop-ups to guide users through the writing process. Both tools also provide help with grammar checks and many more services, all mostly based on the same text generation technology.

The issue with plagiarism is also raised on another website, https://smodin.io/writer, that displays a constant disclaimer that because "articles are generated from

[8] https://github.com/strib/scigen/blob/master/scirules.in.

[9] https://pdos.csail.mit.edu/archive/scigen/.

content on the web, it can be considered plagiarism. It is recommended to rewrite the scraped content." While this website only presents various output suggestions but no editor, it offers a function specifically called "remove plagiarism," very similar to the paraphrasing feature offered by most other tools. https://smodin.io/writer seems more targeted at producing content to be copied and used as is, and less focussed on integrating the text generation technology into a broader writing process.

https://www.writefull.com/ is an example of a fully different approach to merging technology and human writing. It mainly works as a plugin for text editors (e.g., Word) and offers feedback and paraphrase suggestions. It also offers a range of free online tools, like a paraphraser, a title generator, an abstract generator (abstractive summarization), and a collection of sentence patterns sorted by section (introduction to conclusion).

As we can see, these tools can vary greatly in their interface and in the underlying understanding of the writing process. However, most of them draw from similar text generation and/or summarization technology, whose most prominent example is GPT-4. GPT-4, currently one of the largest language models, is usually employed as chat and backend for general text generation, as well as for numerous writing solutions offered online. Many new tools (such as Copy.AI, neuroflash, or open.ai, to name only a few) are based on it (or a similar technology). This means that the text (or the keywords) entered on these websites is sent to the GPT-4 API, its answer collected and then presented to the user on the website. With the right prompting (given by the user themselves or by the service provider), GPT-4 can write a scientific article that seems very convincing at first sight[10] (however, the citations are definitely wrong and other content problems cannot be excluded). Prompting plays a decisive role in the quality of the generated output. For example, the scientific article written entirely by open-GPT3 was the result of concise prompts for each part of the text (Thunström & Steingrimsson, 2022). Here is an example of such a prompt:

> Prompt: Write a methodology section about letting GPT-3 write an academic paper on itself explaining what prompts are. It should include the word Top P, Frequency Penalty, Presence Penalty, Temperature and Maximum length, Best of and how it uses these to create output. Do not give any exact numbers. (Thunström & Steingrimsson, 2022, p. 4)

Finally, new avenues are opening up, for example the idea of generating research questions directly through GPT[11] (Yimam et al., 2020).

4 Research

There is animated discussion of the use of AI in writing, especially since the possibilities have become much more fluent in the last years. Anson (2022) discusses the use of AI in the practice of writing and how the authorship concept becomes less clear.

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[10] https://www.scientificamerican.com/article/we-asked-gpt-3-to-write-an-academic-paper-about-itself-then-we-tried-to-get-it-published/ accessed 2022.7.11.

[11] https://noduslabs.com/research/ai-writing-tool-gpt-3-text-generator-of-research-questions/

Hutson (2021) discusses different problems specific to open-GPT3, from how the language models are getting bigger and bigger, to measuring fluency, to how these models can be biased, because the language of their training data is neither inclusive nor fair.

Relevant insights can also be drawn from the neighboring neural machine translation (NMT) technology. Research has been documenting many aspects of the translator's perceptions and experiences in their work with AI-produced texts on various levels. Here, two domains of research seem to yield transferable insights for the work with text generators: the textual aspect and the cognitive aspect.

NMT produces fluent text almost instantly and at a very low cost, and many researchers resort to this option to ensure good English quality of their research, yet this quite often does not seem to suffice to match the publishing criteria (Escartín & Goulet, 2020). In fact, current NMT systems still have some problems that users need to be aware of. For example, the fact that terminology might not be translated consistently throughout a single text, that hedging and modality are frequently distorted through the reformulation process (Martikainen, 2018), that cohesive devices within a single text tend to be left out in the target translation, resulting in a loss of logical cohesion (Delorme Benites, 2022), and more generally the presence of algorithmic biases resulting from oversized language models (Bender et al., 2021). Further, there is a growing concern about the observed amplification of societal biases through language technology leading to machine translationese (Vanmassenhove et al., 2021), described as an artificially impoverished language characterized by a loss of lexical and morphological richness.

These issues are particularly problematic for scholarly texts, since academic genres (Swales, 1990) have peculiarities such as terminology, low-frequency words (Coxhead & Nation, 2001; Hyland & Tse, 2007), and hedging (Schröder & Markkanen, 1997). Furthermore, most NMT solutions available to the public work mainly at the sentence level, leading to significant text cohesion problems (e.g., unclear pronoun reference, and the aforementioned inconsistent terminology). As a result, many semantic, pragmatic, and textual aspects are still not treated well with current methods. While there is some research on terminology issues (Thunström & Steingrimsson, 2022; Zulfiqar et al., 2018) and domain adaptation (e.g., Haque et al., 2020), overarching academic text features (general academic vocabulary, neologisms, acronyms, intersentential and intrasentential links, overall text cohesion, claim hedging, rhetorical moves) are rarely or not at all considered. Since automated text generation relies on the same technology as NMT, it is likely to pose similar issues for academic writing purposes.

Another finding from translation research that might apply to automated text generation regards the cognitive aspect of working with AI-produced texts: the user's trust in the machine relies more on the fluency of the text than on its accuracy (Martindale & Carpuat, 2018). As a result, AI-produced texts tend to lull readers into trusting blindly their content, discouraging them from questioning the veracity of the information they are presented with. This is confirmed by many professional translators, who claim that post-editing (proofreading and correcting) a machine-translated text requires much more effort than a human-produced text, especially since errors are unpredictable. Should this also apply to automatic generated texts, which we can logically expect, there is a clear need to raise awareness and train users to proofread their texts as thoroughly as possible. Here again, techniques from translation research might prove useful.

In addition to these considerations, there is an intrinsic dilemma in using algorithms to produce academic texts: the core idea of scientific writing is to communicate new ideas and insights; sometimes even the very writing process will contribute to generating these ideas. Yet coming up with new ideas is something that machine learning algorithms can't do, since they are built as extremely well performing imitation machines. What generators can do is to lay out suitable sentence structures and idioms, and present information in various styles (scientific vs. marketing, for example). To sum up, text generators are very powerful tools for the formal part of academic texts. However, they cannot guarantee chains of causality in the content they produce (e.g., if $a > b$ and $b > c$, then $a > c$). To that extent, they can easily introduce erroneous claims in their seemingly fluent output. For example, the aforementioned article written entirely by GPT-3 contained anachronistic citations.

More generally, the nature of these systems is cause for reflection: their strength lies in the enormous amount of data they rely on, but we do not know what exactly is stored in these neural net models and how everything is organized. This makes such systems quite unpredictable, and what they can generate or where they can derail still remains unclear. Further, they are trained to predict missing words in a given sentence, but not to assess the actual consequences of each result on readers (for example, creating an offending output), and the only possibilities are the ones given by the documents used as training corpus. Although the corpora are, indeed, very large, they still are only a fraction of what the entire human language corpus.

Nevertheless, the popularity of automatic text generators is growing, especially among non-native Ph.D. students, who need to write their abstracts, papers, and theses in English. This is why they should be introduced and discussed in tertiary institutions, and their potential and risks should be on the agenda of academic writing training programs.

5 Implications

Many current practitioners of machine learning are driving the focus on machine learning systems and computer-aided systems, and the idea is not to remove humans completely but rather to find ways that computers can assist humans in repetitive and arduous tasks. This enables humans to oversee these tasks and focus their effort on exceptions and more challenging cases.

We can expect that automatic text generators will be used in various ways, according to the user's needs, competences, and time constraints, among other factors. As a result, we can anticipate at least two approaches to the writing process. There will likely be more, and the differentiation might end up being more fine-grained. Nevertheless, we will only describe these two as examples, keeping in mind that practices are yet to be established in this fairly new area. First, automatic text generators can produce a first draft that serves as a basis for the actual writing. In that scenario, users would give a rather procedural input (e.g., a bullet point list) to instruct the machine on what they expect. They can then choose from several suggestions, combine them, use only the first paragraph as a starting point, or even read through all suggestions for inspiration before they write their own text. All those strategies have been observed in the post-editing of machine translation output, and usually depend heavily on the user's personality. Second, automatic text generators could also be used *after* the actual drafting phase, for example in order to transform a raw draft into a fluent text and even render it in a specific style (academic, professional, popular, etc.). This approach could benefit, among others, non-native writers, writers with learning disabilities, or persons who struggle with academic writing in general.

Furthermore, various steps of the scientific work itself could already be tackled using automatic text generators, i.e., searching for relevant information, including adequate citations, as well as creating reviews and surveys using text summarization. In that regard, automatic text generation's impact on scientific writing will probably go beyond linguistic or formal considerations. This, in turn, stresses how important the mutual relationship is between science and science writing.

Still, as mentioned earlier (especially in light of machine translation related findings), a fruitful collaboration with the machine in order to produce good academic texts requires that the user knows how to make the best of the possibilities it offers and remain in control of the writing process. This means, in turn, that a lot of effort has to be invested in overseeing the processes and learning how to do so. Further, a generalized use of automatic text generation can ultimately lead to an overflow of documents, probably with a certain stylistic homogeneity. In turn, creativity and human writing skills could make a major difference between just another paper and a much-cited one in the global race for publication.

There is little doubt that automatic text generators can develop into widely-used writing assistance devices, where humans still perform various parts of the writing process. However, it is difficult to foresee precisely how the use of such automated solutions will change the traditional theoretical stages of writing (e.g., planning, prewriting, drafting, and revising). A possible hypothesis is that the planning and the revising phases would then gain in relevance and take up most of the human effort. On the other hand, one can wonder how different uses of automatic text generators can be accounted for in social constructivist theories of writing, especially since the content suggested by automatic systems is not justified by semantic or extra-linguistic criteria. Finally, the question of pragmatics should be addressed when using automatic text generators. At the moment, there is no evidence that the systems take textual or pragmatic constraints into consideration; in other words, information structure, intertextuality, and rhetorical development cannot be expected to be part of an automated writing process. Hence, notions that proved useful to explain, analyze, and even teach academic writing, i.e. Swales' (1990) CARS model of rhetorical moves, will need to be re-examined in the light of human–machine-interaction.

Appendix

Generated Abstracts

Longformer: in the twenty-first century, academic writing mostly takes place with a minimal setup of at least a computer, a text processor, and an internet connection. in this context, computers are often used to relieve human writers of specific tasks like correcting spelling mistakes, providing results of library or internet searches, and organizing scientific references into standardized quotations. \n however, the author, who actually performs the task of choosing the words and the order they will be presented in, is still human. in the era of computers, \n natural language generation (NLg) long relied on the same principles: combining words, very much like building blocks, using a set of rules in order to produce a text. for decades \n, automated systems have used templates, so that for each text to be produced, only some slots must be filled. however, maintaining such templates and keeping them up to date was a laborious and tedious task, and they performed better with highly standardized texts. besides the creation of new content and summarizing findings, automatic text generation and automatic text summarization are usually considered two distinct yet related fields, which is why we will provide only a brief overview in this chapter.

Openai-GPT-3 (shorten the text to fit 4k Token length, add at the end "abstract:"):

First attempt: In this paper, we discuss the implications of automatic text generation for academic writing. We first review the current state of the technology and how it is being used. We then discuss the implications of using automatic text generators for academic writing, including the need for users to be aware of the limitations of the technology and how to use it effectively. We also discuss how the use of automatic text generation can change the traditional stages of writing, and how it can be accounted for in social constructivist theories of writing.

Second attempt: This article discusses the implications of using automatic text generators for academic writing. It describes how the use of such generators can change the traditional stages of writing, and how the content generated by these systems is not justified by semantic or extra-linguistic criteria. The article also discusses the question of pragmatics when using automatic text generators, and how notions that have been useful for explaining, analyzing, and teaching academic writing will need to be re-examined in the light of human–machine-interaction.

Software	Access	Specificity	Licensing
https://web.writewise.io	Paid	Writing assistance with templates	Proprietary
https://myassignmenthelp.com/mah-bot-editor.html	Free	Given simple keywords, essays are automatically generated	Proprietary
https://www.essayailab.com/	Paid/free	Uses a database to suggest content, and provides writing assistance	Proprietary

(continued)

(continued)

Software	Access	Specificity	Licensing
Openai-GPT3	Paid	General writing assistance (Language Generation)	Proprietary
T5 (Huggingface)	Free	As Openai-GPT3, but it can be downloaded but requires programming knowledge to generate content	Free

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Information Retrieval and Knowledge Extraction for Academic Writing

Fernando Benites

Abstract The amount of unstructured scientific data in the form of documents, reports, papers, patents, and the like is exponentially increasing each year. Technological advances and their implementations emerge at a similarly fast pace, making for many disciplines a manual overview of interdisciplinary and relevant studies nearly impossible. Consequently, surveying large corpora of documents without any automation, i.e. information extraction systems, seems no longer feasible. Fortunately, most articles are now accessible through digital channels, enabling automatic information retrieval by large database systems. Popular examples of such systems are Google Scholar or Scopus. As they allow us to rapidly find relevant and high-quality citations and references to previous work, these systems are particularly valuable in academic writing. However, not all users are aware of the mechanisms underlying relevance sorting, which we will address in this chapter. For example, in addition to searching for specific terms, new tools facilitate the discovery of relevant studies by using synonyms as well as similar works/citations. The near future holds even better tools for the creation of surveys, such as automatic summary generation or automatic question-answering systems over large corpora. In this chapter, we will discuss the relevant technologies and systems and their use in the academic writing context.

Keywords Machine learning · Human–machine interaction · Research for academic writing · Language modelling · Information retrieval · Knowledge extraction

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_19

1 Introduction

The creation of texts has accelerated in the last few decades. The number of patents, websites on the internet, and the amount of data in general has increased exponentially. Searching for the right piece of information is a ubiquitous problem (referred here as general-purpose information searching). Although scientific writing is particularly affected by that, the problem of information searching (especially when writing a literature review) is that many researchers do not know how the search engines work. While journals and renowned conferences help sort articles in a research field and identify the state of the art, individual researchers often struggle to get a comprehensive overview of all the relevant studies. Not only has the speed of the procedures of writing and publishing studies been accelerating, but also the pressure to publish or to perish has been quantified into numbers and scores, such as h-index,[1] finally increasing the amount of data to be searched. The idea that nonetheless digitalization and search engines can simply lead to substantial time gains when surveying a subject for a certain scientific field is appealing, but it actually often entails the problem of finding appropriate studies while being confronted with a too large list of potentially relevant matches.

In this situation, academics are similarly confronted with problems that arose with large data and the internet, especially overflow of information. Information retrieval focuses on developing algorithms for searching for a piece of information in a large corpus or in general in large corpora. This problem appeared in the late 1960s and 1970s with the creation of databases, but more specifically, with the storage of large parts of texts such as in libraries and large institutions. Databases use an index to access data quickly; unfortunately, creating an index over texts is not that easy. For instance, sometimes a part of a word is interesting (when looking for graduate, the word undergraduate is relevant), so using a simple alphabetic index will not cover basic use cases. Better methods needed to be developed, turning databases into search engines. Nevertheless, textual data is unstructured data, which cannot be processed to extract knowledge by computers easily. Knowledge extraction refers to the field which studies approaches targeting the challenge of extracting structured information from a textual form. Since the beginning of electronic computers, there has been a large amount of data embedded into textual data; thus, manually extracting structured information from it is an arduous task. In particular, when performing knowledge extraction, information retrieval might be a first task to execute, so information retrieval and knowledge extraction are closely related.

In the last two decades, the issue of information retrieval has become omnipresent, for example with the dispute between search engines such as Altavista, Yahoo, Microsoft Search (Bing), and Google, who ended up with the lion's share. Even today, there are attempts to break Google's monopoly with new search engines such as ecosia and duckduckgo. However, Google's algorithm in its core (we will cover it later), is the most popular nowadays.

[1] H-index measures how many publications with how many citations an author has (e.g. an h-index of 5 means at least 5 publications with 5 citations).

When writing scientific articles, thanks to the rapid digitalization of academic publishing and the rise of search engines, we now have access to so much more data and information than before that we are now often confronted with the challenge of finding a needle in the haystack. This is where online tools can help, especially those providing access to scientific publications. Hence, academic social network platforms, search engines and bibliographic databases such as Google Scholar (Halevi et al., 2017), Scopus, Microsoft Academic, ResearchGate or Academia.edu have become very popular over the last decade (Ortega, 2014; van Noorden 2014). These specialized search engines are needed and make a great gain in contrast to conventional search engines, since the procedure for academic writing is very different from general purpose information searching (Raamkumar et al., 2017). Most of these online platforms offer more or less detailed search interfaces to retrieve relevant scientific output. Moreover, they provide us with some indicators allowing us to assess the relevance of the search results: the number of citations, specific keywords, reference to further relevant studies through automatic linking from the citation list, articles suggested on the basis of previous searches or according to preferences set in one's profile, amongst others. However, many challenges still remain, such as the ontological challenge of finding the right search terms (many terms being ambiguously coined), including all possible designations for a given topic, as well as assessing the quality of the articles presented in the results list.

On top of that, with the rise of academic social-networking activities, the number of potentially interesting and quickly accessible publications surpasses our human capacities. As a result, we depend more and more on algorithms to perform a first selection and extract relevant information which we can turn into knowledge for our scientific writing purpose. In that sense, algorithms provide us with two important services: on one side, information retrieval, which is becoming each day more sophisticated, and on the other side, knowledge extraction, i.e. the access to structured data[2] allowing us to process the information automatically, e.g. for statistics or surveys. This chapter will present and discuss the methods used to solve these tasks.

2 Information Retrieval

When we use an academic search engine or database to obtain an overview of the relevant articles on a given topic, we come up with a moderate number of words that, to our opinion, sum up the topic, and enter them in the search field. By launching the search, we give over to the machine and the actual information retrieval process. The main purpose of information retrieval is to find relevant texts in a large collection given the handful of words provided by a human user, and, more specifically, to rank these documents on their relevance to the query words. The resulting list of matches is thus created according to various criteria usually not known by the users.

[2] Structured data is data that does have a data model and thus can be easily processed by an algorithm or computer.

Yet, gaining insights into the information retrieval process might help understand and assess the relevance of the displayed search results. Especially, what is on top of the ranked list and what might get suppressed or be ranked down. As we will see later, depending on the search engine a search term needs to be written exactly or the search engine can provide us with helpful synonyms, or links to interesting papers.

The first approach for information retrieval is to break down the query words and analyze the corpora individually, looking for the appearances of each of the terms in the texts. The occurrence of a term in a document might increase the relevance of the document to the query, especially if there are many occurrences of the term within the same document. However, if a term is equally frequent in the language in general compared to its frequency in the corpus, it might be of no help. A metric aiming to engage this issue is term-frequency inverse-document-frequency (TF-IDF) (Manning & Schütze, 1999), which is often used for an array of natural language problems, and, amongst others, in automatic text classification (e.g., spam recognition, document classification [Benites, 2017]), dialect classification (Benites et al., 2018), but also for research-paper recommender systems (Beel, 2015). This method can find words that are important/specific for a certain document within a collection of documents, by giving more weight if a word frequently occurs in the document and less weight if it frequently occurs in the collection. Further, other considerations might help sort the results. If we want to find something about "scientific text writing" in a scientific database of articles on the internet, there will probably be just too many hits. Adding more words will reduce the list of results (since they are aggregated by an AND operation, seldom by an OR), but this implies choosing an adequate term that gives the query more purpose and specificity. For example, adding the word "generation" will break down the result set, but it could be equally helpful to discard some less important query terms, i.e. "text." Moreover, very large documents might contain all the query words, which would lead to considering them a good match. However, if the terms are scattered throughout different parts of the document and have no vicinity or direct relation with each other, chances are that there are different disjoint subjects that do not automatically reunite towards the subject of interest. This is why some methods also foresee the penalization of lengthy documents as well as the prioritization of documents showing indicators of centrality, such as the number of citations, to obtain a more relevant set of results. And more importantly, these criteria have a direct impact on the ranking order of the results.

However, all those aspects do not consider the semantic context of the word. A "bank" can be a piece of furniture, a financial institution, or the land alongside a river. This is why more and more search engines use so-called contextual language models (such as transformers): artificial neural networks (machine learning approaches) trained to predict missing words in sentences from a collection of billions of texts (Devlin et al., 2018). This training procedure is called a self-supervised[3] task but is also known as pre-training. This approach helps the model memorize which

[3] Self-supervised tasks refer to the procedure to take a training sample and remove parts of it, so the machine learning model needs to reconstruct the sample by itself (related to auto-associative memory).

words are used in the vicinity of certain words. After the pre-training phase, these models can be fine-tuned to down-stream tasks, such as document classification, similarity ranking of documents, sentiment analysis (e.g., is a tweet negative or positive), named-entity recognition (e.g., classification of words: Mr. President Obama, Senator Obama, Barrack Obama, all refer to one entity), language generation (for chatbots, for rephrasing tools), and the list goes on and on. Their range is so broad because they can create document representations[4] that take the context into account, and they can determine if two documents are relevant to each other, even though they might only be connected by synonyms, i.e., they do not use the same exact vocabulary but have a similar meaning. This allows a search which is much more semantically guided and less orthographic (the exact spelling of a word).

After breaking the text into single words and examining them, the next step in providing better ranking is to not only look for a single word, but to analyze word combinations and see if they constitute a term/construction in the corpus. The TF-IDF approach would only search for n-grams (a contiguous sequence of words) of the terms, and to that purpose, it would need to build an index with all the possible word combinations (usually n-grams of 3–7 words). This index can quickly become oversized with the explosion of combinations (multiple hundreds of gigabyte, depending on the corpus size and diversity of the vocabulary). Newer language models, such as transformers, take a different approach. They dissect the words in subwords and then try to grasp the combination from the whole sentence or paragraph (usually 512 subwords which can be up to 200–300 words). They use a mechanism called self-attention, which weights a word from different perspectives (one for being a query of other words, one for being a key for other words, and lastly one for being the value searched by the query and key), using a positional encoding for each word. The intuition is that it can then check correlations between the words, as it takes the whole sentence as input. Plus, neural networks consider all possible combinations at the same time. This creates a computational problem, which is dealt with by a myriad of heuristics and a massive amount of computational power. Consequently, this produces powerful language models able to grasp context even over long distances in the sentences, enabling, for instance, context-aware coreference resolution (the cat ate the mouse, it was hungry, "it" is referring to which animal?). This can be used for search engines when analyzing search words: are the queried words found in the documents and if so, are they used as central words in the right context?

While search terms play a major role in the information retrieval process, most academic search engines also still heavily rely on citations, using them to create graphs. Such graphs can use the PageRank (Page et al., 1999) algorithm[5] to prioritize works that are highly cited. CiteSeer used a different approach and implemented a "Common Citation Inverse Document Frequency" (Giles et al., 1998). It is also

[4] The language models can transform the text to a latent space (latent representation), from which simple linear classifiers can perform a specific task.

[5] PageRank algorithm gives better score for entities (documents, websites, persons in social networks) which are referred more often by other entities (e.g. websites linked to others).

possible to create networks based on the search terms and count only citations that are relevant for the search. The use of citations for Google Scholar was also examined in Beel and Gipp (2009). The paradigm of the PageRank algorithm can be observed in a citation network[6] by ranking more important seminal papers. As Raamkumar et al. (2017) point out, seminality is critical for a scientific reading list, along with sub-topic relevance, diversity, and recency. These criteria can also be applied for a literature survey and for ranking scientific publications for the use case of scientific writing.

In sum, automatic information retrieval is a complex process involving multiple elements such as words, subwords, synonyms, document length, and citations. However, the way these elements are used and combined by the machine to establish a ranked list of matches is generally not displayed along with the results. This is why being aware of such mechanisms can help take a constructive critical stance towards the identified literature.

3 Knowledge Extraction

As the amount of scientific literature grows significantly, the need for systematic literature reviews in specific research fields is also increasing. Human-centered approaches have been developed and established as standards, e.g., the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) method (Page et al., 2021). Nevertheless, the overwhelming amount of available literature in some fields calls for automated solutions. Unlike information retrieval, knowledge extraction directly taps into a publication's content to extract and categorize data.

The construction of structured data that can be saved into a schematized database and processed automatically from unstructured data (e.g., a simple text document) is a vast research field. The ultimate goal of processing unstructured data, especially documents or articles, is of great importance for algorithms. For example, in medical research, contraindications of a substance or illnesses associated with a certain drug could be easily found automatically in the literature, therefore guiding the search process and speeding up research even more. Unfortunately, it is not so easy to identify the substances, or which relationship connects them. In the field of natural language processing (NLP), we speak of named entity recognition (substances) and relation extraction (how do the substances relate to each other). Although finding relevant entities seems easy enough, there are many cases where it is quite difficult. For example, the 44th President of the United States of America can be referred to by his name Barack Hussein Obama II, Mr. President (even though he is not active in this position anymore), candidate for President, Senator Obama, President Obama, Peace Nobel Prize laureate, and so on. Usually, authors will use multiple denominations of the same entities to avoid repetitions, rendering the finding and tracking of named entities very difficult for an automatic algorithm. Although, in the last years, many

[6] Citation network refers to the network of citations created by a paper.

improvements were made to grasp the semantic context of a word, the understanding and world modelling (real world) of the NLP algorithms is extremely limited. The algorithms can extract many relations from texts, but a chain of consequences is difficult to form. They are merely advanced pattern matching procedures: given a word, they find which words are related to that; however, they are not yet capable of extrapolation or abstract association (i.e., connecting the associations to rules or rule chains). Nonetheless, the results can be quite impressive in some specific tasks, such as coreference resolution of entities, which has some very accurate approaches (Dobrovolskii, 2021), yet not perfect nor near human performance. Although the current generation is learning to master relatively simple tasks for the next generation of algorithms, a paradigm change is yet to be developed.

Being able to search for entities and for relations between entities can be helpful in many fields, such as chemistry or drug-development (contraindications). When performing a literature review, it is equally important to know what the key papers are, what methods were used, how the data were collected, etc. Automatic knowledge extraction could also be used for creating surveys on a new task or a specific method. Although creating a database of entities and their different relations is not new, and even constitutes a paradigm in the field of database (graph database), it remains very complicated, especially when it comes to resolving conflicts, ambiguities, and evolving relations. On the other hand, if a document contains a graph, a text can be created automatically (see Benites, Benites, & Anson, "Automated Text Generation and Summarization for Academic Writing").

Still, some information, like cited authors or how certain research objects are dealt with, can be extracted automatically, and this method can be applied to hundreds of papers, which makes the writing of research synthesis papers much easier. We can cluster and find similarities and differences much faster. Extracting entities from unstructured data such as texts is usually performed with neural networks that are trained on news articles. Until recently, this meant that the language model of these algorithms was confined to the so-called "news article" genre. Transformers (Vaswani et al., 2017), especially BERT (Devlin et al., 2018), changed that since they are trained on a very large corpus using multiple genres, from Wikipedia articles, to books, to news articles, and to scientific articles, but in an unsupervised manner[7] allowing the language model to learn different facets of the language. After the first training phase, the transformer is fine-tuned in a supervised manner to a specific task (e.g., entity recognition in books, where much less data is needed to achieve satisfying results). In that sense, the first step constitutes a pre-training, allowing the actual training to be performed with low amounts of specific data and without substantial computational effort.

This method, however, is still pattern matching, although in a much broader context. As a result, certain manipulations and associative relations are not accounted for (such a triangle inequality), showing the limitations of these large language

[7] Supervised learning refers to machine learning algorithms which need labelled data, i.e. for sentiment classification if a tweet was positive or negative. Unsupervised learning algorithms process the data so that groups, similarities and discriminations in the data are apparent.

models. Some newer approaches try to tackle the problem of semantic relation and logical implications, but there are many problems to be solved before they can be used; for instance, some language models in summarization can count from 2–5 but jump to 7 skipping 6 (e.g., number of ships in an article, Zhang et al., 2020). Other approaches use a graph over the documents to infer relations and central entities from the documents, but this is not very reliable, as pointed out earlier.

Thus, although knowledge extraction is a very promising avenue in light of the exploding amount of scientific data being released every day, there is still work to be done before this can be considered a reliable, fully automated solution. At the moment, there is no clear path how to inject the information of knowledge extraction into large text generation models (see Benites, Benites, & Anson, "Automated Text Generation and Summarization for Academic Writing"), which could make many mistakes (false facts) avoidable in many cases. The combination of knowledge graphs and language models is a possibility since the extracted knowledge can be embedded into a graph where reasoning can be performed. This would allow to check the content of a sentence while writing against the facts stored in the knowledge graph, and thus contributing to speeding up writing, making better citations, etc.

Knowing the entities and relations could also help information retrieval systems since the connection between synonyms becomes clearer, and reasoning over the search query could also be performed. This could helps researchers find what they are looking for faster and even help gather data for statistics. For example, in a Google Scholar search the number of hits is shown, but it would be good to know if they all handle the same use case or a method across disciplines, what the time span is, and whether the subjects are about the same or different topics. Also, a survey of papers could show how many papers use a certain dataset, employ a certain methodology, or refer positively or negatively to a specific term.

3.1 Functional Specifications

Search engines allow us to do a literature review or survey much faster and more precise than 20–30 years ago. More importantly, they allow us to also scavenge social media, a facete that is becoming more important for science. Which papers are discussed in the community and why, are there some critical issues that cannot be easily inferred from the paper?

However, finding an interesting paper (because it uses similar methodology) without knowing the specific words it uses still remains a challenging task. Using knowledge graphs of a certain field, allows to find these scattered pieces and put together a more precise and concise image of the state of the art. Although generating such graphs is also not trivial, it could be much easier to perform with automated procedures. Maintaining a certain degree of scepticism towards the results may nonetheless be a good precaution.

3.2 Main Products

Both information retrieval and knowledge extraction belong to the technologies used by scholarly search engines—and hence used by a wide majority of researchers, scientific writers and students, even when they are not aware of them. This is why a succinct overview of current academic search engines can help establish their relevance for academic writing.

CiteSeer (Giles et al., 1998) was an early internet index for research (beginning of 2000s), especially for computer science. It already offered some knowledge extraction in the form of simple parsing such as extraction of headers with title and author, abstract, introduction, citations, citation context and full text. It also had a citation merging function, recognizing when the same article was being cited with a different citation format. For information retrieval, CiteSeer used a combination of TF-IDF, string matching[8] and citation network.

The most part of popular databases and search engines for scientific article search do not disclose their relevance ranking algorithm. For Google Scholar, we do not know much about the algorithm behind Google Scholar's search engine, only that it uses the citation count in its ranking (Beel & Gipp, 2009). Researchgate and Academia.edu are new social networks for the scientific community, both offering to upload and share scholarly publications. This also enables a search engine capability, and a recommendation system for papers to read. Springer's SpringerLink is an online service that covers reputable conferences and journals. IEEE Xplore, ACM Digital Library, and Mendeley/Scopus are similar to SpringerLink for the respective publishers IEEE, ACM and Elsevier.

Martín-Martín et al. (2021) published a comparison of the various popular search engines for academic papers and documents. The study examined the index of most used search engines such as Google Scholar and Elsevier's Scopus. The authors compared the coverage of these databases of 3 million citations from 2006. Further, in the discussion, the authors argue that the algorithms for ranking are non-transparent and might change the rankings over time. This last issue will hinder reproducible results, but as the popularity of the papers change over time, it might also be difficult to argue against it. The authors point out that while Google Scholar and Microsoft Academic has a broad coverage, there are more sophisticated search engines as Scopus and Web of Science (WoS), but they cover mostly articles behind paywalls. Further comparisons between Google Scholar, Microsoft Academic, WoS, and Scopus can be found in Rovira et al. (2019), and between Google Scholar and Researchgate in Thelwall and Kousha (2017). The most relevant finding for academic writing is that Google Scholar attributes great importance to citation, and Researchgate seems to tap the same data pool as Google Scholar.

[8] String matching is a way computers compare two words, simply by comparing character by character.

3.3 Research on Information Retrieval and Knowledge Extraction

Much research is being conducted in information retrieval and knowledge extraction, especially in the light of the recent developments in NLP and big data. The new, better-learning language models and broader representation of documents through contrastive learning[9] will heavily influence the next generation of search engines. One focus of the research is the field of author academic paper recommender system and academic search engine optimization (Rovira et al., 2019), which will become more and more important, especially given the growing awareness of these search engines among academic writers and the distribution of scholarship to wider audiences. As previously mentioned, the amount of research to be reviewed before writing will increase, and methods for automatization of selection will prevail over manual evaluation of certain sources.[10] For writers, this would optimize the writing process since the search engine would display the work more prominently.

Other rapidly-developing technologies might heavily influence the way how we perform searches in the near future. Automatic summarization is getting better and better, leading the way to automatically summarizing a collection of results provided by a search engine and even grouping the documents by topics. This can help easily create a literature overview and even give an overview over the state of the art, shortening by a large margin the work performed by researchers when writing articles. The most relevant paper for a search can also be highlighted as well as papers that may contradict its findings.

A further advance is the automatic question answering, where an algorithm tries to find an answer to a question within a given text. Hereafter, the search question answering system can further refine the list by recommending keywords or by filtering irrelevant articles from the result list, even by posing questions to the user, helping the user find relevant terms and aspects of the document collection resulting from the search. Lastly, the results can be better visualized as graphs showing clusters and influential concepts for each cluster, thus grasping the essence of the search results. This can help not only to refine the research question when writing but also to find good articles, insights, and ideas for writing.

[9] Contrastive learning refers to the tasks to learning similar samples from a collection, this produces usually better representation of the samples in an abstract latent space. These representations are often used afterwards for classification.

[10] Precision is important, finding trustworthy and relevant sources, however, researchers will not accept a complete missing of a very similar study. This might render the whole writing of their research redundant and irrelevant. Thus, the bigger the pool of articles the more certain researchers can be of creating new findings.

3.4 *Implications of This Technology for Writing Theory and Practice*

The way the results are prioritized makes quite an impact, especially since many researchers will not scroll through the exhaustive number of hits of their query to find appropriate papers. If they do not find relevant matches within the first entries, they will most likely rephrase their query. Papers that are highly cited might be more prominently placed in the list, although they might be only a secondary source (such a case occurred with the field of association rules in data mining where a concept was reintroduced in the 1990s, although it was discovered in the 1960s, and the former became the defacto standard citation). Many concepts are coined almost simultaneously by different authors using different terminologies, and generally only one becomes mainstream, making it difficult to obtain a fair overview of a field with search methods based on TF-IDF and citation count. This might change in the future, as there is progress on structured data and some subfields as mathematics (Thayaparan et al., 2020), but understanding that two concepts are similar/related requires cognition and understanding, something that algorithms still cannot perform over scientific natural language.

Google's PageRank (and thus citation counts) was built for the internet. If a group of persons finds an internet page interesting, they will link this to this page, and thus make the work of marking interesting sites for the algorithm. However, if something new and relevant but less popular or known emerges, this algorithm might take a while to catch up. Finding early citations is very important to stay current and relevant and have a longer citation span for an article, which impacts the career of a researcher. While it seems that Google Scholar is very good at it (Thelwall & Kousha, 2017), the algorithm still does not know if the results are truly relevant for your research or not. This shows the limits of ranking paradigms based on non-academic internet popularity for scientific research, since novelty and relevance are usually more important factors than popularity. From the academic writing point of view, search engines can only take you so far; a good scholarly network and dissemination of research at different venues can help get to new research findings faster.

4 Tool List

Software	Access	Specificity	Licensing
https://scholar.google.com	Free	Google search engine for scientific publications. It has some features for managing literature, calculates an h-index and has often the respective references linked to an article. Does not belong to any specific publisher	Proprietary

(continued)

(continued)

Software	Access	Specificity	Licensing
https://citeseerx.ist.psu.edu/	Free	A academic solution (Pennsylvania State University) for archiving scientific articles allows to search	Proprietary
https://ieeexplore.ieee.org/	Paid/free	Search engine and archive of IEEE published papers	Proprietary
https://dl.acm.org/	Paid/free	Search engine and archive of ACM published papers	Proprietary
https://link.springer.com/	Paid/free	Search engine and archive of Springer published papers	Proprietary
https://www.sciencedirect.com/	Paid/free	Search engine and archive of Elsevier published papers	Proprietary

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Analytic Techniques for Automated Analysis of Writing

Antonette Shibani

Abstract Analysis of academic writing has long been of interest for pedagogical and research purposes. This involves the study of students' writing *products* and *processes*, often enabled by time-consuming manual analysis in the past. With the advent of new tools and analytic techniques, analysis and assessment of writing has become much more time and resource efficient. Advances in machine learning and artificial intelligence also provide distinct capabilities in supporting students' cognitive writing processes. This chapter will review analytical approaches that support the automated analysis of writing and introduce a taxonomy, from low-level linguistic indices to high-level categories predicted from machine learning. A list of approaches including linguistic metrics, semantic and topic-based analysis, dictionary-based approaches, natural language processing patterns, machine learning, and visualizations will be discussed, along with examples of tools supporting their analyses. The chapter further expands on the evaluation of such tools and links above analysis to implications on writing research and practice including how it alters the dynamics of digital writing.

Keywords Writing analytics · Taxonomy · Digital writing · Automated analysis · Writing assessment

1 Overview

Interest in the analysis of writing dates all the way back to the origin of writing using scripts, as there is enduring value for good writing and understanding what makes a piece of writing particularly good. With regards to *academic writing*, this interest stems from the need for assessment in the classroom to evaluate students' learning and capabilities. With the advent of technological advances came about approaches to automate writing analysis using tools and analytical techniques.

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_20

Previous reviews have discussed the affordances and challenges in the use of computational tools to support writing. The review on computerized writing instruction (Allen et al., 2015) discussed the opportunities offered by tools for small and large scale assessments and writing instruction. It covered tools with capabilities of providing automated scoring, feedback, or adaptive instruction, predominantly from the US school education context. A more recent review recognized a number of additional tools, both commercial and research-based, that support student writing (Strobl et al., 2019). However, the technologies running behind the use of such tools in educational practice is not discussed extensively other than through the lens of orientations and intentions for writing analytics (Gibson & Shibani, 2022), and hence forms the focus of the current chapter. I posit that an understanding of the underlying technology would lay the foundation for choosing the right tools for the task at hand to deliver appropriate writing instruction and strategies for learners, and this chapter aims to aid such appreciation. The chapter discusses computational techniques that underpin writing analysis considering both summative and formative assessments of writing.

2 Core Idea of the Technology

The key rationale behind the usage of technological and analytical approaches is the need to automate/semi-automate the analysis of writing artefacts. The manual process behind writing assessment is time-consuming and only increases with large amounts of text. Furthermore, the assessment of writing quality can be inconsistent across assessors—assessment of writing requires a certain level of expertise for accuracy (and even this comes with disagreements, implicit biases and different points of view in human assessment with standard rubrics). Automated analysis and assessment provide consistency, objectivity and speed in a way that humans are not capable of providing. The main purpose of developing automated approaches is hence to improve efficiency. Such analysis is also much more scalable to a large set of students than manual assessment (for instance, in the case of standardized tests for all school students across the country).

3 Functional Specifications

The technologies and specific tools discussed in this chapter aid consistent, quick assessment of writing quality for both written products (essays, research articles etc.) and writing processes (drafting, revising etc.). They generate metrics and summaries that can act as proxies for the quality of writing. The tools are discussed based on the type of analysis they can perform on writing in the order of lower-level fine grained metrics to higher order human-defined categories.

At the lowest level are simple textual features that are calculated using computational linguistics and Natural Language Processing (NLP) methods. This includes metrics such as number of words, word frequencies, connectives, parts-of-speech and syntactic dependencies which can contribute to the calculation of readability, syntactic complexity, lexical diversity and cohesion scores among sentences (Graesser et al., 2004).

In simple terms, these are ways of numerically representing a text by calculating measurable features we are interested in. For instance, a readability score indicating how easy the text is to read can be calculated from a formula comprising of average sentence length and the average number of syllables per word (Graesser et al., 2004). There is an accepted level of agreement in the measurement of these linguistic indices as they are derived from standard language rules, although many ways of calculating them exist.

At the next level are approaches that aim to capture the *meaning* of the written content using automated and semi-automated methods. One common technique is called Latent Semantic Analysis (LSA), which helps calculate the semantic similarity of texts (Landauer et al., 1998). LSA is a statistical representation of word and text meaning which uses singular value decomposition (SVD) to reduce a large word document matrix to a smaller number of functional dimensions (Foltz, 1996). It can be used to calculate similarity in meaning and conceptual relatedness between two different texts, say our current text for analysis and a higher dimensional world knowledge space created from a pre-defined large corpus of texts.

Another analysis based on the content of texts is the use of topic models such as Latent Dirichlet Allocation (LDA) for unsupervised detection of the themes/topics in a set of documents (Blei et al., 2003). LDA generates a probability distribution of topics for a given text based on the word occurrences in the whole set of documents using an algorithm called Gibbs sampling, and is useful in contexts where we would like to identify the key themes occurring in a large text corpus. The automated topics derived from LDA are a combination of words, which should be further interpreted with human expertise for insights about the context (Xing et al., 2020).

More recently, word embedding models have revolutionized text analysis by learning meaningful relations and knowledge of the surrounding contexts in which a word is used (Mikolov et al., 2013). It is based on the principle that we can gain knowledge of the different contexts in which a word is used by looking at words commonly surrounding it. Words similar in meaning appear closer in distance in the word embedding vector space in comparison to words that have no semantic relationship. For instance, we would expect words like "mom" and "dad" to be closer together than "mom" and "apple" and "dad" and "sky". Such representations are widely used to improve the accuracy of NLP tasks in state-of-the-art research.

Another level up are approaches that predict automatically higher-order categories and constructs that are manually defined. Examples include the classification of sentences as background knowledge, contrast, trend, the author's contribution, etc. based on rhetorically salient structures in them (Sándor, 2007), and identifying moves and steps in a research article based on the Creating a Research Space [C.A.R.S.] Model (Swales, 2004). For such automated writing classification, three kinds of methods are used: (1) Dictionary-based approaches (2) Expert defined NLP rules (3) Supervised machine learning. Each method has its own advantages and disadvantages, and are explained as follows.

As defined in the name, dictionary-based approaches make use of a pre-defined set of words and co-occurrences as dictionary entries to assign a certain category for the unit of analysis (say, a sentence) (Wetzel et al., 2021). This means that once an extensive dictionary is set up, the accuracy of assignment is perfect, as it is calculated based on the presence or absence of dictionary entries. A more advanced method is the definition of NLP patterns and rules by linguistic experts which extends beyond just looking for the occurrence of words. These expert-defined rules can look for more complex syntactic structures and dependencies in addition to the occurrence of words such as with the use of meta discourse markers and concept matching (Sándor, 2007).

The approaches above offer explainability in the results as one can pinpoint why a certain category was assigned based on the manually defined words and rules, which can increase user trust. A caveat however is that they will fail to work or capture instances incorrectly if the corresponding patterns/words were not previously defined on the system; the definition of rules also require expertise in linguistics and contexts. On the other hand, the assignment of categories are automatically done using machine learning approaches once the gold standard human codes are available (Cotos & Pendar, 2016). They predict categories in new unseen textual data by learning features from past data the system is fed with (training data for the model). This means that large volumes of text can be analysed easily for future data. But, the models can be a black box where the rationale behind why a particular category was predicted unknown, hence lacking explainability. Advanced deep learning techniques using neural networks are now being developed for automated text generation in writing (Mahalakshmi et al., 2018).

In addition to the above, there are graphical representations of written texts and visualisations that can be used to study writing. These include concept maps (Villalón & Calvo, 2011), word clouds (Whitelock et al., 2015) for representing writing products, and revision maps (Southavilay et al., 2013), automated revision graphs (Shibani, 2020), etc. for representing writing processes.

Other analytical techniques that are used for specific purposes such as the calculation of text similarities and clustering (for instance, to detect plagiarism), automatic text generation and recommendation (E.g. possible synonyms, paraphrasing, and more recently, advanced sentence generation capabilities with generational AI tools like Generative Pre-trained Transformer 3/GPT-3) and text summarization (E.g. summarizing the crux of a large piece of writing) also exist. Finer-grained analysis of writing processes is made possible with the use of keystroke analysis which logs and studies students' typing patterns (Conijn et al., 2018). A taxonomy of the different approaches discussed above is provided in Fig. 1. In next section, I will discuss examples of *tools* which utilise these analytical approaches for automated writing analysis. Note that many of these approaches are used in an integrated fashion in tools by combining more than one analytical method.

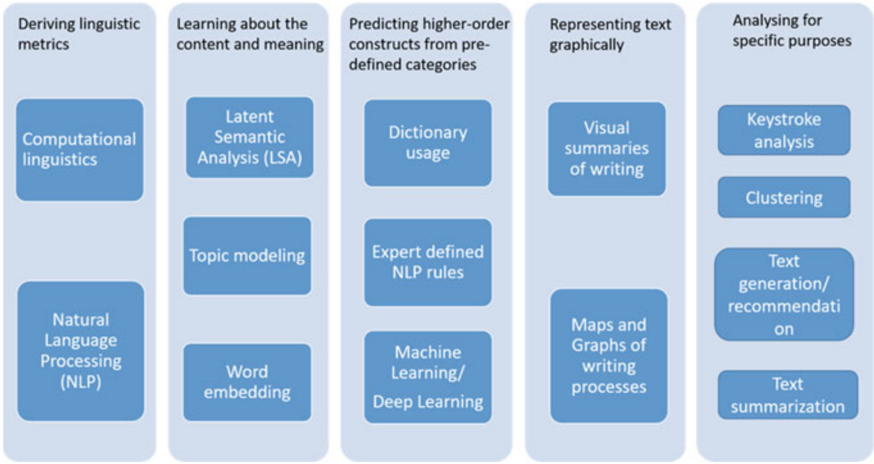

Fig. 1 Taxonomy of analytical approaches used for automated writing analysis

4 Main Products

A number of stand-alone and integrated tools perform automated analysis of writing. The kinds of tools that process writing using computational features are discussed first as a vast majority of tools fall within this category. The most common versions make use of low-level language indices to assess writing features and map them to higher-level categories and scores. Tools such as *Coh-metrix* (Graesser et al., 2004), *Linguistic Inquiry and Word Count or LIWC* (Pennebaker et al., 2001), *Stanford CoreNLP* (Manning et al., 2014) calculate measurements of linguistic textual features discussed in the previous section, which can then be used for various purposes of writing analysis including automated scoring and the provision of automated feedback. Alternatively, many tools have their in-built text analysis engines that calculate those metrics. Tools falling under the category of Automated Essay Scoring (AES) systems, Automated Writing Evaluation (AWE) tools and Intelligent Tutoring Systems (ITS) all make use of above analytical techniques but for specific purposes. These are covered extensively in other chapters (see Chapter "Automated Scoring of Writing" for a comprehensive review of AWE tools, and Chapter "The Future of Intelligent Tutoring Systems for Writing" for ITS), and hence the current chapter only discusses key examples to illustrate each analytical method discussed in the previous section. Furthermore, the tools reviewed here only include those that have a pedagogical intent of teaching or helping students to improve their writing with the help of instructions and/or automated feedback. This means that operational tools such as *Microsoft Word* are not included even though they perform computational analysis to provide suggestions on spelling, grammar and synonyms.

Criterion, a web-based essay assessment tool to provide scores and feedback to school students (Burstein et al., 2003) used an essay scoring engine called *e-rater* that assessed the writing on linguistic features such as grammar, usage, mechanics, style and essay discourse elements. A similar tool called *WriteToLearn*, developed by Pearson, evaluated essays based on writing traits such as content development, effective use of sentences, focus, grammar usage, mechanics, and word choice, along with more specialized measures such as semantic coherence, voice, or the reading difficulty of the essay (Landauer et al., 2009). Most of the automated essay scoring tools use this linguistic approach, some of which are currently no longer in use (Dikli, 2006).

Writing Mentor, a Google doc plug-in for writing feedback used NLP methods and resources to generate feedback in terms of features and sub-constructs like the use of sources, claims, and evidence; topic development; coherence; and knowledge of English conventions (Madnani et al., 2018). Using those features, it highlighted features of text to show if the writing is convincing, well-developed, coherent and well-edited, and raises prompting questions to explore them further. Grammarly[1] is a popular web-based tool that provided feedback on spelling, grammar and word usage for all forms of writing based on NLP and machine learning technologies. The intelligent tutor *Writing-Pal (W-Pal)* provided scores and feedback using linguistic text features for students to practice timed persuasive essays using SAT prompts. It taught writing skills to school students providing strategy instruction, modularity, extended practice, and formative feedback using game-based and essay-writing practice (McNamara et al., 2019).

The second type of tools that perform semantic or topic analysis are discussed next. *EssayCritic* performed latent semantic analysis by identifying the presence of specific topics in short texts (<500 words) by training the system using a pre-defined knowledge base of themes and concepts related to a particular topic (Mørch et al., 2017). Feedback was provided to students in the form of sub-themes identified and sub-themes suggested (currently missing) from the written essay. *WRITEEVAL* was another tool used to assess school students' textual responses to short answer questions in Science as correct, partially correct or incorrect using text similarity and semantic analysis techniques (Leeman-Munk et al., 2014). While it performed well with summative analyses of student performance, note that it was not designed for open-ended writing. Studies have also used semantic and word similarities (Afrin & Litman, 2019; Shibani, 2020) at the sentence level to perform revision analysis.

An example of the third type of tools where the underlying technology is Natural Language Processing (NLP) patterns is *AcaWriter*. AcaWriter (previously called *AWA*) provided automated feedback on academic writing tuned to specific learning contexts in higher education by highlighting rhetorically salient sentences (Knight et al., 2020). It used natural language processing rules defined by linguistic experts to extract rhetorical moves such as establishing background knowledge, summarising ideas, contrasting existing work etc. and contextualizes its feedback to specific subjects by co-designing them with the instructors (Shibani et al., 2019). AcaWriter also consisted of a reflective parser which aided the development of reflective writing skills among students, previously using a NLP based approach (Gibson et al., 2017),

[1] https://www.grammarly.com/.

which is now moving towards including machine learning techniques. *Docuscope* is another tool that used patterns and tokens for computer-assisted rhetorical analysis and writing instruction (Wetzel et al., 2021). It contained an expansive dictionary of more than 12 million base patterns in a three-level taxonomy: "36 categories at the highest level of the dictionary (which DocuScope terms "Clusters"), 3,474 categories at the middle level (called "Dimensions"), and 56,016 categories at the lowest level (called "LATs")". The tool has been used in multiple cases of curriculum mapping and classroom feedback.

A recent research area around argumentation mining and computational argumentation is gaining momentum, which aids automatic extraction of arguments from text. This has been applied to persuasive essays for identifying argumentative discourse structures to classify each clause as major claim, claim, premise, non-argumentative, or none (Stab & Gurevych, 2014) using a NLP rules based approach, with more recent work using machine learning approaches to detect the quality of arguments (Stab & Gurevych, 2017). This can aid the development of tools with the capability of giving feedback on transferable 'soft skills' such as argumentation, reflection and creativity in writing, which are still relatively rare in higher education (Shibani et al., 2022) and identified as an area for future research (Allen et al., 2015).

The final type of tools using machine learning approaches are discussed next. *Research Writing Tutor (RWT)* is an AWE tool tuned for graduate student contexts to learn research article writing (Cotos & Pendar, 2016). RWT contained three modules: a learning module called Understand Writing Goals, a demonstration module called Explore Published Writing, and a feedback module called Analyze My Writing which used supervised machine learning to automatically identify moves and steps in a research article using the CARS model (Swales, 2004). *Turnitin Revision Assistant* is an automated feedback tool that also used machine learning techniques to provide data-driven contextualization using a large text corpora with millions of student examples. It had a generalized set of features which are mapped to rubric elements of specific prompts for feedback on essays written for the prompt (Woods et al., 2017).

5 Research and Evaluation

Research on the effectiveness of technologies and tools discussed above generally falls within two categories:

1. Validation of the technical approach used (for example, accuracy of the machine learning model in comparison to human scoring).
2. Effectiveness of the tool in improving student writing and usability.

AES systems used a large number of graded texts to predict the scores of student essays in standardized writing tests, and/or used benchmarked essays for a topic which were then used to compare and grade student essays with high reliability (Rudner et al., 2006; Shermis et al., 2003). For WritetoLearn, the validity of the underlying Intelligent Essay Assessor which scored the essays was established using high accuracy and 91% reliability correlation with human raters (Foltz et al., 2000).

In educational settings however, it is important to evaluate how automated tools impact student writing practice and such studies are discussed next. One study on the usage of *Criterion* reported improvements in essay scores, error rates and introduction of discourse elements in subsequent versions (Attali, 2004), whereas another also showed concerns about the quality of feedback (Li et al., 2015). *WritetoLearn* evaluations from over 1.3 million student essays showed improved writing skills (Foltz & Rosenstein, 2015).

For *Writing Mentor*, perceived usability of the tool was found to be generally positive (Madnani et al., 2018), but the impact of its feedback on actual improvements in writing is yet to be tested. A research article exploring the use of Grammarly by higher educational students found that students generally thought that Grammarly was useful and easy to use, and stated that it increased their confidence in writing and their understanding of grammatical concepts (Cavaleri & Dianati, 2016). A user study with 65 high school students using *W-Pal* found it moderately helpful with a call for combining feedback with strategy instruction, educational games, and essay-based practice to support writing (McNamara et al., 2019). An experimental study for the evaluation of *Essay critic* found no statistically significant difference in grades or essay length (Lee et al., 2013), however, in a more recent study, students receiving feedback from the tool wrote more sub-themes than the other group (Mørch et al., 2017).

AcaWriter empirically evaluated in authentic classroom settings in large undergraduate classrooms showed significant differences in perceived usefulness among students in experimental settings with writing improvements in students receiving automated feedback and positive comments from instructors (Knight et al., 2020). Numerous studies have been conducted to determine usefulness and effectiveness *Research Writing Tutor (RWT)* with empirical evidence that the tool helped students learn genre conventions, enhance their cognition and revision strategies, and improve their writing and motivation (Cotos & Pendar, 2016). A large-scale evaluation of the *Turnitin Revision Assistant* provided moderate evidence of growth in student outcomes from 33 high schools in the US (Woods et al., 2017).

A conclusion from many student evaluation studies is that it is necessary to couple the tools with well-designed writing instruction to make effective use of them in classroom practice.

6 Implications for Writing Practice

Analytic techniques and automated approaches to analyse writing have several implications for writing research and practice. Firstly, they make the assessment process more efficient and scalable by offering speed, consistency and objectivity. As discussed earlier, these tools and techniques are used in standardized testing and automated scoring engines by capturing writing features that predict quality.

Although automated essay evaluation systems have demonstrated reasonable performance in some studies, they are also criticized in other studies for using shallow features, predetermined comments, and ignoring content meaning and argumentation (Chen & Cheng, 2008; Ericsson & Haswell, 2006). Critics argue that automated essay evaluations do not consider the social aspect of writing and are decontextualized from specific sites of learning (Vojak et al., 2011), so they induce training students to write for machines and not for humans (Cheville, 2004; Kukich, 2000). The efficiency of such systems was thus questioned since writing includes more meaningful engagement than merely formulaic features of text.

In addition, the automated scores are validated using statistical evidences of human–computer agreement, but how do we determine how much agreement is acceptable? The reliability measures for computational systems might not work in complex learning environments, and in some cases even imperfect analytics could lead to better learning opportunities for the student (Kitto et al., 2018). The implicit biases in models can also lead to disadvantages for L2 writers and incorrect high-stakes decisions (for example, outliers and cases that don't confine to standards might be penalized). Hence, such systems should be used with utmost care ensuring algorithmic fairness and ethical use, and offer explainability for the decisions made (Khosravi et al., 2022). Further, the errors flagged to students as a result of formulaic features might direct students to place a lot of emphasis on errors which may not be very serious threats to writing skills (Cheville, 2004). The over-reliance on automated scoring could also reduce focus on the development of human assessment skills for teachers. Hence, it is important to use it as a tool for additional assistance, always in combination with human support.

A significant implication of such systems is that they can change the nature of writing if they become the general norm. Students learning to write for the machine (consciously or unconsciously) and teachers teaching tricks from the pressure for high performance can fundamentally change the definitions of good writing. Students might game the system in order to get high marks by writing longer essays and plagiarising since the systems cannot detect such features; on the other hand, these can easily be detected by human graders (Kukich, 2000). Writing prompts could also be reduced to what can be programmed by the machine rather than building higher order skills such as creativity and argumentation as systems cannot verify factual correctness and argumentation quality. In addition, automated feedback might ignore context and be incorrect because of the inherent imperfections in algorithms. Future learners should develop advanced competencies such as Automated feedback literacy (Shibani et al., 2022) for meaningful engagement by learning when to agree and when to disagree and push back against the feedback. Such skill development will require purposeful design for learning to increase students' cognition and writing skills aligning them to specific instructional goals and curriculum (Shibani et al., 2019).

Another key aspect in the use of computational techniques is that they enable the study of previously invisible writing processes using finer grained log data. This can aid writing research of drafting, revision and editing processes at a larger scale and in a non-invasive manner when compared to traditional methods (Conijn et al., 2018; Shibani, 2020). However, they can tend to emphasize quantitative over qualitative approaches, missing the nuances in writing and the thought processes involved. Also, while there are a number of techniques and features used by different tools, there is no single integrated tool that provides all options for a user to choose from. Such a tool can let users understand the features the analysis is based on and select different quality metrics to provide maximum control and personalized support relevant to individual needs.

7 Conclusion

As writing becomes increasingly digitized, tools and technologies offer automated analysis to increase the efficiency of feedback, scoring, and writing instruction. The chapter provided an overview of the analytic techniques that support automated writing analysis and introduced a taxonomy for the different approaches used. An understanding of the underlying technology and analytical approaches helps in identifying suitable tools to address specific needs of educators and students. In the current scenario where a plethora of tools are available for analysis, including educational technology specifically developed for writing instruction, moving beyond the appreciation of technical capabilities to finding actual impact in the classroom and selecting the right tools that are fit for purpose is a necessity—this chapter is a guiding step towards that direction.

A careful examination of the roles and implications of technology for writing analysis highlights that while machines can reliably assess the quality of writing to an extent, they do not truly understand texts and its social contexts. Rather than being over-awed by the capabilities and opportunities offered by automated analysis, it is imperative to understand their underlying biases and errors due to the inherent complexities in language, as they can lead to negative consequences such as lack of trust, disadvantages for some writers and incorrect high-stakes decisions. The over-reliance on such technology can also reduce focus on the development of human skills and create a dependence on the system for writing.

Hence, it is ideal to use such technology to provide just-in-time assistance for writing in combination with other forms of pedagogical support for specific learning goals and provide due attention to the development of human skills in tandem. The writing support tools should also focus on upskilling learners using new perspectives and ways, rather than just making existing processes more efficient.

8 List of Tools Referenced in the Chapter

S. No.	Tool/software	Description of the tool and underlying technology	Reference [#]	URL if available
1	Coh-metrix	Computational tool to calculate metrics of cohesion and coherence	Graesser et al. (2004)	http://cohmetrix.com/
2	Linguistic Inquiry and Word Count (LIWC)	Text analysis tool for the calculation of linguistic metrics	Pennebaker et al. (2001)	https://www.liwc.app/
3	Stanford CoreNLP	Downloadable toolkit for the calculation of NLP metrics	Manning et al. (2014)	https://stanfordnlp.github.io/CoreNLP/
4	Criterion	Automated Writing Evaluation (AWE) tool based on linguistic features	Burstein et al. (2003)	https://criterion.ets.org/criterion/default.aspx
5	WriteToLearn	Automated Writing Evaluation (AWE) tool based on linguistic features	Landauer et al. (2009)	https://www.pearsonassessments.com/store/usassessments/en/Store/Professional-Assessments/Academic-Learning/WriteToLearn/p/100000030.html
6	Writing Mentor	A Google doc plug-in for automated feedback using NLP and linguistic features	Madnani et al. (2018)	https://mentormywriting.org/
7	Grammarly	A web-based writing assistant using NLP and machine learning	Cavaleri and Dianati (2016)	https://www.grammarly.com/
8	Writing-Pal (W-Pal)	Intelligent Tutoring System (ITS) based on linguistic features	McNamara et al. (2019)	http://www.adaptiveliteracy.com/writing-pal
9	EssayCritic	Web-based automated feedback tool based on semantic analysis of short texts	Mørch et al. (2017)	NA (Unavailable for external access)
10	WRITEEVAL	Text analytics method using text similarity and semantic analysis techniques for analysing constructed question responses	Leeman-Munk et al. (2014)	NA (Unavailable for external access)

(continued)

(continued)

S. No.	Tool/software	Description of the tool and underlying technology	Reference [#]	URL if available
11	AcaWriter	Web-based automated feedback tool using NLP rules	Knight et al. (2020)	https://acawriter.uts.edu.au/
12	Docuscope	Automated feedback and corpus analysis tool using pre-defined dictionaries and visualisations	Wetzel et al. (2021)	https://www.cmu.edu/dietrich/english/research-and-publications/docuscope.html
13	Research Writing Tutor (RWT)	Web-based automated feedback tool for graduate students using machine learning	Cotos and Pendar (2016)	NA (Unavailable for external access)
14	Turnitin Revision Assistant	Automated feedback tool using machine learning	Woods et al. (2017)	https://www.turnitin.com/products/revision-assistant

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Automated Scoring of Writing

Stephanie Link and Svetlana Koltovskaia

Abstract For decades, automated essay scoring (AES) has operated behind the scenes of major standardized writing assessments to provide summative scores of students' writing proficiency (Dikli in J Technol Learn Assess 5(1), 2006). Today, AES systems are increasingly used in low-stakes assessment contexts and as a component of instructional tools in writing classrooms. Despite substantial debate regarding their use, including concerns about writing construct representation (Condon in Assess Writ 18:100–108, 2013; Deane in Assess Writ 18:7–24, 2013), AES has attracted the attention of school administrators, educators, testing companies, and researchers and is now commonly used in an attempt to reduce human efforts and improve consistency issues in assessing writing (Ramesh and Sanampudi in Artif Intell Rev 55:2495–2527, 2021). This chapter introduces the affordances and constraints of AES for writing assessment, surveys research on AES effectiveness in classroom practice, and emphasizes implications for writing theory and practice.

Keywords Automated essay scoring · Summative assessment

1 Overview

Automated essay scoring (AES) is used internationally to rapidly assess writing and provide summative holistic scores and score descriptors for formal and informal assessments. The ease of using AES for response to writing is especially attractive for large-scale essay evaluation, providing also a low-cost supplement to human scoring and feedback provision. Additionally, intended benefits of AES include the elimination of human bias, such as rater fatigue, expertise, severity/leniency, inconsistency,

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_21

and Halo effect. While AES developers also commonly suggest that their engines perform as reliably as human scorers (e.g., Burstein & Chodorow, 2010; Riordan et al., 2017; Rudner et al., 2006), AES is not free of critique. Automated scoring is frequently under scrutiny for use with university-level composition students in the United States (Condon, 2013) and second language writers (Crusan, 2010), with some writing practitioners discouraging its replacement of adequate literacy education because of its inability to evaluate meaning from a humanistic, socially-situated perspective (Deane, 2013; NCTE, 2013). AES also suffers from biases, such as imperfections in the quality and representation of training data to develop the systems and inform feedback generation. These biases question the fairness of AES (Loukina et al., 2019), especially if scores are modeled based on data that does not adequately represent a user population—a particular concern for use of AES with minoritized populations.

Despite reservations, the utility of AES in writing practices has increased significantly in recent years (Ramesh & Sanampudi, 2021), partially due to its integration into classroom-based tools (see Cotos, "Automated Feedback on Writing" for a review of automated writing evaluation). Thus, the affordances of AES for language testing are now readily available to writing practitioners and researchers, and the time is ripe for better understanding its potential impact on the pedagogical approaches to writing studies by first better understanding the history that drives AES development.

Dating back to the 1960s, AES started with the advent of Project Essay Grade (Page, 1966). Since then, automated scoring has advanced into leading technologies, including e-rater by the Educational Testing Service (ETS) (Attali & Burstein, 2006), Intelligent Essay Assessor (IEA) by Knowledge Analysis Technologies (Landauer et al., 2003), Intellimetric by Vantage Learning (Elliot, 2003), and a large number of prospective newcomers (e.g., Nguyen & Dery, 2016; Riordan et al., 2017). These AES engines are used for tests like the Test of English as a Foreign Language (TOEFL iBT), Graduate Management Admissions Test (GMAT), and the Pearson Test of English (PTE). In such tests, AES researchers not only found the scores reliable, but some argued that they also allowed for reproducibility, tractability, consistency, objectivity, item specification, granularity, and efficiency (William et al., 1999), characteristics that human raters can lack (Williamson et al., 2012).

The immediate AES response to writing is without much question a salient feature of automated scoring for testing contexts. However, research on classroom-based implementation has suggested that instructors can utilize the AES feedback to flag students' writing that requires teachers' special attention (Li et al., 2014), highlighting its potential for constructing individual development plans or conducting analysis of students' writing needs. AES also provides constant, individualized feedback to lighten instructors' feedback load (Kellogg et al., 2010), enhance student autonomy (Wang et al., 2013), and stimulate editing and revision (Li et al., 2014).

2 Core Idea of the Technology

Automated essay scoring involves automatic assessment of a students' written work, usually in response to a writing prompt. This assessment generally includes (1) a holistic score of students' performance, knowledge, and/or skill and (2) a score descriptor on how the student can improve the text. For example, e-rater by ETS (2013) scores essays on a scale from 0 to 6. A score of 6 may include the following feedback:

Score of 6: Excellent
Your essay
Looks at the topic from a number of angles and responds to all aspects.
Responds thoughtfully and insightfully to the issues in the topic.
Develops with a superior structure and apt reasons or examples.
Uses sentence styles and language that have impact and energy.
Demonstrates that you know the mechanics of correct sentence structure.

AES engine developers over the years have undertaken a core goal of making the assessment of writing accurate, unbiased, and fair (Madnani & Cahill, 2018). The differences in score generation, however, are stark given the variation in philosophical foundations, intended purposes, extraction of features for scoring writing, and criteria used to test the systems (Yang et al., 2002). To this end, it is important to understand the prescribed use of automated systems so that they are not implemented inappropriately. For instance, if a system is meant to measure students' writing proficiency, the system should not be used to assess students' aptitude. Thus, scoring models for developing AES engines are valuable and effective in distinct ways and for their specific purposes.

Because each engine may be designed to assess different levels, genres, and/or skills of writing, developers utilize different natural language processing (NLP) techniques for establishing construct validity, or the extent to which an AES scoring engine measures what it intends to measure—a common concern for AES critics (Condon, 2013; Perelman, 2014, 2020). NLP helps computers understand human input (text and speech) by starting with human and/or computer analysis of textual features so that a computer can process the textual input and offer reliable output (e.g., a holistic score and score descriptor) on new text. These features may include statistical features (e.g., essay length, word co-occurrences also known as n-grams), style-based features (e.g., sentence structure, grammar, part-of-speech), and content-based features (e.g., cohesion, semantics, prompt relevance) (see Ramesh & Sanampudi, 2021, for an overview of features). Construct validity should thus be interpreted in relation to feature extraction of a given AES system to adequately appreciate (or challenge) the capabilities that system offers writing studies.

In addition to a focus on a variety of textual features, AES developers have utilized varied machine learning (ML) techniques to establish construct validity and efficient score modeling. Machine learning is a category of artificial intelligence (AI) that helps computers recognize patterns in data and continuously learn from the data to make accurate holistic score predictions and adjustments without further programming (IBM, 2020). Early AES research utilized standard multiple regression analysis to predict holistic scores based on a set of rater-defined textual features. This approach was utilized in the early 1960s for developing Project Essay Grade by Page (1966), but it has been criticized for its bias in favor of longer texts (Hearst, 2000) and its ignorance towards content and domain knowledge (Ramesh & Sanampudi, 2021).

In subsequent years, classification models, such as the bag of words approach (BOW), were common (e.g., Chen et al., 2010; Leacock & Chodorow, 2003). BOW models extract features in writing using NLP by counting the occurrences and co-occurrences of words within and across texts. Texts with multiple shared word strings are classified into similar holistic score categories (e.g., low, medium, high) (Chen et al., 2010; Zhang et al., 2010). E-rater by ETS is a good example of this approach. The aforementioned approaches are human-labor intensive. Latent semantic analysis (LSA) is advantageous in this regard; it is also strong in evaluating semantics. In LSA, the semantic representation of a text is compared to the semantic representation of other similarly scored responses. This analysis is done by training the computer on specific corpora that mimics a given writing prompt. Landauer et al. (2003) used LSA in Intelligent Essay Grade.

Advances in NLP and progress in ML have motivated AES researchers to move away from statistical regression-based modeling and classification approaches to advanced models involving neural network approaches (Dong et al., 2017; Kumar & Boulanger, 2020; Riordan et al., 2017). To develop these AES models, data undergoes a process of supervised learning, where the computer is provided with labeled data that enables it to produce a score as a human would. The supervised learning process often starts with a training set—a large corpus of representative, unbiased writing that is typically human- or auto-coded for specific linguistic features with each text receiving a holistic score. Models are then generated to teach a computer to identify and extract these features and provide a holistic score that correlates with the human rating. The models are evaluated on a testing set that the computer has never seen previously. Accuracy of algorithms is then evaluated by using testing set scores and human scores to determine human–computer consistency and reliability. Common evaluations are quadrated weighted kappa, Mean Absolute Error, and Pearson Correlation Coefficient.

Once accuracy results meet an industry standard (Powers et al., 2015), which varies across disciplines (Weigle, 2013), the algorithms are made public through user-friendly interfaces for testing contexts (i.e., to provide summative feedback, formal assessments to assess students' performance or proficiency) and direct classroom use (i.e., informal assessments to improve students' learning). For the classroom, teachers should be active in evaluating the feedback to determine whether it is reasonably accurate in assessing a learning goal, does not lead students away from the goal, and encourages students to engage in different ways with their text and/or the course content. Effective evaluation of AES should start with an awareness of AES affordances that can impact writing practice and then continue with the training of students in the utility of these affordances.

3 Functional Specifications

The overall functionality of AES for classroom use is to provide summative assessment of writing quality. AES accomplishes this through two key affordances: a holistic score and score descriptor.

Holistic score: The summative score provides an overall, generic assessment of writing quality. For example, Grammarly provides a holistic score or "performance" score out of 100%. The score represents the quality of writing (as determined by features, such as word count, readability statistics, vocabulary usage). If a student receives a score below 60–70%, this means that it could be understood by a reader who has a 9th grade education. For the text to be readable by 80% of English speakers, Grammarly suggests getting at least 60–70%.

Score descriptor: The holistic score is typically accompanied by a descriptor that indicates what the score represents. This characterization of the score meaning can be used to interpret the feedback, evaluate the feedback, and make decisions regarding editing and revising.

That is, these key affordances can be utilized to complete several main activities.

Interpreting feedback: Once students receive the holistic score along with the descriptor, they should interpret the score. Information provided for adequate score interpretation varies across AES systems, so students may need help in interpreting the meaning of this feedback.

Evaluating feedback: After interpreting the score and the descriptor, students need to think critically about how the feedback applies to their writing. That is, students need to determine whether the computer feedback is an adequate representation of their writing weaknesses. Evaluating feedback thus entails noticing the gap or problem found in one's own writing and becoming consciously aware of how the feedback might be used to increase the quality of writing through self-editing (Ferris, 2011).

Making a decision about action: Once students evaluate their writing based on a given score and descriptor, they then need to decide whether to address the issues highlighted in the descriptor or seek additional feedback. Making and executing a revision plan can ensure that the student is being critical towards the feedback rather than accepting it outright.

Revising/editing: The student then revises the paper and resubmits it to the system to see if the score improves—an indicator of higher quality writing. If needed, the student can repeat the above actions or move on to editing of surface-level writing concerns.

4 Research on AES

AES research can be categorized along two lines: system-centric research that evaluates the system itself and user-centric research that evaluates use/impact of a system on learning. From a system-centric perspective, various studies have been conducted to validate AES-system-generated scores for the testing context. The majority have focused on reliability, or the extent to which results can be considered consistent or stable (Brown, 2005). They often evaluate reliability based on agreement between human and computer scoring (e.g., Burstein & Chodorow, 1999; Elliot, 2003; Streeter et al., 2011). (See Table 1 for a summary of reliability statistics from three major AES developers.)

The process of establishing validity should not start and stop with inter-coder reliability; however, automated scoring presents some distinctive validity challenges, such as "the potential to under- or misrepresent the construct of interest, vulnerability to cheating, impact on examinee behavior, and score users' interpretation and use of scores" (Williamson et al., 2012, p. 3). Thus, some researchers have also demonstrated reliability by using alternative measures, such as the association with independent measures (Attali et al., 2010) and the generalizability of scores (Attali et al., 2010). Others have gone a step further and suggested a unified approach to AES validation (Weigle, 2013, Williamson et al., 2012). In general, results reveal promising developments in AES with modest correlations between AES and external criteria, such as independent proficiency assessments (Attali et al., 2010; Powers et al., 2015, suggesting that automated scores can relate in a similar manner to select assessment criteria and that both have the potential to reflect similar constructs, although results across AES systems can vary, and not all data are readily available to the public.

While much research has focused on reliability of AES, little is known about the quality of holistic scores in testing or classroom contexts as well as teachers' and students' use and perceptions of automatically generated scores. In a testing

Table 1 Summary of human–computer reliability studies from three top developers

AES system	Testing context[a]	Prompt types	Human–Computer Reliability	Study
e-rater	GRE TOEFL iBT	Argument and issues prompts	Weighted Kappa 0.70–0.78 Pearson's r 0.70–0.80	Attali et al. (2010)
IntelliMetric	GMAT	Argument and issues prompts	Pearson's r 0.80–0.84	Rudner et al. (2006)
Intelligent Essay Assessor	PTE	Argument, issues, and narrative prompts	Pearson's r 0.88–0.91	Streeter et al. (2011)

Note [a]GRE = Graduate Record Examination
TOEFL = Test of English as a Foreign Language internet-based test
GMAT = Graduate Management Admission Test
PTE = Pearson Test of English

context, James (2006) compared the IntelliMetric scores of the ACCUPLACER OnLine WritePlacer Plus test to the scores of "untrained" faculty raters. Results revealed a relatively high level of correspondence between the two. In a similar study with a group of developmental writing students in a two-year college in South Texas, Wang and Brown (2007) found that ACCUPLACER's overall holistic mean score showed significant difference between IntelliMetric and human raters, indicating that IntelliMetric tends to assign higher scores than human raters do. Li et al. (2014) investigated the correlation between Criterion's numeric scores with the English as a second language instructors' numeric grades and analytic ratings for classroom-based assessment. The results showed low to moderate positive correlations between Criterion's scores and instructors' scores and analytic ratings. Taken together, these studies suggest limited continuity of findings on AES reliability across tools.

Results of multiple studies demonstrate varied uses for holistic scores and varied teachers' and students' perceptions toward the scores. For example, Li et al. (2014) found that Criterion's holistic scores in the English as a second language classroom were used in three ways. First, instructors used the scores as a forewarning. That is, the scores alerted instructors to problematic writing. Second, the scores were used as a pre-submission benchmark. That is, the students were required to obtain a certain score before submitting a final draft to their teacher. Finally, Criterion's scores were utilized as an assessment tool—scores were part of course grading. Similar findings were reported in Chen and Cheng's (2008) study that focused on EFL Tawainese teachers' and students' use and perception of My Access! While one teacher used My Access! as a pre-submission benchmark, the other used it for both formative and summative assessment, heavily relying on the scores to assessing writing performance. The third teacher did not make My Access! a requirement and asked the students to use it if they needed to.

In terms of teachers' perceptions of holistic scores, holistic scores seem to be motivators for promoting student revision (Li et al. 2014; Scharber et al., 2008) although a few teachers in Maeng (2010) commented that the score caused some stress albeit was still helpful for facilitating the feedback process (i.e., for providing sample writing and revising). Teachers also tend to have mixed confidence in holistic scores (Chen & Cheng, 2008; Li et al, 2014). For example, in Li et al.'s (2014) study, English as a second language instructors had high trust in Criterion's low holistic scores as the essays Criterion scored low were, in fact, poor essays. However, instructors possessed low levels of trust when Criterion assigned high scores to writing as instructors judged such writing lower.

Students also tend to have low trust in holistic scores (Chen & Cheng, 2008; Scharber et al., 2008). For example, Chen and Cheng (2008) found that EFL Taiwanese students' low level of trust in holistic scores was influenced by teachers' low level of trust in the scores as well as discrepancies in teachers' scores and holistic scores of My Access! that students noticed. Similar findings were reported in Scharber et al.'s (2008) study that focused on Educational Theory into Practice Software's (ETIPS) automated scorer implemented in a post-baccalaureate program at a large public Midwestern US university. The students in their study experienced negative emotions due to discrepancies in teachers' and ETIPS' holistic scores. ETIPS scores were one point lower than teachers' scores. Additionally, the students found holistic scores with the short descriptor insufficient in guiding them as to how to actually improve their essays.

5 Implications of This Technology for Writing Theory and Practice

The rapid advancement of NLP and ML approaches to automated scoring lends well to theoretical contributions that help to (re-)define traditional notions of how learning takes place and the phenomena that underscores language development. Social- and cognitive-based theories to writing studies can be expanded with the integration of AES technology by offering new, socially-situated learning opportunities in online environments that can impact how students respond to feedback. These digitally-rich learning opportunities can thus significantly impact the writing process, offering a new mode of feedback that can be meaningful, constant, timely, and manageable while addressing individual learner needs. From a traditional pen-and-paper approach, these benefits are known to contribute significantly to writing accuracy (Hartshorn et al., 2010), and so the addition of rapid technology has the potential to add new knowledge to writing development research.

AES research can also contribute to practice. Due to its instantaneous nature, AES holistic scores could be used for placement purposes (e.g., by using ACCUPLACER) at schools, colleges, and universities. However, relying on the AES holistic score alone may not be adequate. Therefore, just like in large-scale tests, it is important that students' writing is double-rated to enhance reliability, with a third rater used if there is a discrepancy in AES holistic score and a human rater's score. Similarly, AES holistic scores could be used for diagnostic assessment. Diagnostic assessment is given prior to or at the start of the semester/course to get information about students' language proficiency as well as their strengths and weaknesses in writing. Finally, AES scoring could be used for summative classroom assessment. For example, teachers could use AES scores as a pre-submission benchmark and require students to revise their essays until they get a predetermined score, or teachers could use the AES score for partial (rather than sole) assessment of goal attainment (Li et al., 2014; Weigle, 2013). Overall, in order to avoid pitfalls such as students focusing too intensively on obtaining high scores without actually improving their writing skills, teachers and students need to be trained or seek training on the different merits and demerits of a selected AES scoring system.

6 Concluding Remarks

While traditional approaches to written corrective feedback are still leading writing studies research, the ever-changing digitalization of the writing process shines light on new opportunities for enhancing the nature of feedback provision. The evolution of AI will undoubtedly expand the affordances of AES so that writing in digital spaces can be supplemented by computer-based feedback that is increasingly accurate and reliable. For now, these technologies are only foregrounding what can come from technological advancements, and in the meantime, it is the task of researchers and practitioners to cast a critical eye while also remaining open to the potential for AES technologies to promote autonomous, lifelong learning and writing development.

7 Tool List

List of well-known Automated Essay Scoring (AES) Tools

N	Tool	Description	Suggested use	Reference
1	**E-rater** in Criterion (https://criterion.ets.org/criterion/default.aspx) and Turnitin (https://www.turnitin.com/)	E-rater was developed by Educational Testing Service (ETS) to identify features related to writing proficiency in student essays	The suggested use is with middle school to high school students with writing prompts available for first- and second-year university students	Attali and Burstein (2006)
2	**Intellimetric** (https://www.intellimetric.com/direct)	Intellimetric that was developed by Vantage Learning is a web-based tool capable of scoring short and long writing pieces in more than 20 languages (e.g., English varieties, Bahasa Malaysia, Chinese, Turkish, and Spanish)	Although marketed for all aged-writers, most research using Intellimetric is found to successfully assess writing of middle-schoolers (about ages 11–13) and those seeking writing placement using the accompanying technology the ACCUPLACER OnLine WritePlacer Plus test, a standardized placement test that measures writing proficiency of entry-level college students (https://accuplacer.collegeboard.org/)	Elliot (2003)

(continued)

(continued)

N	Tool	Description	Suggested use	Reference
3	**Intelligent Essay Assessor (IEA)** (https://www.pearsonassessments.com/)	IEA uses knowledge analysis technologies (KAT) engine and is available in Pearson's WritetoLearn web-based tool	IEA is intended for grades 4–12. This technology can assess English, Spanish, and Chinese writers	Landauer et al. (2003)
4	**Educational Theory into Practice Software (ETIPS)** (http://www.etips.info/)	ETIPS is an online learning environment that was developed in 2003. Its AES engine is built using a Bayseian model for essay scoring. It is noteworthy that ETIPS AES does not score essays that "deal with other than ETIPS case-specific questions and topics" (Scharber et al., 2008, p. 9)	Its intended audience are pre-service teachers preparing for technology implementation in their classrooms. Its embedded assessment feature is designed for K-12 students	Dexter (2007)

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Automated Feedback on Writing

Elena Cotos

Abstract Automated Writing Evaluation (AWE) tools have not only confidently entered the scene of digital writing technologies but also secured a prominent space in teaching and learning practices due to their formative automated feedback on various traits of the writing construct. The nature and types of AWE feedback vary depending on the history and origins of the tools. Having evolved through multiple generations, they can be broadly categorized as assessment-driven and genre-based. This chapter elaborates on both of these ramifications of AWE, describing their purposes, functional specifications, and two exemplary tools. AWE research has been increasingly adopting the validity argument framework, which allows to consolidate multifarious evidence into a progression of empirically supported inferences about AWE uses. To that end, AWE effectiveness has been investigated in terms of: how well the tools represent the target writing domains; how accurate, consistent, and appropriate the feedback is; whether the feedback extrapolates to other contexts and feedback sources; how the tools are utilized; and what their beneficial effects are. The implications discussed following a brief synthesis of this research highlight the need for advancing the theory-research-practice interface, contemplating the potential for theorizing the modelling of cognitive writing in a digital environment, which could further inform the design and implementation of the next-generation of AWE tools.

1 Overview

The definition commonly attributed to automated evaluation of writing is "the ability of computer technology to evaluate and score written prose" (Shermis & Burstein, 2003, p. xiii). Digital writing environments that provide automated feedback on writing are known as Automated Writing Evaluation (AWE) tools. AWE tools originated from automated essay scoring (AES) (chapter "Automated Scoring of Writing"). It must be noted, however, that AWE is not interchangeable with AES and its sister-term automated essay evaluation (AEE). Unlike, AES/AEE whose focus

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_22

is on summative assessment, AWE tools support the process of writing by providing formative feedback that is typically displayed on an engaging graphic interface. Moreover, AWE is a more encompassing term, where *writing* covers any genre and *evaluation* extrapolates to uses beyond scoring.

As AES derivatives, AWE tools employ computational engines that rely on natural language processing (NLP), artificial intelligence, and statistical modelling approaches (chapters "Automated Text Generation and Summarization for Academic Writing to Analytic Techniques for Automated Analysis of Writing;" also Burstein et al., 2003a) to analyze lexical, syntactic, semantic, and discourse traits in written texts. Therefore, their design, development, and implementation are grounded in multi-disciplinary perspectives including Applied Linguistics, Educational Measurement, Computer and Information Sciences, Psychometrics and Quantitative Psychology, Cognitive Psychology and Psycholinguistics, and Writing Studies in first and second languages.

Noting that a "comprehensive history of AWE has yet to be written," Hazelton et al. (2021) delineate AWE tools into three generations based on how technological capabilities developed over time (p. 43). The first-generation exemplar, in their view, is represented by Project Essay Grade (PEG) introduced in the 1960s. While PEG is indeed the pioneer that spearheaded AWE, it aimed to address the challenge of time-intensive grading of student writing and thus essentially falls within the purview of AES (chapter "Automated Scoring of Writing"). Second-generation AWE, which emerged in the 1980s also primarily as efficiency-driven technology, includes tools that provide immediate individualized feedback aiming to alleviate the labour-intensive task for teachers needing to respond to student writing in formative ways. The Writer's Workbench was among the first tools of this kind that provided feedback on aspects of writing including errors and topic sentences, followed by Criterion, MY Access!, Write-To-Learn, etc. It is worth noting that, while initially AWE tools hardly accounted for the needs of second and foreign language learners, language learning theories began to gain a steady influence on AWE research and development in the 2000s (Xi, 2010). The third generation of AWE has taken a "left turn" expanding the ability of this technology to analyze student writing across academic disciplines and writing genres (Burstein et al., 2016a, p. 6). Most recent third generation tools (e.g., freely available Writing Mentor app installed from the Google Docs add-on store) are approaching the functionality of intelligent tutoring systems (ITS) since they provide guided activities to complement the feedback. The Writing Pal is the only ITS representative tool that has an AWE component (McCarthy et al., 2022). Writing Pal is modular, and the AWE component can be used solely for feedback as well as for instruction (chapter "The Future of Intelligent Tutoring Systems for Writing").

2 Core Idea of the Technology

AWE tools serve the purpose of formative assessment and provide practice for writing development. They have been promoted and largely implemented as enhancements for process writing instruction, emphasizing the value of multiple drafting fostered by feedback and other forms of scaffolding. Aligned with the move towards individualized teaching and assessment, AWE is deemed to enhance the dynamics of classroom instruction and to also ensure cross-curricular consistency of writing evaluation. For students, automated feedback is intended as a motivational factor that can guide revision and sustain learner autonomy.

Considering that feedback is at the core of AWE, a two-pronged categorization of AWE alternative to Hazelton et al.'s (2021) can be conceptualized based on the origin of the automated feedback. As mentioned above, most existing AWE tools are descendants of traditional AES used to assess writing performance on constructed-response writing tasks. Such tools can be categorized as *assessment-driven.* Their feedback is corrective in nature, flagging writing traits that may need to be addressed. Most assessment-driven AWE tools are asynchronous and attempt to address grammatical errors as well as more global discourse traits. There are also a few tools such as Grammarly and CyWrite that deliver the feedback synchronously. The second category comprises *genre-based* AWE, whose design is guided by discourse analysis studies of the target domain, learning theories, and pedagogical principles (Cotos, 2022). The first genre-based automated analysis tool called Mover was introduced by Anthony and Lashkia (2003), and the Research Writing Tutor (RWT) and AcaWriter are more recent. What sets them apart is that their asynchronous feedback is operationalized to reflect the rhetorical conventions of specific genres and not to facilitate error correction. The development of genre-based AWE requires large-scale corpus-based research of particular genres, which is why there are still very few such tools. This is perhaps the reason why they were not explicitly noted within Hazelton et al.'s (2021) third generation.

Both assessment-driven and genre-based tools have been used by teachers as a complement to instruction and by writers as aids for independent self-paced and self-regulated writing and revision. Assessment-driven AWE has been widely implemented at all levels of formal instruction, from elementary to higher education and to non-traditional adult learning environments. Higher education has witnessed most implementations in English composition courses at undergraduate level as well as in English as a second and foreign language academic writing university courses. There is hardly a 'prescribed' use. Rather, teachers make decisions regarding the uses of AWE based on instructional needs and learning goals or based on their level of familiarity with the tool. Some teachers encourage students to process and respond to AWE feedback on lower-level concerns and complement that with their own feedback on more global aspects of writing. Others prefer to incentivize students' revision by directing them to the summative, scoring-based feedback on specific writing traits. Yet others tend to disregard automated formative feedback and resort to scoring capabilities only for assessment or test preparation purposes (Stevenson, 2016).

3 Functional Specifications

AWE tools are user-facing systems powered by back-end engines used to generate feedback. For assessment-driven tools, these are scoring engines; for example, Criterion as well as Turnitin's Revision Assistant and Draft Coach use e-rater, Write-To-Learn uses Intelligent Essay Assessor, and MY Access! uses IntelliMetric (chapter "Automated Scoring of Writing"). For genre-based tools, the engines are analytic, trained to 'learn' the rhetorical traits of the genre from a representative annotated corpus and then apply the 'learned' information to identify those traits in new texts. These analytic engines use different text classification approaches (chapter "Analytic Techniques for Automated Analysis of Writing"). For example, AntMover uses a NaïveBayes classifier, RWT uses support vector machine classifiers, and AcaWriter uses a rule-based parser. Distinct from its counterparts whose classifiers adopt models of consecutive words, AcaWriter's parser identifies words or expressions and syntactic dependencies that may instantiate rhetorical concepts.

Given that the scoring engines are trained to detect numerous characteristics of texts, assessment-driven tools' feedback is manifold targeting grammatical forms, syntactic complexity, lexical complexity, style, organization, topical content, idea development, redundancy, relevance, deviance, semantic coherence, mechanics, etc. The formative feedback is commonly embedded in the student's draft. Some tools flag errors and suggest corrections, which are mostly based on how the scoring engine was trained to evaluate writing but can also draw on individual students' error correction history (e.g., TechWriter). Summative feedback can also be offered as a performance summary containing a holistic score, a quantification of errors based on the analyzed traits of writing, and hyperlinks to detailed descriptive feedback on each error category. While most AWE tools are for writing in English, some generate multilingual feedback for second language writers (e.g., Criterion and MY Access!).

Genre-based exemplars address higher order concerns related to rhetorical effectiveness as expected by target discourse communities. Their feedback is operationalized per Swales' (1981) theorizing of genre conventions in terms of communicative goals called 'moves' and functional strategies called 'steps'. Swales' Create-A-Research-Space (CARS) model comprising three moves (Establishing a Territory, Identifying a Niche, Addressing the Niche) and their respective steps (e.g., Claiming Centrality, Highlighting a Problem, Stating the Value, etc.) is to some extent at the core of all existing genre-based tools' analytic engines. While different tools articulate and present their feedback in different ways, essentially writers receive feedback indicating what the sentences in their text are doing communicatively. AntMover, trained to analyze research article abstracts, displays the text split into sentences that are labeled with CARS categories. IADE's feedback visualized the rhetorical composition of research article introductions by color-coding all the sentences in a text for moves, and its RWT successor has expanded this feature with step-level, move-level, and discipline-specific comparative feedback on all the sections of research articles—Introduction-Methods-Results-Discussion/Conclusion (IMRD/C). AcaWriter, on the other hand, gives feedback only for sentences where its rule-based parser identifies concepts indicative of moves (e.g., summarizing issues, describing an open question).

Regardless of the origin and nature of the feedback, AWE tools incorporate a vast array of additional scaffolding features for students. In the interest of brevity, I will only mention select examples here. First, automated feedback may be accompanied by interface features enabling students to solicit feedback from their instructor, who can point to more subtle and more global issues not identifiable automatically. There are also features designed to facilitate guided practice and to help foster the more germane activities of pre-writing, drafting, and revision. Criterion, for instance, contains a Make a Plan feature with a number of templates for planning strategies. MY Access! offers graphical pre-writing tools to assist students with the formulation and organization of their ideas, a word bank for appropriate vocabulary use, a checklist for scoring rubrics for self-assessment, a so-called 'writing coach' suggesting revision goals and remediation activities, and an 'editor' that supplies suggestions for editing. In addition to such features, WriteToLearn uses text-to-speech technologies so that students can hear the text and see the definitions of words in on-demand pop-up windows. MI Write and MI Tutor, the legacy of PEG, offer students graphic organizers, peer review options for giving and receiving peer feedback, and portfolios that allow them to chart their progress toward grade-level proficiency. The WritingRoadmap embeds model sentence diagrams, tutorials on grammar and syntax, a thesaurus, and tips for essay improvement. RWT provides video tutorials for all IMRD/C moves and steps, a move/step annotated multi-disciplinary corpus of published research articles, and a concordancer searchable for examples of all the steps in all the IMRD/C texts in the corpus. Being an ITS, the Writing Pal provides the most tailored scaffolding focused on writing strategies during prewriting, drafting, and revising stages of the writing process.

Apart from this variety of student-focused features, most tools integrate features for teachers. Perhaps most popular are features like chat or electronic sticky notes that bring teacher's comments into the feedback loop for the student. Writing prompts, whether ready-made or created by teachers based on stimulus reading materials pre-packaged in the system, enable them to customize writing assignments for better alignment with learning objectives. Additionally, there are options for monitoring students' use of available scaffolding features and for tracking student progress, as well as for generating proficiency reports for individual students and for full classes or across demographic groups.

4 Main Products

While there are a number of AWE tools that can be considered main products, this section reviews one representative assessment-driven tool and one genre-based tool. Among the former, Criterion is perhaps the most researched and widely implemented commercial product, with features similar to most such tools. Genre-based AWE is well represented by RWT. This non-commercial tool can be considered paradigmatic because it is truly genre-specific, with features most comprehensively covering the rhetorical traits characteristic of the research article genre.

4.1 Criterion

The Educational Testing Service developed Criterion, formally called The Criterion Online Writing Evaluation service, for writers of various age groups in primary, secondary, and higher education settings. The developer describes it as an instructor-led system aimed to help teachers assess student writing performance and progress, and to provide students with self-paced independent writing practice guided by immediate automated feedback. Criterion's technical capabilities are based on two complementary applications: e-rater and Critique. The former is a scoring engine that assigns a holistic score based on statistical modelling of how linguistic and text features are related to overall writing quality; the latter contains a suite of programs that generate feedback (Burstein et al., 2003b). The feedback covers five major traits: grammar, usage, mechanics, style, and organization and development, detailing specific types of errors within each trait (see Table 1).

It takes Criterion less than twenty seconds to assess a submitted text and generate a performance summary presenting a holistic score, the number of errors, and feedback comments corresponding to each error. Note that it does not display the errors of all

Table 1 Criterion's feedback traits and error types

Grammar	Usage	Mechanics	Style	Organization and development
Fragment or missing comma Run-on sentences Garbled sentences Subject–verb agreement Ill-formed verbs Pronoun errors Possessive errors Wrong or missing word Proofread this!	Determiner noun agreement Missing or extra article Confused words Wrong form of word Faulty comparisons Preposition error Nonstandard word form Negation error Wrong part of speech Wrong article	Spelling Capitalize proper nouns Missing initial capital letter in a sentence Missing question mark Missing final punctuation Missing apostrophe Missing comma Hyphen error Fused words Compound word Duplicates Extra comma	Repetition of words Inappropriate words or phrases Sentences beginning with coordinating conjunctions Short sentences Long sentences Passive voice	Introductory material: thesis statement, topic relationship and technical quality Main ideas Supporting ideas Conclusion Transitional words and phrases Other

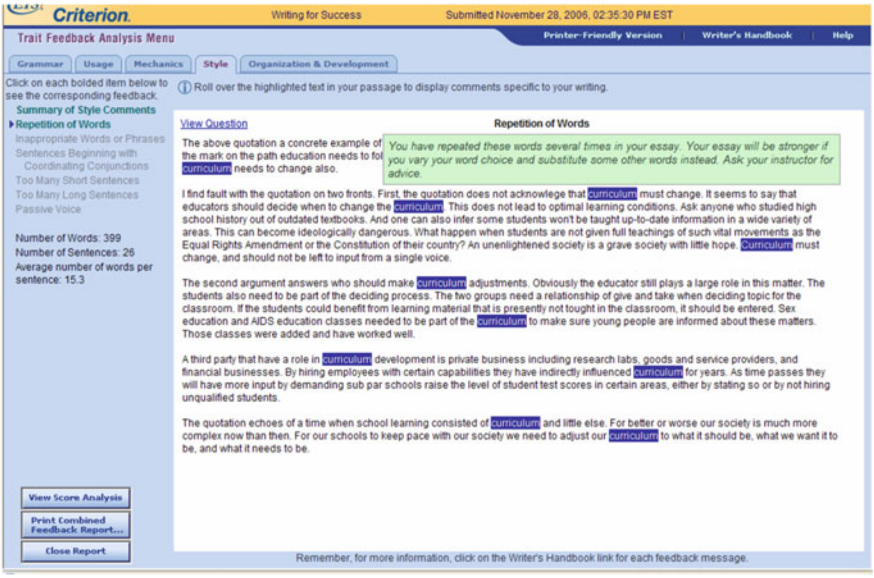

Fig. 1 Example screenshot of the feedback screen for Style (Repetition of words) (from ETS, 2007)

types at the same time; rather, students can view the feedback selectively by clicking on one of the tabs of the Trait Feedback Analysis Menu, which opens a trait-specific feedback screen. Figure 1 is a screenshot of the feedback screen for Style (Repetition of words). A roll-over message appears when moving the cursor over a highlighted word, expression, or stretch of text, presenting formative feedback on the identified type of error; e.g.:

- Grammar—Fragment or missing comma: *This sentence may be a fragment or may have incorrect punctuation. Proofread the sentence to be sure that it has correct punctuation and that it has an independent clause with a complete subject and predicate.*
- Usage—Missing comma: *You may need to place a comma after this word.*
- Style—Passive voice: *You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may wish to revise it using the active voice.*

Another form of feedback is provided along with the holistic score, summarizing the trait feedback analysis to reflect the overall quality of the text and the number of errors (per trait and per error type). To help students understand the meaning of their score, Criterion makes available a score guide with descriptions for basic, proficient, and advanced levels. According to the First Year 6pt Scale—Criterion Scoring Guide (n.d.), an author whose essay scores 2 out of 6, for instance, would receive feedback specifying the following weaknesses of the essay:

You have work to do to improve your writing skills. You probably have not addressed the topic or communicated your ideas effectively. Your writing may be difficult to understand. In one or more of the following areas, your essay:

- Misunderstands the topic or neglects important parts of the task
- Does not coherently focus or communicate your ideas
- Is organized very weakly or doesn't develop ideas enough
- Generalizes and does not provide examples or support to make your points clear
- Uses sentences and vocabulary without control, which sometimes confuses rather than clarifies your meaning.

Criterion's feedback, multiple revision, and unlimited resubmission features are meant to support revising and editing. Like other AWE tools, Criterion has additional features for students planning and writing, offering planning templates editable while completing the writing assignment, a catalogue of well-written essays, and a thesaurus. Its online Writer's Handbook can be tailored to different levels of English language proficiency, to a certain first language (Spanish, Simplified Chinese, Japanese, Korean), and to elementary, middle school, high school, or college educational levels. Students' communication and access are supported by features that facilitate dialogue and development of online portfolios. Teachers, in turn, can enable available pre-writing features, designate a particular planning template, adjust assignments to target specific abilities, and select resources appropriate for the development of those abilities. They can also operate with a library of more than 400 essay topics at various skill levels and pertaining to different kinds of essays (narrative, expository, persuasive). When designing a writing assignment, teachers can select options most suitable for the writing task (e.g., time allocated, number of allowed submissions of revised text). Importantly, they can set the type of automated feedback to be displayed and can also comment on their students' work through different modalities. For a description of how teachers and students can engage with this tool procedurally, see Lim and Kahng (2012).

4.2 Research Writing Tutor (RWT)

RWT was developed for advanced academic writers needing to learn how to produce publishable quality research articles responsive to the expectations of their socio-disciplinary discourse communities (Cotos, 2014). This tool comprises three standalone yet interconnected modules. 'Understand Writing Goals' is a learning module, which contains multimodal content explaining the communicative purposes of the moves and the functions of the steps (see the IMRD/C move-step framework in Cotos et al., 2015), as well as the patterns of language use characteristic of those rhetorical traits. 'Explore Published Writing' serves as a demonstration module with IMRD/C Section Structure, Move/Step Examples, and original Research Articles components, which expose students to different forms of a move/step annotated corpus of 960 published articles representative of authentic discourse in 32 disciplines. 'Analyze my writing' is the AWE feedback module providing different forms of individualized automated feedback designed for scaffolded revision.

A notable strength of this tool is its integrative theoretical grounding in socio-disciplinary and cognitive dimensions of scientific writing that are important for the development of genre knowledge and research writing competence. From a socio-disciplinary standpoint, the features in the feedback module are designed to render the rhetorical composition of research articles (informed by Swalesian genre theory) and the language choices that instantiate functional meaning (informed by systemic functional linguistics). From a cognitive standpoint, it operationalizes tenets from writing, language learning, and skill acquisition theories. With this grounding, RWT's features depicted in Fig. 2 are designed to create the learning affordances summarized in Table 2. In ensemble, its features and affordances create conditions for scaffolded writing practice, during which students are able to detect and address discourse-level shortcomings in their drafts, whether related to rhetorical structure, intended mental representation of ideas, or language choices needed to convey specific functional meanings (Cotos, 2017; Cotos et al., 2017, 2020).

RWT is used in various contexts, including credit-bearing writing courses employing data-driven learning pedagogy, hands-on workshops, peer review group activities, individual tutoring with writing consultants, and independent revision. The feedback and scaffolding features provide writers with exposure to authentic disciplinary discourse, directions for how to discern the writing norms of their discourse community, guided writing practice, and productive interaction.

5 Research

Over the last decade, the fields of AES/AEE and AWE have emerged as distinct areas of scholarship. Both these areas still adjoin under the validity argument framework (Kane, 1992), which consists of a chain of inferences that guide research. While describing the framework is beyond the scope of this chapter, highlighting it as an increasingly prolific heuristic adopted in AWE studies is necessary. It has enabled researchers to consolidate various types of empirically supported claims into a systematic progression of inferences about the effectiveness of AWE tools, thus strengthening the defensibility of decisions regarding their uses. For Criterion and RWT reviewed above, claims systematized under this framework can be found in Chapelle et al. (2015) and in Cotos (forthcoming), respectively. Unlike more recent studies, earlier works, many of which were reviewed in meta-analyses (Graham et al., 2015; Nunes et al., 2022; Stevenson & Phakiti, 2014), are not are explicitly positioned within the validity argument framework but still address different inferences. Table 3 synthesizes the findings from example studies to show that there is substantial positive evidence for the successful application of AWE across these key areas.

As with other educational technologies, some studies unveil rebuttal evidence, or issues that weaken the strength of the claims one would like to make about AWE.

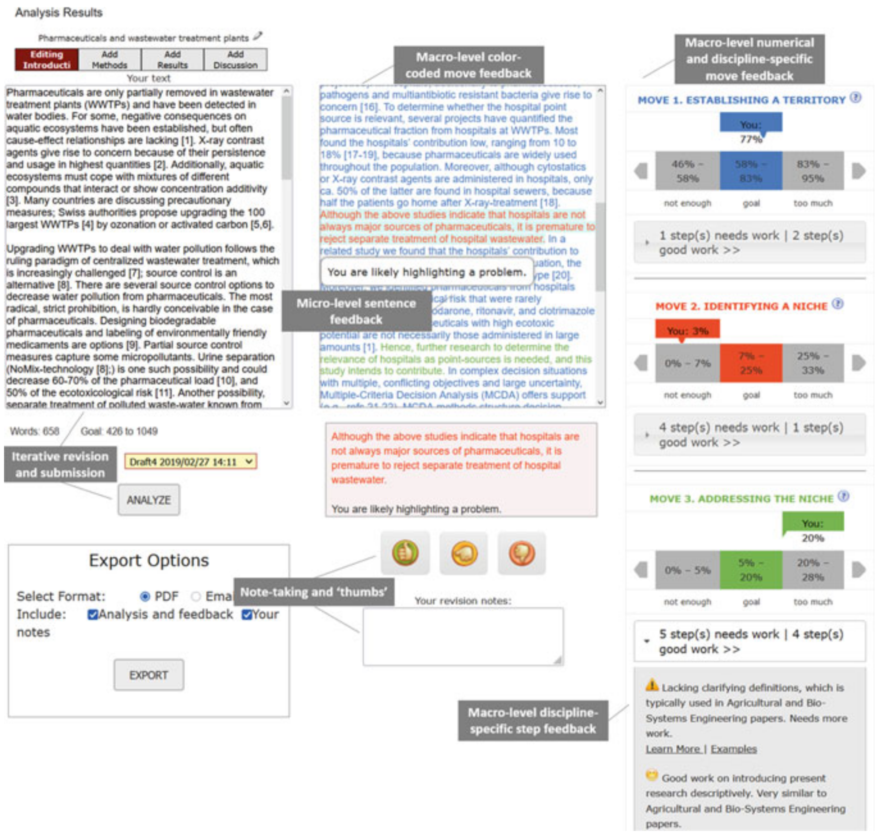

Fig. 2 Screenshot of the features of the 'Analyze My Writing' feedback module of RWT

For instance, Extrapolation cannot be confidently claimed because AWE feedback may not always be as good as teacher or peer feedback (Dikli & Bleyle, 2014). Impact may be affected because assessment-driven AWE feedback tends to promote surface-level revisions, may have no or low uptake on some writing traits, and can inhibit revising of propositional content (Li et al., 2015; Ranalli, 2021; Ware, 2014).

Such variability in outcomes is not surprising because it depends not so much on the tools themselves but on how they are implemented. Moreover, the research methods adopted stem from different disciplinary paradigms. Mixed methods have gained ground, but there is a clear need for longitudinal studies examining the effects of AWE feedback over an extended period of time. Variability in findings is also due to differing assumptions about what constitutes effectiveness (e.g., engagement, motivation, affect, writing improvement, skill development in first and second language) and how it is measured. Measures like error frequency and error reduction, for instance, are confined to impact on revised texts and do not extrapolate well to new compositions. In future research, revision quantity should be reported along with large-scale analyses of specific qualitative changes in writing performance. Not to overemphasize writing products, they should be examined vis-à-vis the process of writing with AWE feedback, and interaction behaviours should be scrutinized to reveal the metacognitive processes activated by writers along with the strategies they develop when drafting and revising.

Table 2 The features and affordances of the 'Analyze My Writing' feedback module of RWT

Feature	Description	Desired learning affordance
Feedback		
Macro-level color-coded move feedback	All sentences in the draft color-coded (blue Move 1, red Move 2, green Move 3, gold Move 4)	Examine the rhetorical composition of own drafts
Macro-level numerical and discipline-specific move feedback	Range bars with goal-orienting percentages for each move (*not enough*, *goal*, *too much*) Pie charts with percentages for each move in the draft and in an average text from the corpus	Examine move distribution in own drafts Compare with published disciplinary texts from the corpus Monitor writing progress in relation to discipline-specific writing
Macro-level discipline-specific step feedback	Expandable from the range bars for each move, comments about the presence, absence, or insufficiency of steps within each move	Compare with published disciplinary texts from the corpus Identify rhetorical strategies to add or revise
Micro-level sentence feedback	Suggestive comments or clarifying questions about the rhetorical intent of a given sentence	Self-analyze rhetorical intent Detect discrepancies between intended and expressed functional meaning
Additional scaffolding		
Note-taking and 'thumbs'	Interactive 'thumbs' up, neutral, and down Text box for revision notes	Reflect on the effectiveness of expressed rhetorical intent Take notes for further revision
Learn more	Brief step definitions as pop-up messages Hyperlink to full explanation of steps in 'Understand Writing Goals'	Improve understanding or consolidate knowledge of rhetorical strategies

(continued)

Table 2 (continued)

Feature	Description	Desired learning affordance
Examples	All the examples of a step within a discipline, section, and move accessible from a function-based concordancer Annotated disciplinary corpora	Identify linguistic instantiations of functional meaning Explore the rhetorical composition of the target genre Explore the discourse conventions of target disciplinary communities

Table 3 AWE validity argument inferences and claims

Validity inference	Empirically supported claims
Domain definition	Feedback is based on comprehensive descriptions of the writing characteristics (genre, textual, linguistic) of the target domains where students' knowledge, skills, processes, and strategies required for the writing task would be exercised via AWE (Burstein et al., 2016b; Cotos et al., 2015)
Evaluation	Feedback accurately points out relevant areas for revision (Lavolette et al., 2014; McNamara et al., 2015; Ranalli & Yamashita, 2022)
Generalization	Feedback is consistent across the instances of the same error or writing trait (Liu & Kunnan, 2015)
Explanation	Feedback reflects the aspects of the construct of writing ability and is pertinent to the quality of student's writing (Ma & Slater, 2016)
Extrapolation	Feedback is comparable to that provided by humans and accounts for the quality of students' written performance in other relevant contexts (Dikli & Bleyle, 2014; Wilson & Roscoe, 2020)
Utilization	Feedback and features are useful for students and teachers (Grimes & Warschauer, 2010; Koltovskaia, 2020; Link et al., 2020; Ranalli et al., 2017; Wilson et al., 2021; Zhang, 2020)
Impact	Uses of AWE tools are beneficial for learning, revising, and improvement of writing quality (Chodorow et al., 2010; Cotos et al., 2020; Dizon & Gayed, 2021; Knight et al., 2020; McCarthy et al., 2022; Na & Ma, 2021; Wilson, 2017)

6 Implications of This Technology for Writing Theory and Practice

Considering the snapshots of the research and the representative tools above, it can be argued that AWE technology appears to have reached significant milestones in its specific goals to address the challenges inherent in writing development and the teaching of writing. However, this does not mean that AWE has arrived at a standard solution. First, assessment-driven and genre-based strands have been developing in parallel. In the future, it is likely that a fourth generation of AWE will emerge drawing on the features and affordances of both assessment-driven and genre-based tools. The AWE evolution will also leverage the capabilities of ITSs with animated agents (as those of the Writing Pal, chapter "The Future of Intelligent Tutoring Systems for Writing") and biometric technology (chapter "Investigating Writing Processes with Keystroke Logging") to personify the feedback and generate interactive, strategic, and data-driven feedback fit for particular stages of the writing process.

To materialize these envisioned directions, it is of utmost importance for research to enrich existing writing theories. One possible scenario falls under the framework of cognitive writing models, where theoretical understanding could be deepened in terms of whether and how cognitive writing modelling applies to the revision process when assisted by AWE tools. Empirical investigations of the effects of cognitive mechanisms activated during AWE-assisted revision will have direct implications for writing theory, as empirical results will lead to devising an enhanced cognitive model of writing that would incorporate the role of technology as the digital environment.

This, in turn, will have ramifications for the next-generation of AWE, as it will enable developers to efficiently map metacognitive participatory engagement and to design an AWE-assisted writing conceptual 'corridor' linkable to different realizations of cognitive activities. In other words, when developing writers appear to drift away from critical cognitive and metacognitive paths, advanced artificial intelligence-enabled features might steer them through successful AWE-interaction trajectories with feedback and scaffolding that would facilitate the activation of appropriate aspects of metacognition at appropriate stages of drafting and revision (see Banawan et al., chapter "The Future of Intelligent Tutoring Systems for Writing").

Furthermore, research conducted in different instructional settings with different learner characteristics and targeting different genres will address the relationship between the cognitive processes activated during AWE-facilitated writing and the instructional practices brought into play by teachers. This intersection with practice will yield potentially generalizable insights informing principles for creating optimal digital conditions for AWE-supported writing skill development and implementation guidelines for effective broader use and integration. Those principles and guidelines would be developed to support possible variations in enactment and to allow practitioners to create AWE-facilitated instructional ecosystems that would be appropriate for different types of learners, contexts, and writing tasks.

Before this (and other) theory-research-practice concatenation scenarios become reality, teachers are encouraged to begin developing what Argyris (1997) terms theory-in-use models for educational effectiveness of an innovation. Hazelton et al. (2021) demonstrate two theory of action models based on instructors' standpoints for using an AWE tool (Writing Mentor) with non-traditional adult learners and with two-year college students. Their models account for the features of the tool (as instances of digital-technology mediation of the writing construct), demonstrated and hypothesized pedagogical actions (as defined teaching objectives), and intended and unintended consequences (positive and negative, intermediate and long-term effects). With all these model components maintaining a constant focus on learners, Hazelton et al. (2021) argue that the pedagogical future for formative AWE "may best be charted by standpoint theory of action" (p. 81).

7 AWE Tools

See Table 4.

Table 4 Select AWE tools

AWE tools	Developer or reference	URL (if available)
Assessment-driven		
CyWrite	Feng et al. (2016)	
Criterion	Burstein et al. (2003b)	https://www.ets.org/criterion
Draft Coach	Turnitin	https://www.turnitin.com/products/features/draft-coach
Grammarly	Grammarly Inc	https://www.grammarly.com
iWrite	Unipus.cn, 版权所有	http://iwrite.unipus.cn
Revision Assistant	Turnitin	https://www.turnitin.com/products/revision-assistant
MY Access!	Vantage Learning	https://www.vantagelearning.com/products/my-access-school-edition
MI Write and MI Tutor	Measurement Incorporated	https://miwrite.com
Pigai	PIGAI.ORG	http://en.pigai.org
ProWritingAid	ProWritingAid	https://prowritingaid.com
TechWriter	Napolitano and Stent (2009)	
Writing Pal	Roscoe and McNamara (2013)	http://www.adaptiveliteracy.com
Write & Improve	University of Cambridge	https://writeandimprove.com
Writer's Workbench	Bell Labs	https://www.writersworkbench.com/WWB_OL/WWB_OL.html
Writing Mentor	Educational Testing Service	https://mentormywriting.org

(continued)

Table 4 (continued)

AWE tools	Developer or reference	URL (if available)
WritingRoadmap	CTB/ McGraw-Hill	https://www.mheducation.com
Write-To-Learn	Pearson Educational Technologies	https://www.pearsonassessments.com/store/usassessments/en/Store/Professional-Assessments/Academic-Learning/WriteToLearn/p/100000030.html
Genre-based		
AntMover	Anthony and Lashkia (2003)	https://www.laurenceanthony.net/software/antmover
AcaWriter	University of Technology Sydney, Australia	https://acawriter.uts.edu.au
Intelligent Academic Discourse Evaluator	Cotos (2009)	
Research Writing Tutor	Cotos (2014)	https://rwt.grad-college.iastate.edu/wordpress

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The Future of Intelligent Tutoring Systems for Writing

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Abstract Writing is essential for success in academics and everyday tasks, but the development of writing skills depends on consistent access to high-quality instruction, extended practice, and personalized feedback. To address these demands and meet students' needs, educators and researchers have turned to technology-based writing tools. Ideally, these tools integrate the core components of intelligent tutoring, including a domain model, student model, tutor model, and interface model to engage students with individualized feedback that is linked to adaptive writing instruction. However, the landscape of writing tools still has much room for improvement in terms of incorporating advanced artificial intelligence-enabled features to better approximate intelligent tutoring systems (ITSs). This chapter describes the key elements of ITS technologies and how they can be integrated to further develop ITS tools for writing. To this end, this chapter (1) summarizes evidence-based aspects of successful ITSs and how they might be integrated into computer-based tools for writing, (2) reviews how existing systems have leveraged intelligent tutoring approaches, and (3) articulates how future technology-based writing tools could implement advanced

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_23

intelligent tutoring features to better meet students' needs. The chapter concludes with the implications and future directions of intelligent tutoring for the teaching and learning of writing.

Keywords Intelligent tutoring systems for writing · Architecture of intelligent tutoring systems · Writing Pal

1 Overview

Strong writing skills are essential to academic performance across nearly all domains as well as for success in everyday life (Powell, 2009). However, writing is challenging because of the demands it places on cognitive skills and knowledge (Deane et al., 2008). Improving students' writing skills requires enormous amounts of high-quality instruction, deliberate practice, and individualized formative and summative feedback. Curricula developed to provide students with these resources can be challenging to implement in the classroom due to the time required for educators to read and provide individualized feedback on students' writing. Thus, educators have turned to intelligent writing tools as a means of supplementing classroom instruction and increasing students' opportunities to engage in deliberate writing practice. Most widely used for these purposes are automated essay scoring (AES) systems that provide valid and reliable scores and feedback-generating automated writing evaluation (AWE) systems (Cotos, 2018) (see Chapters S3C5, S3C6).

Many of the components of AES and AWE systems have also been integrated into prototypes of intelligent tutoring systems (ITSs), incorporating instructional content, game-based practice, and iterative practice with feedback into their architectures. Thus, the development of digital tools for writing has followed a trajectory from a focus on scoring to a focus on feedback and instruction, thereby becoming more ITS-like over time. However, the landscape of writing tools has much room for the design and development of cutting-edge systems for writing by implementing both traditional ITS elements and advances in artificial intelligence (AI), natural language processing (NLP) , and human–computer interaction (HCI). Compared to well-defined domains (e.g., algebra) for which ITSs have traditionally been developed, there are unique challenges in developing ITSs for writing. This chapter reviews several existing writing tools using ITS architecture as the analytic frame to identify challenges and forecast how intelligent tutoring for writing could be successfully implemented. In doing so, our goal is to capture the current state of the art in digital writing tools and stimulate future research regarding ITSs for writing.

ITSs are automated learning platforms that simulate tutor-tutee interaction while providing detailed feedback, assessments, and personalized learning, often through content adaptation that leverages the tutees' strengths and addresses their specific needs. ITS implementations emulate the known benefits of tutoring (Bloom, 1984) while simultaneously addressing limitations such as tutor subjectivity, fatigue, cost, and limited resources. ITSs employ a variety of pedagogical tools to support desired learning outcomes in a specific domain without intervention from human tutors or experts (Graesser et al., 2012; Ma et al., 2014).

2 Core Idea of the Technology: Architecture of Intelligent Tutoring Systems

There are four components of contemporary ITSs: *domain model*, *student model*, *tutor model*, and *interface model*. Earlier architectures encompassed the first three components (Derry et al., 1988). These core components provided the ITS with critical information on what to teach, who to teach, and how to teach (Nwana, 1990). The three-model architecture later expanded to include a fourth component, the user interface, and the four-model architecture has become the standard architecture for ITSs (Almasri et al., 2019).

2.1 Domain Model

The domain model represents the idealized expert knowledge domain, which may include the concepts, rules, skills, and strategies of the topics to be learned (Sottilare et al., 2016). It thus serves as the standard for evaluating students' performance and as the reference used to detect errors or deviations from expected knowledge and skills. This component is often organized into a curriculum that links all knowledge elements according to a pedagogical sequence. Domain models frequently implement a sequenced curriculum such that new material builds on prior knowledge and aspects of the curriculum that were previously administered.

2.2 Student Model

The student model focuses on students' cognitive and meta-cognitive states throughout the learning process. It represents what the students learn and how they learn, capturing the processes and strategies by which they learn. This component maps to the domain model, wherein students' knowledge is measured in terms of ideal expert knowledge (Sottilare et al., 2013). In other words, the student model captures the deviations from the expert knowledge base (represented by the curriculum) by highlighting gaps in students' knowledge. Therefore, it reflects the set of skills that students have mastered, thereby affording customized and individualized learning paths, feedback, and support. ITSs that recommend appropriate content or specific learning pathways based on students' progress, assessment results, or behaviors while using the system are usually informed by dynamic and adaptive student models.

2.3 Tutor Model

The tutor model, also known as the pedagogical model, teaching model, or expert model, relies on the interplay between the domain and student models to provide pedagogical strategies and actions that are most appropriate for a given student (e.g., providing a hint in response to an incorrect answer or assigning specific problems that target the skills that the student needs to improve upon). Additional tasks for this model include adjusting the speed of tutoring actions, checking the learning progress through questions, providing feedback, and offering additional information to assist with gaps in students' knowledge (Almasri et al., 2019). Knowledge tracing, or tracking students' progress while building a profile of strengths and weaknesses (Ahuja & Sille, 2013), is another important ability of the tutor model.

2.4 Interface Model

The user interface model, also referred to as the communication model, comprises the human–computer interaction features that are necessary to interpret and facilitate the learning process. The interface model provides the presentation of the learning material to the student and controls the communication and interaction between the student and the system. This component allows dialogue between students and the ITS to simulate tutor-tutee interaction. Intelligent interfaces focus on adaptive or adaptable interfaces to enhance user experience and learning (Sarrafzadeh et al., 2008). ITS interface models are implemented as pedagogical agents, menu-driven interfaces, text-driven interfaces, speech-driven interfaces, or via worked examples that demonstrate the steps necessary to complete a learning task. In addition, modern ITSs immerse students in a graphic environment enhanced by AI and virtual reality by employing animated and empathic pedagogical agents.

3 Functional Specifications: ITS Components in Action

ITSs implement the aforementioned components in different ways, but it is the integration of these components working together that greatly influences the effectiveness of intelligent tutoring. Considering that ITS for writing is still an underdeveloped area, in this section, we provide examples of representative ITSs from the domains of math and science. These exemplars depict the dynamic interplay between the four ITS components and how each component informs another, which is important to consider in the design of future ITSs for writing.

The Practical Algebra Tutor (PAT) is a system that mimics the steps a student would take to solve a problem and solves the problem at the same time as the student (Koedinger et al., 1997). The student model tracks students' steps in solving the problem and compares those steps against the domain model to check for discrepancies. In turn, the tutor model provides appropriate feedback at specific steps via the user interface. PAT has a domain model for each type of problem, as well as a representation of common student misconceptions. If students exhibit misconceptions in the domain model, the system leverages the tutor model to offer feedback that guides students back to the correct path. Students who used this step-based tutoring system performed significantly better compared to students following a traditional approach in a real-world problems assessment (Akyuz, 2020; Corbett et al., 1997).

The Andes Physics Tutoring System is another ITS that provides homework problem-solving support to students learning physics. Andes' tutor model consists of a coached problem-solving environment and provides immediate feedback through dialogue capabilities integrated into the interface model that provide students with increasingly specific hints for problem-solving. Importantly, the tutor models' feedback encourages the students to find the solution and not rely on the feedback system to provide the solution. The student model tracks students' responses and automatically notes when answers are inconsistent with the domain model. Because Andes allows students to perform tasks in no particular order, the student model cannot rely on accomplished tasks as the basis for the students' level of knowledge or mastery. Instead, the student model combines information on problem-specific knowledge that the students are working on or have completed along with information on the domain-general assessments that all problems have (Gertner & VanLehn, 2000). Encouraging results were found by many studies that evaluated the effectiveness of Andes in terms of increasing the learning gains of students as they are provided homework problem-solving support (VanLehn et al., 2005). The success of Andes' immediate feedback and hint progression strategies continue to spur similar implementations in more recent ITSs (Sale & Muldner, 2019).

As a final example (of many other potential exemplars), AutoTutor is a problem-oriented ITS that presents interactive content and uses conversational agents to help students learn. AutoTutor's domain model contains lessons and problems that cover the content of specific domains like computer literacy, critical scientific thinking, physics, and reading. The problems that the students work on are mapped to the knowledge components comprising the lessons. AutoTutor's tutor model leverages natural language and text-to-speech features in dialogue. Its interface model implements animated conversational agents that have facial expressions and can make various gestures (Cai et al., 2019; Graesser et al., 2007). Different versions of AutoTutor's student model also capture student affective states in real-time and modify the instruction that the tutor model provides to enhance student engagement (D'Mello et al., 2007). Students' affective states are derived from the dialogue patterns and physical markers that include facial expressions and posture students exhibit when interacting with the interface.

4 Main Products: A Landscape of Intelligent Writing Tools

Existing digital tools for writing have leveraged one or more components of intelligent tutoring that are present in the paradigmatic math and science ITSs presented in the previous section. In this section, we provide a selective overview of several digital tools for writing, including AWE systems (see S3C6) and highlight each tool's most noteworthy ITS-like component (see Table 1). By outlining the landscape of intelligent tools for writing and articulating how these tools integrate various components of intelligent tutoring, we clarify how an ITS for writing might be further improved.

Table 1 Intelligent features of digital writing tools

	Student model	Tutor model	Domain model	Interface model
Criterion		Formative and summative feedback on different writing traits and customized based on grade levels and prompts	Library of expository and argumentative prompts	Various learning artifacts
Research Writing Tutor		Formative feedback on rhetorical conventions of scientific writing	Annotated corpus of published discipline-specific scientific writing	Learning, demonstration, and feedback modules
Sword/ Peerceptiv		Open-ended feedback and weighted scores based on system-calculated accuracy of peer reviews	Double-blind reviews by students across disciplines	Task-driven user interface with elements reflecting different steps of the writing process and task
HARRY		Conversation-based feedback on narrative writing at word, sentence, and idea levels	Story themes and tasks organized based on writing stages	Scaffolding specific to writing stages
Writing Pal	Dynamic student model representation based on practice and summative performance	Formative and summative feedback on writing strategies Coached practice Gamified practice	Corpora of essay prompts Flexible sequencing of content / instruction Various pedagogical strategies	Freewriting, Planning, Introduction Building, Body Building, Conclusion Building, Paraphrasing, Cohesion Building, and Revising modules

4.1 Criterion® Online Writing Evaluation Service

Criterion® Online Writing Evaluation Service was developed by the Educational Testing Service (ETS) (see Chapter S3C6). Criterion is a representative AWE tool that exhibits built-in intelligence in providing feedback. Criterion's domain model is comprised of a content library of 180 essay topics and over 400 expository and argumentative assignments and prompts designed for students from fourth grade through college. Criterion uses NLP techniques to score and provide feedback on students' writing. Along with a holistic score, students also receive feedback on language errors (e.g., grammatical errors) and discourse elements (e.g., the absence of a thesis statement). Though teachers may provide the assignment and give feedback, the system is meant to be fairly independent by giving specific, timely feedback. The scoring and feedback are driven by the e-rater AES engine. Different scoring models are created for different grade levels and sometimes for specific prompts, and the resulting scores are displayed to students and teachers. The system's interface model serves as the platform for user interaction providing learning artifacts such as online portfolios with peer-to-peer feedback, teacher feedback, and two-way student–teacher communication.

ETS designed Criterion as a venue for frequent writing practice during self-study. Criterion's extensive types of feedback on the different writing traits (i.e., grammar, usage, mechanics, style, and organization) make it an exemplar of using real-time feedback as a pedagogy to achieve desired learning outcomes. Hence, Criterion's tutor model design contributes to its successful deployment.

4.2 Research Writing Tutor

Another representative intelligent AWE tool is Research Writing Tutor (RWT) (Cotos et al., 2020; see Chapter S3C6). RWT teaches students to write scientific discourse, specifically the Introduction, Methods, Results, and Discussion/Conclusion sections of a research article. RWT has a complex interface composed of three interactive modules for learning, demonstration, and feedback (Cotos, 2017). The learning module is designed for students to understand goals specific to research writing, and the demonstration module is comprised of a wide selection of pedagogically mediated research articles demonstrating the use of effective rhetorical strategies in various disciplines (currently an annotated corpus of 32 disciplines). Together, these modules can be considered the domain model of RWT representing the expert knowledge domain. This knowledge, derived from published research articles, is used to analyze students' drafts and generate automated discipline-specific feedback.

The implementation of an expansive representation of domain-specific content and applicable pedagogies are both resource-intensive and difficult in terms of domain modeling in ITS design. RWT has been successful in deploying one such approach that is aligned with the requirements of a curriculum for learning research writing.

RWT's interface is characterized by its alignment with scaffolding on the specific rhetorical strategies of the target genre that the system is designed for.

4.3 Scaffolded Writing and ReWriting in the Disciplines (SWoRD)/Peerceptiv

SWoRD supports peer review for high school and college students (Cho & Schunn, 2007). Having undergone rapid growth and significant improvements to its student and teacher interfaces, it was renamed Peerceptiv (Schunn, 2016) and now addresses common problems with peer review, such as a lack of effort on the part of the reviewer or a tendency to be overly positive (VanDeWeghe, 2004). When using Peerceptiv, teachers provide a list of topics, due dates, and the number of reviews they want each paper to receive. Students then choose which topic they want to write about, as well as which topics they would like to review. Students receive and write reviews for the initial draft, second draft, and final draft. Reviewers are asked to provide a rating on flow, logic, and insight; to give comments; and to provide a score on a seven-point scale for each essay. The peer reviews consist of both open-ended feedback and scores that reflect the average rating of the reviewers. Peerceptiv's domain model captures the double-blind review artifacts submitted by the students in their writing and rewriting tasks across disciplines. The student model represents the students' learning progress that is captured through the ratings and grades from submitted reviews of the drafts. Peerceptiv looks at systematic differences, consistency, and spread to determine the accuracy of each review. Peerceptiv then creates a weighted grade for each essay, with less accurate reviews receiving less weight. These review-based grades are presented to the students as feedback. The peer review mechanism affords students the knowledge of expected outcomes and competencies necessary to write effective research papers (Schunn et al., 2016).

Peerceptiv's interface is among its strengths as a platform for learning writing. An interface feature worth highlighting is the students' timeline view, which clearly shows the status and progress of each writing assignment. Peerceptiv's forms reflect the appropriate affordances necessary for collaborative learning and optimizing the benefits of feedback from relevant peer reviews. For example, the Reviewing form allows students to scroll through the document while giving open-ended feedback and view the appropriate rating rubric to be used for a specific task. Peerceptiv continues to contribute to the overall classroom review process as more current work use Peerceptiv's review artifacts and corpora for further analysis related to review relevance and metareview criteria (Lam, 2021; Zhang et al., 2020).

4.4 Harry

HARRY is a web-based tutor designed to support narrative writing for students in elementary grades to engage in higher-level thinking (Holdich & Chung, 2003). HARRY's tutor model provides individualized comments and feedback to guide students as they write stories. HARRY's domain model has four story themes (pirates, space, woodland adventure, and enchanted journey) and writing tasks organized into three stages (story composition, editing, and finalizing). The students' progress in the different stages of narrative writing is instantiated in the student model. HARRY's interface model presents its narrative writing scaffolds specific to each stage (e.g., writing prompts and stylistic suggestions) as the students go through the different stages of the writing task.

HARRY's strength is its tutor model, which guides students through the writing process via conversation-based prompting. This addresses the "what next" approach of beginners as their writing evolves across revisions. With conversational dialogues, the tutor does not just deliver information or instructions but guides the students as they engage in meaning-making processes. This dialogue-based pedagogical strategy is a notable implementation of the ITS' tutor model that is anchored in educational theories with strong evidence of positive outcomes (Lefstein & Snell, 2013; Liu et al., 2019). In addition, HARRY provides help via prompts for word, sentence, and idea levels that encourage students to review and revise their work. HARRY-assisted narratives of elementary school-aged children were characterized to have varied vocabulary use, more sophisticated sentence construction, and appropriate use of punctuation than control narratives that were written without using this tool (Beam & Williams, 2015; Holdich et al., 2004).

4.5 Writing Pal

Writing Pal (Roscoe & McNamara, 2013) is the only ITS for writing developed to date. It is an online tutoring platform designed for struggling writers. It provides instructional video modules for each stage of the writing process, game-based practice, and essay-writing practice with formative and summative feedback (similar to AWE tools). Compared to most writing systems, Writing Pal has more features that depict underlying domain, student, tutor, and interface models typical of representative ITSs. Specifically, writing Pal's domain model is represented across its eight modules (Freewriting, Planning, Introduction Building, Body Building, Conclusion Building, Paraphrasing, Cohesion Building, and Revising; see Fig. 1) spanning the three main phases of writing: prewriting, drafting, and revising. Each module starts with an introductory video lesson, followed by lessons on specific strategies. For example, the Planning module includes lessons on "Positions, Arguments, and Evidence" and "Outlines and Flowcharts". The interface model includes three virtual characters (i.e., a teacher and his two students) that present instructional content. At

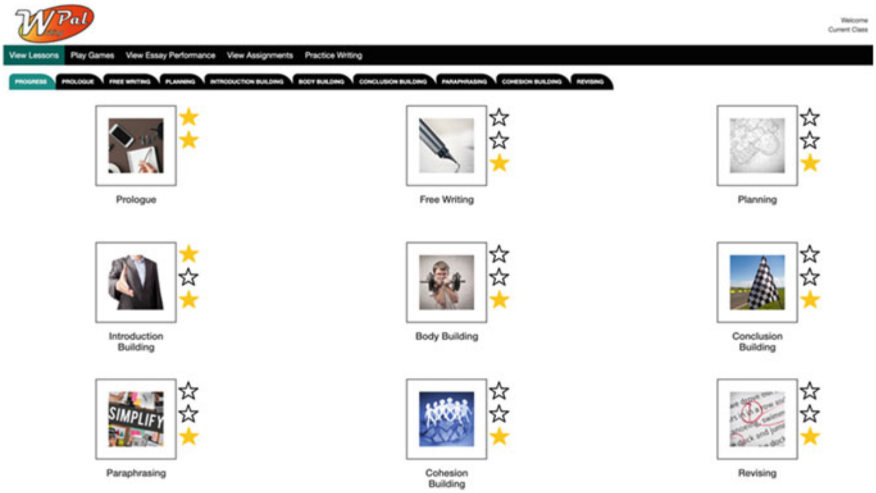

Fig. 1 Writing Pal Modules

the end of each lesson, students are tested on their knowledge via a short quiz, which is in turn incorporated into Writing Pal's evolving dynamic student model.

Writing Pal's tutor model includes multiple opportunities to practice writing strategies in the context of game-based practice and coached practice (Roscoe et al., 2014b). The games (see Fig. 2) allow students to better understand the individual strategies as well as practice using them to promote automaticity of strategy use. Specifically, identification games require students to recognize example strategies and text features (via multiple choice), such as irrelevant information in a body paragraph. Generative games require constructed responses, such as writing a topic sentence and providing evidence in response to a thesis. Practice games are inherently adaptive because advancing, leveling, and earning points during gameplay are based on performance within the game. In essence, gamification within the Writing Pal is also a form of intelligent tutoring, albeit veiled in the guise of short, dynamic games.

Writing Pal's tutor model incorporates many opportunities for practice. At the end of each module, students can write an essay in response to a prompt (i.e., whole-task practice). The essay gives students practice executing and combining the strategies they learned throughout the instructional modules and games. Each essay is automatically evaluated and scored using NLP techniques (McNamara et al., 2013, 2015). Students are presented with a score from "Poor" to "Great" along with specific suggestions for improving the essay. For instance, a short essay might receive recommendations for using freewriting to substantiate their ideas. Students are encouraged to use the feedback to revise and resubmit their essays for the second round of feedback. Although the scoring and feedback features are similar to the functionality of AES and AWE tools, Writing Pal is unique because of its dynamic tutor model—that is, formative feedback points specifically to writing strategies introduced within the

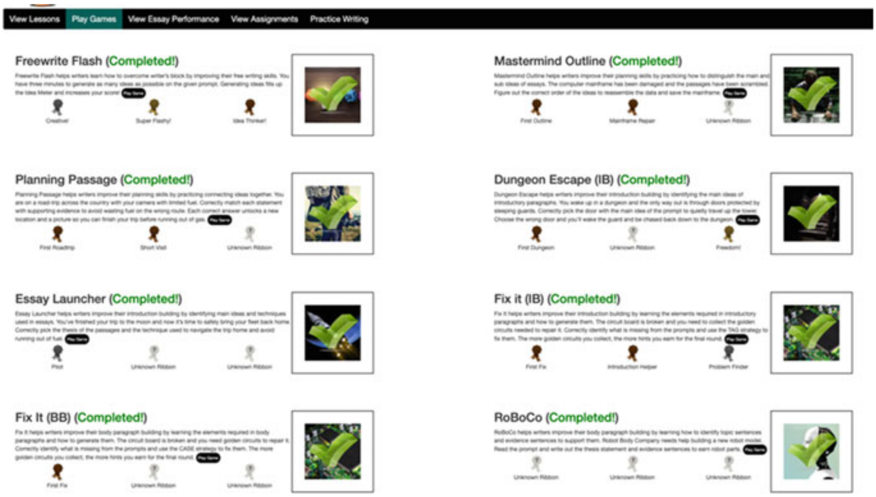

Fig. 2 Writing Pal Games

lessons and games, rather than solely to aspects of the essay that need to be fixed. Thus, there is an explicit link between the tutor model, as manifested through the lessons and games, and the feedback provided to the students based on their writing performance.

Students can either complete the modules in a fixed sequence, or flexibly choose which modules they complete, how long they interact with each module, and which games they play. The modular format of Writing Pal allows teachers to flexibly tailor instruction, including which modules to cover, their sequencing, which games to include, and the extent to which students engage in writing practice with automated feedback. Although Writing Pal's domain model comprises corpora of essay prompts that the teachers can readily use in their classes, Writing Pal also allows instructors the flexibility to incorporate their own essay prompts.

In sum, there are multiple ITS components and principles incorporated within Writing Pal, as well as functionality to customize its intelligent features. Foremost, what makes Writing Pal "intelligent" is the NLP algorithms embedded in the grading of the essays to provide formative feedback to students, which is intrinsically tied to the tutor model. The tutor model implements a wide variety of pedagogical strategies to enhance student writing, such as modular or adaptive instruction, formative and summative feedback, and gamified practice.

5 Research

ITS research has focused on investigating educational outcomes and which parameters, features, and scaffolding make ITSs effective tools for learning. Various reviews reported ITSs to be more effective than small-group instruction and some to be equivalent to one-to-one tutoring (Kulik & Fletcher, 2016; Steenbergen-Hu & Cooper, 2014; VanLehn, 2011). Across the many years of development, deployments, and subsequent commercialization, ITSs evolved to become important tools for both educators and students, as in the case of PAT (Kelkar, 2022). Significant learning gains were observed in AutoTutor implementations compared to the students reading the learning materials on their own for the same amount of time, and equivalent learning gains were observed as compared to human tutoring with experienced tutors (Graesser, 2016).

Specific to writing, ITS research continues to explore whether the integration of both cognitive and meta-cognitive processes in writing within ITSs may hold strong potential for effective scaffolding in explicit strategy instruction, increased practice opportunities, and individualized formative and summative feedback. When ITSs are designed such that their educational and theoretical anchors are clear and well-implemented in their components (i.e., domain, student, tutor, and interface models), writing instruction becomes more effective and results in the achievement of positive learning outcomes (Godwin-Jones, 2018; Roscoe et al., 2014a, 2014b). For example, classroom implementations of Writing Pal and teacher focus groups indicate that some instructors require the flexibility to cover various writing topics and modules at the classroom level, rather than allowing students to cover the material at individualized pace (Roscoe & McNamara, 2013). This is a natural tension between intelligent tutoring and the inherent nature of classroom instruction. Flexible sequencing of instructional modules is somewhat antithetical to adaptive sequencing that follows a more traditional intelligent tutoring design. Thus, parameterization in the Writing Pal interface model enables this function, allowing this tool to monitor student progress and performance and to suggest subsequent modules, lessons, or practice games. Research continues to suggest that Writing Pal's adaptive strategy instruction shows successful uptake of feedback from the tutor model during training and improves the quality of students' essays overall, as well as the more specific dimensions of essay quality (Butterfuss et al., 2022). However, ITSs, digital writing tools included, do not always lead to positive learning outcomes, especially in the absence of teacher regulation and intervention, as it found in one of Criterion's implementations (Heffernan & Otoshi, 2015).

Notably, much of the work on ITS (as well as on AWE) has focused on the development and implementation of machine learning algorithms and scaling AI to provide students with more accurate feedback necessary to monitor and assess their work. These algorithms typically leverage information from and about texts, but keystroke data have also emerged as valuable because they reveal temporal characteristics and offer insights into students' writing processes. For example, in Writing

Pal deployments, behavioral data derived from keystroke dynamics serve as important indicators of the processes that unfold in the production of written output (Allen et al., 2016; Conijn, 2020; Likens et al., 2017).

6 Conclusions and Implications for Writing Theory and Practice

The foundational ITS implementations described in this chapter, PAT, Andes Physics Tutoring System, Auto Tutor, and Writing Pal - demonstrate how the dynamic interplay of the domain, student, tutor, and interface models scale AI or intelligence to afford effective scaffolding in support of personalized learning. Specific to the writing domain, existing digital tools similarly demonstrate intelligence and emulate ITS components that result in positive learning outcomes. If the design of intelligent writing tools adheres to the underlying architecture of paradigmatic ITSs, writing instruction can become more personalized relative to the evolving context of the students. This entails designing comprehensive and adaptive ITS components that dynamically inform each other.

The scope of possible knowledge domains that might be integrated within writing ITSs is incredibly vast, and designing a complete domain model is nearly impossible. Domain models need to encompass knowledge of the language, general world knowledge, as well as knowledge of the writing task. Also, domain models should embed expertise that is sufficiently general yet representative of specialized and targeted topics, writing strategies (e.g., paraphrasing, bridging, question-asking), and writing tasks (e.g., summarization, source-based writing, argumentative writing). Student models are equally (if not more) challenging, as they should capture the dynamic and diverse students' contexts, prior knowledge, baseline skills, and individual progress. For example, student models should represent the distinct contexts of L1 and L2 student populations. Capturing the heterogeneity of the students' learning requirements should allow a respective tutor model to provide scaffolding and support pertinent to the specific needs of the students via an equally dynamic and personalized instantiation of the interface model. Furthermore, writing ITSs may benefit from a greater focus on enhancing the user experience through the implementation of more engaging and immersive student interfaces. Future writing systems have the potential to improve system interaction when navigating the system, recovering from errors, and receiving feedback by implementing dialogue-based interfaces as in Andes, empathic chatbots as in Auto Tutor, animated pedagogical agents as in Writing Pal, and augmented reality-enhanced user interfaces, among others. The user interface should be flexibly designed to be conducive to a specific learning goal given students' learning context and writing task at hand. For example, enhanced user experience and learning outcomes can be achieved by ensuring the correspondence between the expected written output and the size of the text boxes (as in Peerceptiv), using mini-games for supplemental practice opportunities for complex writing tasks (as in Writing Pal), and implementing text-to-speech functionality for longer texts.

Future ITSs for writing will continually face the challenges of (1) personalized instruction adapted to evolving student attributes, (2) provision of appropriate and relevant instruction contingent on the domain and student, (3) provision of formative and summative feedback, (4) appropriate design of user interface elements to facilitate learning, and (5) tensions between classroom instruction and adaptive instruction, to name a few. Nonetheless, incorporating intelligent tutoring principles within digital writing technologies has strong potential to improve performance for the learning and teaching of writing. In their present form, digital writing tools have yet to fully optimize the canonical and cutting-edge features of modern ITSs when it comes to AI-enabled domain, pedagogical, tutoring, and intelligent interface designs. Despite their known benefits, there is still untapped potential and much room for improvement to serve as an impetus for subsequent work in this area.

7 Tools

No	Tools	Descriptors	References/links
1	Andes Physics Tutoring System	Non-writing ITS, physics, homework problem-solving support	Gertner and VanLehn (2000) and VanLehn et al. (2005)
2	AutoTutor	Non-writing ITS, computer literacy, physics, conversational ITS, NLP-enabled dialogue system	Graesser et al. (2001)
3	Criterion Online Writing Evaluation Service	NLP-based assessment and formative error-correction feedback	Burstein et al. (2004), Burstein et al. (2013), and Ramineni and Deane (2017) https://www.ets.org/criterion.html
4	HARRY	Web-based tutor, narrative writing, dialog-based prompts, conversational dialogues	Holdich and Chung (2003)
5	Practical Algebra Tutor	Non-writing ITS, algebra, step-based tutor, cognitive task analysis	Koedinger et al. (1997)
6	Research Writing Tutor	Discipline-specific rhetorical feedback on scientific writing, genre-based learning	Cotos (2017)
7	Scaffolded Writing and ReWriting in the Disciplines (Sword)/ Peerceptiv	Peer review platform, feedback and scores based on reviewer ratings	Cho and Schunn (2007) https://peerceptiv.com/

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No	Tools	Descriptors	References/links
8	Writing Pal	Web-based Tutor, platform for struggling readers, NLP algorithms, adaptive instruction;	Roscoe and McNamara (2013) http://www.adaptiveliteracy.com/

Acknowledgements The authors disclosed receipt of the following financial support for the research, author-ship, and/or publication of this chapter. This work was supported in part by IES Grants R305A180261 and R305A180144, as well as the Office of Naval Research (Grant: N00014-17-1-2300). Opinions, conclusions, or recommendations do not necessarily reflect the view of the Department of Education, IES, or the Office of Naval Research.

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On Corpora and Writing

Madalina Chitez and Andreea Dinca

Abstract The chapter aims at providing an overview of the modalities in which linguistic corpora have been integrated in writing related approaches and technologies. The history of corpus linguistics is almost one century old, demonstrating a wide range of applications and interdisciplinary research potential. In this study, two main directions have been identified which describe approaches at the interface of corpora and writing. The first direction is represented by a large body of literature and refers to the use of corpora for academic writing research. The second direction focuses on the applicability of corpora for writing support, covering three aspects: (a) A section on corpora as a basis for primary linguistic tools for writers, which illustrates the use of corpora for the creation of dictionaries and phraseology lists. (b) A section on the use of corpora to teach academic writing. This section captures and exemplifies Data Driven Learning methods for corpus based academic writing and tools that support such approaches. (c) The third section refers to the use of built-in corpora for the creation of writing support tools (e.g. Ludwig.guru) or corpus related integrative tools (e.g. Thesis Writer).

Keywords Academic writing · Writing tools · Corpus based writing tools · Corpus linguistics

1 Overview

1.1 Introduction

Language use and writing strategies are two inseparable facets of the same process: knowledge creation and sharing. In order to produce valuable pieces of writing, either creative or scientific in nature, writers of all ages and competence levels are

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_24

challenged with tasks that range from simple word selection (Cameron & Dempsey, 2013) to adapting writing style to being formal or informal (Reppen et al., 2002). The first inventories of words were dictionaries which were structured archives of contextual uses of linguistic items present in the language at a certain point in time. They also served as the first linguistic research outcomes. In this context, the emergence of corpora seemed like the natural methodological evolution in language sampling and research. When lexicographers started collecting data for corpus based dictionaries (Teubert, 2007), their purpose was not only to disambiguate vocabulary terms and their meaning but also to provide lexical options based on authentic language samples (Hanks, 2009).

Being collections of naturally occurring samples of language, corpora represent reliable guidance resources for writers of all disciplines, genres and purposes. Beside instant access, as simple user, student or researcher, another applicability of corpora for language use in writing or writing process in general is the facilitation of digital tool creation:

> People are not generally aware that computational linguists use corpora to develop all sorts of language tools that have become commonplace in our everyday lives, from simple spell checkers, to auto-correct options in word processors and web browsers, to sophisticated machine translation programs. (Frankenberg-Garcia, 2014)

Besides basic challenges such as choice of words, in the process of writing, a frequently encountered problem is the writer's block, a phenomenon which is intrinsically cognitive (Hodges, 2017) but which can be overcome, oftentimes, through linguistic support. This can be automatic in nature, like paragraph generation (Duval et al., 2021) or support during the lexical refinement process (Baker-Brodersen, 1988). Such prompts are often based on corpora, and they are readily available online provided that the user is aware of the limitations of corpus queries (Kaltenböck & Mehlmauer-Larcher, 2005).

1.2 Evolution of Corpus Linguistics

Nowadays, corpora represent collections of texts that are collected, processed, analysed and exploited with the help of computer technology. But corpora have not always been digital and, as the name corpus implies, i.e. 'body' of language in Latin (Bondi, 2017, p. 46), they existed even before the advent of technology, when linguists used pre-computer corpora as a base for their linguistic studies (Biber & Reppen, 2015, p. 2). For example, when writing the Dictionary of the English Language, published in 1755, Samuel Johnson used around 150,000 natural sentences written on slips of paper to show the natural use of words (p. 2). Up to the 1960's other noteworthy works include dictionaries, e.g. *The Oxford English Dictionary* published in 1928, empirical vocabulary studies, such as the *General Service List* (West, 1953), and

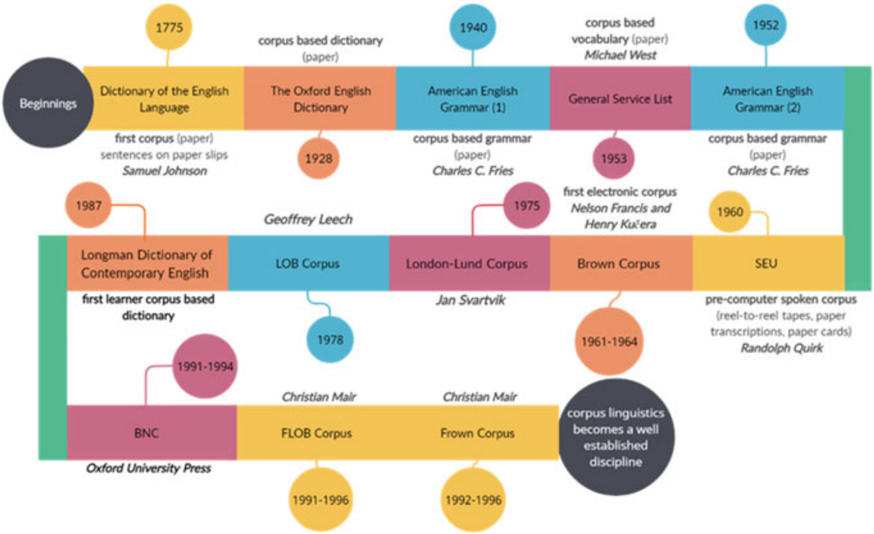

Fig. 1 History of corpus linguistics beginnings (Timeline)

grammar studies, as, for example, the two American English corpus based grammars by C. C. Fries published in 1940 and 1952 (Biber & Reppen, 2015, pp. 2–3) (Fig. 1).

An important change occurred in the 1980's when large electronic corpora became widely available and computational tools started to be used to perform linguistic analyses on that type of corpora (Biber & Reppen, 2015, p. 3). This gave rise to a flurry of linguistic studies using electronic corpora that focused on various linguistic features, ranging from lexis and grammar to register variation (pp. 3–4).

The two milestone corpora, Brown and LOB, have been paralleled by later versions, Frown (Freiburg-Brown corpus of American English) and FLOB (Freiburg-LOB Corpus of British English), initiated by Christian Mair at the University of Freiburg in Germany in 1991. The linguistic data in the later versions were meant to reflect the language development from the initial corpora (1960's) to that time (1990's).

Since then, the continuous advances in technology enabled the use of electronic corpora and corpus tools at a very large scale. At the moment, corpus linguistics is a well-established discipline, and its data analysis methods contribute to investigating language from various perspectives related to topics such as registers, dialects or entire languages (Egbert et al., 2020, p. 3).

1.3 Core Idea of the Technology

Corpora can be broadly defined as machine-readable sets of texts compiled following criteria that are analysed with the help of computer software, as they are too large to undergo manual analysis (McEnery & Hardie, 2012, pp. 1–2). The way a corpus is built is of very much importance, because a corpus should ideally "represent, as far as possible, a language or language variety as a source of data for linguistic research." (Sinclair, 2005).

Web-based corpora, mainly composed of web pages, are the largest corpora available, containing billions of words. For example, the filtered version of the Common Crawl[1] used for the pre-training dataset for GPT-3 (i.e. Generative Pre-trained Transformer 3[2]) consists of 410 billion tokens. This large quantity of data enables powerful quantitative analyses. In addition, it is now possible to apply corpus linguistics methods to less structured language repositories, such as text archives (e.g. LexisNexis, Google Books), or even the entire web. Common search interfaces allow basic queries that can yield linguistically relevant results. More powerful, however, are the so-called corpus architectures, which enable more complex queries usually found in corpus linguistics tools. Examples of corpus architectures include the googlebooks.byu.edu interface, which uses n-grams extracted from the Google Books, and the web-based tool Sketch Engine which, along a variety of other corpora, hosts several enormous web-based corpora that can be searched using all the tool's features (Davies, 2015, pp. 19–22).

While web-based corpora are very successful in representing the genres normally found on the web, e.g. newspaper articles, they cannot offer a comprehensive picture of other language varieties, such as fiction or spoken language. General purpose genre-balanced corpora seem to be a good middle ground between size and representativeness. Corpora of this type contain sub-sections which are representative of several registers, and are also considerably large in size, so that powerful statistical analyses are supported. Two famous genre-balanced corpora are the *British National Corpus (BNC)* and the *Corpus of Contemporary American English (COCA).* COCA, which currently contains more than one billion words, is representative for eight registers including academic texts, speech, and fiction. New data is continuously being added to the corpus in a controlled manner, much attention being dedicated to preserving the genre balance in each subsection.

Even so, in certain cases, the language domain studied is composed of texts that are not found in general-purpose corpora. This, therefore, requires the usage of a specialized corpus, a type of corpus that represents as far as possible the full range of linguistic variation from a specific variety of language (Clancy, 2010, p. 82). The representativeness of the corpus is more important than its size, because it was proven that a well-designed specialized small corpus can provide more relevant results regarding "specialized lexis and structures" (O'Keeffe et al., 2007, p. 198)

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[1] https://en.wikipedia.org/wiki/common_crawl.

[2] https://en.wikipedia.org/wiki/GPT-3.

than a large corpus that was not customized to meet the researcher's needs (Nesi, 2012, p. 408).

Yet, there are situations in which no ready-made corpus can meet the needs of a specific research question, and, in these cases, scholars need to compile new corpora. Sometimes called DIY corpora, these corpora are compiled in basic formats, e.g. txt files, and are smaller than ready-made specialized corpora, but because they contain only the language variety under investigation, their analysis yields valuable results (Nesi, 2012, p. 408). However, most of the time DIY corpora remain private due to copyright laws.

1.4 Processing and Tools

In order to apply corpus linguistics methods to a data set, several steps need to be taken. The corpus is first compiled, then the corpus data is annotated, and, finally, the corpus is analysed using corpus linguistics software (Rayson, 2015). Annotation is a procedure which "allows the researcher to encode linguistic information present in the corpus for later retrieval or extraction" (Rayson, 2015, p. 38). Certain types of annotation can be done automatically, while others are done manually. Automatic annotation with a high degree of accuracy has already been achieved for English (and other major languages) at the levels of: "morphology (prefix and suffix), lexical (part-of-speech and lemma), syntax (parsing)" sense) (Rayson, 2015, p. 39), and, in many cases, semantics (semantic field). However, one downside of automatic annotation is that it is not accurate enough for every language. Manual annotation, on the other hand, is done for areas not supported by automatic annotation, e.g. discourse (Rayson, 2015).

After having been compiled and annotated, the corpus can be searched using software tools for corpus analysis. The tools can be standalone software that one installs on their computer, e.g. Wordsmith, Antconc, Lancsbox. One important goal of these tools is to be user-friendly. However, they still require a learning curve, and this may discourage non-corpus linguists from using them.

1.5 Functional Specifications

The use of corpora equals, primarily, as previously mentioned, access to authentic language samples. Such access can be performed unsystematically, via large search engines (e.g. Google), or in a more structured manner, through dedicated corpus search platforms (e.g. COCA corpus platform). Nevertheless, users should consider the following types of shortcomings in relationship to both access situations: first, unsystematic databases contain linguistic information which is unfiltered, not properly verified nor structured; then, corpus platforms, while including linguistic information that has been collected according to specific representativeness criteria, are, quite frequently, not open source (i.e. licence-based).

Writing-focus tools are built and designed to integrate large amounts of linguistic information with the purpose of extracting statistically validated language patterns and offer context specific solutions. For example, such instruments can perform instant searches in their in-built corpora, select multiple word associations and generate best-matching collocation lists. This could benefit writers who are uncertain about the grammatical construction of a linguistic cluster, about the lexical choice within a structure or about the phraseological options to mark a specific rhetorical move.

The ultimate benefit of collecting large amounts of linguistic data is opening up immense possibilities for research and applications in areas at the intersection of Natural Language Processing and Artificial Intelligence. Because most large corpora nowadays can be easily compiled using web-scraping methods (see previous sections), computers can be trained to recognize linguistic patterns and predict others.

Since this latter aspect is quite vast and requires clarifications which are beyond the scope of explaining how corpus linguistics contributes to writing research and applications, in general, we exemplify such uses in the following two sections: corpus linguistics for writing studies and corpus related writing applications.

2 Corpus and Writing Research

2.1 Learner Corpora

The language produced by foreign, or second language learners is called learner language (Gilquin & Granger, 2015, p. 418) and it is investigated within a branch of corpus linguistics named Learner Corpus Research. Research in this field has provided valuable insight into various learner language areas, such as grammar, lexis, phraseology, various discourse phenomena and pragmatics. Since English is the preferred language for "international research and global communication" (Flowerdew, 2015, p. 466), and, as a consequence, non-native novice writers are required to master English academic writing norms, learner corpus research covers many aspects of writing in English. The learner corpora investigating English for Academic Purposes (EAP) are of two types: English for general academic purposes (EGAP) corpora and (2) English for specific academic purposes (ESAP) corpora. Corpora of the EGAP type contain writing common to multiple disciplines, such as argumentative essay writing on general topics, which, even if it is not discipline specific, helps students "practise the same rhetorical functions found in disciplinary writing" (Flowerdew, 2015, p. 468). One such corpus is the *International Corpus of Learner English*

(ICLE) (Granger et al., 2009), which consists of essays written by undergraduate students, foreign or L2 learners of English from various L1 backgrounds.

The ESAP type of corpora usually contain texts which are representative of "written disciplinary genres that tertiary students have to master" (Flowerdew, 2015, p. 467), and contain sub-corpora divided by discipline or genres. Large-scale international corpus building initiatives exist, such as the *Varieties of English for Specific Purposes* (VESPA) and the *Corpus of Academic Learner English* (CALE). Both corpora aim at collecting texts from multiple L1s, disciplines and genres (Flowerdew, 2015, p. 468). Other ESAP learner corpora have been compiled for a specific ESP/EAP context, and they usually consist of texts from certain L1 users or from certain disciplines or genres. A case in point is the Romanian Genre Corpus / ROGER (Chitez et al., 2021), a comparable bilingual corpus which comprises university writing by L1 Romanian students, in their mother tongue and in English as a Foreign Language.

2.2 Research, Teaching and Development

As explained at the beginning of this chapter, corpus linguistics has become an independent and multivalent discipline which has attracted the attention of many researchers. With a history of almost a century, corpus based research has migrated from the field of linguistics towards interdisciplinary areas that centre round information technology. Corpus linguistics research is now performed at departments of modern languages and IT alike, with extensions towards Digital Humanities approaches. This multidisciplinary expansion has also been absorbed by teaching initiatives in all types of educational settings: pre-university language related approaches, university corpus based teaching and post-university further education programs. But the group that profits the most from the existence and improvement of corpus based writing research methods is the application and development group, represented by the applied research departments at universities and language related industry. It is now widely acknowledged that, by compiling linguistic datasets, practical tools and digital products can be developed which are supposed to improve processes in all sectors that involve linguistic analyses or language use, including writing. Numerous products (see Sect. 3) have been launched internationally and have billions of users.

3 Main Products

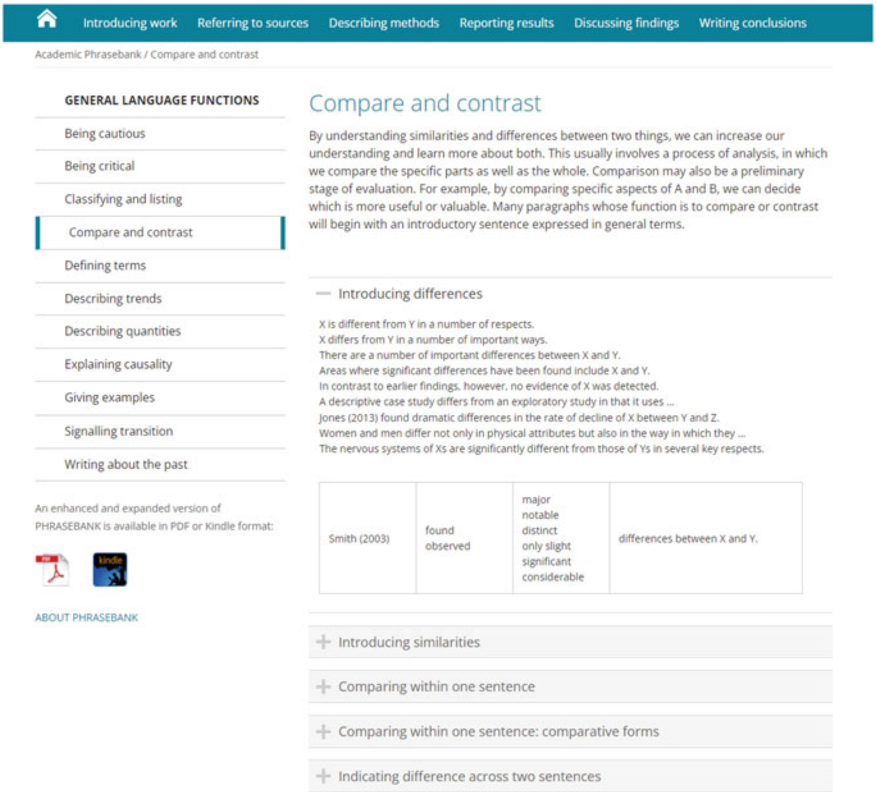
3.1 Corpora as a Basis for Primary Linguistic Tools for Writers

There are two main categories of corpus based primary linguistic tools for writers that have helped both expert and novice writers to foster their general or academic writing skills: dictionaries and phraseology databanks. The first category is fairly widespread and it is the main language instrument that students, teachers and general language users consult in order to validate their linguistic choices or search for refined alternatives. The inventory created by Frankenberg-Garcia (2014) includes the textbook and dictionary series of the five major UK academic publishers: Cambridge, Collins, Longman, Macmillan and Oxford. All of them have produced language support resources that target the general language user (e.g. Cambridge Dictionary of American English), the grammar rule seeker (e.g. Cambridge Grammar of English), the L2 English language user (e.g. Collins COBUILD English Dictionary for Advanced Learners) or the writing challenged user (e.g. Macmillan Collocations Dictionary). The Cambridge series is quite rich with books from the following internationally used series: Cambridge Dictionary of American English, Cambridge International Dictionary of English, Cambridge Grammar of English, Cambridge Learner Corpus, Touchstone series, Vocabulary in Use series. They are based on the Cambridge English Corpus, which includes all the words at CEFR levels A1–C2. The Cambridge corpus based language aids are mainly used by those who want to write in a native-like manner.

In the second category, a valuable academic writing resource that has corpus based research at its roots is the Academic Phrasebank (Morley, 2018), developed at the University of Manchester (Picture 1). The phrases have been ‘harvested’ (Morley, 2018, p. 4) from a corpus consisting of “100 postgraduate dissertations completed at the University of Manchester” while “phrases from academic articles drawn from a broad spectrum of disciplines have also been, and continue to be, incorporated” (p. 4).

3.2 Corpus Based Data Driven Learning

The use of linguistic corpora has not been limited to research in the field of corpus linguistics, but instead it has become an indispensable practice in all language related areas such as translation studies, applied linguistics, sociolinguistics or language teaching. The use of linguistic corpora has garnered the interest of researchers, teachers and students alike (Boulton & Tyne, 2013; Tribble, 2002). Corpus based teaching activities have proven to have a positive effect on the students’ linguistic competences, as their writing improves at multiple levels, such as, for example,



Picture 1 Examples of phrases for 'Compare and Contrast' in Academic Phrasebank

lexico-grammatical features (Boulton & Tyne, 2013; Chitez & Bercuci, 2019; Cortes, 2007; Levchenko, 2017; O'Sullivan, 2010).

The study by Tatyana Karpenko-Seccombe (2020), *Academic Writing with Corpora: A Resource Book for Data Driven Learning*, introduces the latest corpora-based resources suitable for teachers and students interested in language and writing improvement. Beside introducing various online corpora and several free-to-use tools, the book also provides practical examples of corpus based language acquisition improvements and shows the practicality of corpora in improving academic writing, both at micro (e.g., argumentative writing) and macro (e.g., writing a literature review) levels.

Most corpora in English can be used in classroom activities for teaching academic writing, whether as general/reference or specialized corpora. Many such resources are readily available online on websites comparable to https://www.english-corpora.org/, the largest and most frequented online resource of English-language corpora. For example, COCA (*Corpus of Contemporary American English*) has been used by Chang (2014) alongside a private specialized corpus (*Michelangelo*) to improve the students' writing in ESL (English Second Language). Likewise, the BNC (*British National Corpus*) and iWEB (formerly *BYU Corpora*) have been used productively by Khan (2019) to teach academic lexical bundles to ESL students. As far as specialized corpora are concerned, MICUSP (*Michigan Corpus of Upper-Level Student Papers*) has been used by Ädel (2010) to effectively introduce students to rhetorical moves in academic writing. Similarly, The ICLE corpus family—International Corpus of Learner English (Granger, 2003) has been used in numerous studies (e.g. McEnery et al., 2019) to analyse interlanguage phenomena or extract potential learner error areas that can be exploited pedagogically. More recent academic writing databases are: CROW (*Corpus and repository of writing*) (Staples & Dilger, 2018), containing US college writing samples, and ROGER (Corpus of Romanian Academic Genres) (Chitez et al., 2021), containing university students writing in Romanian L1 and English L2.

As many experts note, one of the most successful methods of integrating corpora in teaching academic writing was by having students create their own specialized corpora (Chang, 2014; Cortes, 2007; Levchenko, 2017; Yoon, 2008). To this end, there are undeniable benefits of user-friendly software that can be used in corpora-based teaching activities for academic writing classes both by teachers and their students. Standard corpus analysis tools are the free-to-use #Lancsbox (Brezina et al., 2020) and AntConc (Anthony, 2022), the available-for-purchase WordSmith Tools (Scott, 2020) and many others that are mentioned on the webpage *Tools for Corpus Linguistics*.[3]

3.3 The Use of Built-In Corpora in Writing Tools

3.3.1 Corpus Based Writing Improvement Tools

Corpus based writing improvement tools integrate searches specific to corpus linguistics into user-friendly, web-based platforms. In other words, users can perform linguistic searches in a variety of corpora hosted by the platform. Some of these platforms are commercial (e.g. Ludwig.guru[4]) and others are developed in academic contexts (e.g. AWSuM[5]). The commercial platforms address multiple audiences, such as scholars, students, or professionals, whereas the academic tools target academic oriented audiences, such as students or researchers.

The target audience influences the corpus data contained by the platforms. Ludwig.guru, directed towards several audiences, hosts a variety of corpora divided into several categories based on register (e.g. News and Media, Science and Research or Formal and Business). In addition, users can create a corpus with their own linguistic data. By contrast, AWSuM, directed towards an academic audience,

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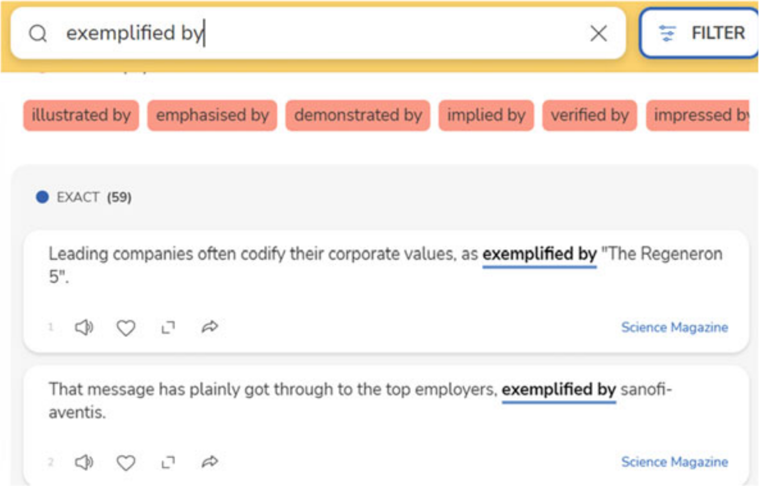
[3] https://corpus-analysis.com/

[4] https://ludwig.guru/.

[5] https://langtest.jp/awsum/.



Picture 2 Concordance function Ludwig.guru

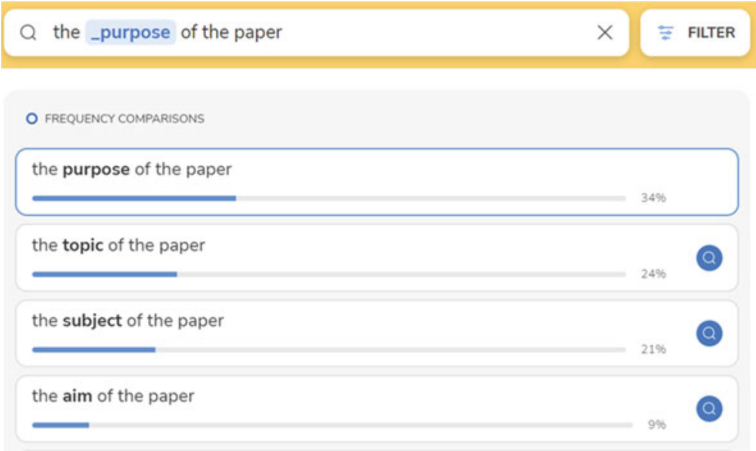
contains a corpus of academic writing, divided into two datasets made up of published research articles from two disciplines: Applied Linguistics and Computer Science. One important advantage of the AWSuM corpus is that it has been annotated for rhetorical moves (Atsushi, 2017).

Ludwig.guru provides several corpus based search features. Basic and complex free searches in the corpora hosted by the platform can be performed. The user can input a search word or phrase and explore their use in a variety of authentic language contexts (Picture 2). An example of a complex free search is the use of the wildcard "_", through which the user gets synonym suggestions for a certain word in a phrase, as shown in Picture 3.

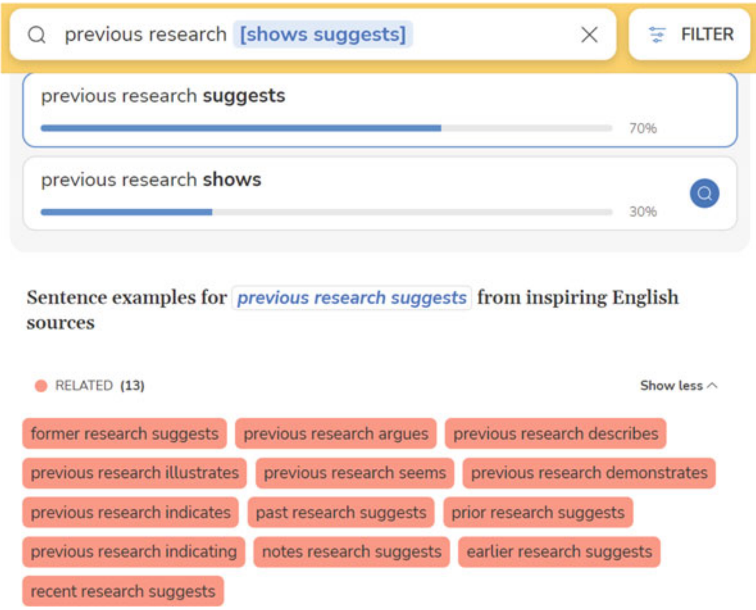
In addition, the frequency of two words or two sentences can be compared (Picture 4). This can be useful when the writer is unsure of the structure of a multi-word unit or what words that have a similar meaning are preferred in a certain register (Charles, 2018, p. 20). Phraseological suggestions are also offered based on the user's input, helping the writer to diversify the language he or she is using.

3.3.2 Genre Writing Tutors That Use Built-In Corpora

Tools for genre writing pedagogy also use built-in corpora. These tools are mainly developed in academic contexts, with the aim to provide support for students when writing certain academic genres, such as bachelor thesis or research paper. Apart from various writing support functionalities, such as writing tutorials, or phrase banks, certain tools of this type incorporate a specialized corpus that users can search via an integrated corpus search function.



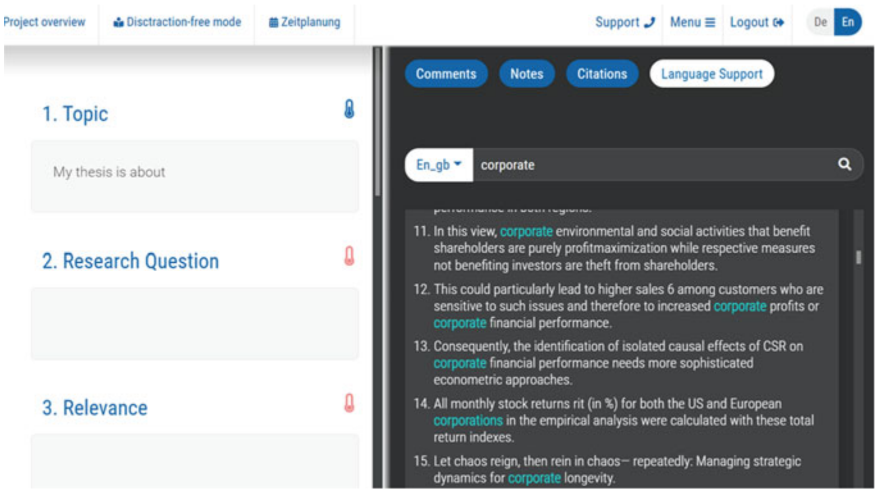
Picture 3 Synonym search Ludwig.guru



Picture 4 Phraseological support Ludwig.guru

Thesis Writer[6] is a tool developed at Zurich University of Applied Sciences in Switzerland which assists economics students write their bachelor or master thesis in either German or English. The platform integrates an economics discipline-specific,

[6] https://thesiswriter.zhaw.ch/



Picture 5 Thesis Writer. *Examples of word use* feature

open-source corpus that can be explored via a keyword-in-context free search. Students can explore various authentic language excerpts containing the search term (Picture 5). Additionally, related collocations can be retrieved by using the tool's feature "Associated words."

The Research Writing Tutor (Cotos, 2014), thoroughly described in "Automated Feedback on Writing" also uses a specialized academic corpus. The multidisciplinary corpus, composed of "900 journal articles published in the top journals of 30 disciplines" (Cotos, 2017, p. 258), was manually annotated for rhetorical moves and steps. The moves were color-coded, and the steps were glossed. One module of the platform entitled "Explore Published Writing" gives access to the annotated texts and integrates a concordancer that can be used to search the corpus by move, step and discipline. In this way the users can get "examples of functional language indicative of the step's rhetorical meaning" (Cotos et al., 2017, p. 110).

4 Future Developments

Although the modern writing research community is more and more aware of the potential of corpus research and applications for writing, there are still aspects that can make the collaboration between the two communities more effective. At this stage, it appears that there is the group of corpus linguists that performs linguistic analyses regarding L1 and L2 phenomena, which often include writing topics, and the group of writing research, which is interested in pedagogical concepts of writing, the writing processes that are associated with them or the socio-cultural writing embedment, which sometimes include corpora in their investigations. The synergy between these two areas can be improved by creating networking (e.g. common conferences and dedicated sessions in existing conferences) and dissemination opportunities (e.g. dedicated journals) in which mixed methods are encouraged.

Moreover, the field of computational sciences has become essential for further developments. This means that, if valuable improvements are to be made in the corpus use for writing studies and applications, IT specialists should be involved. Linguistics and writing departments should work more closely with the IT departments at the university or outside university. The same is valid for IT companies that develop writing apps: they should not ignore the importance of having linguists and writing specialists in their teams. This can make the difference between having a general use product that is limited in applicability and complex tools that address specific writing groups. Also, it is clear that the Artificial Intelligence corpus related methodologies are the future of writing support technologies: more and more linguistic data need automatic processing and evaluation, which cannot be performed via traditional methods any more.

Last but not least, resources that regard corpora and writing can be made more systematic and visible, with clearer indications on how to use them. Particular attention should be paid to updating corpus and tool lists and recommendations for specific writing interest groups. At the moment, there are disparate locations for such resources, such as: CLARIN (section: Language Resources [1]), Corpus Resource Database (CoRD) [2] or the webpage Corpus-Analysis [3].

[1] More information at: https://www.clarin.eu/content/language-resources
[2] More information at: https://varieng.helsinki.fi/CoRD/
[3] More information at: https://corpus-analysis.com/

5 Tools

No	Tool / Software	Description of the tool and underlying technology	Reference	URL if available
1	Antconc	freeware corpus analysis toolkit for corpus analysis; downloadable; versions for Windows, MacOS and Linux	Anthony (2022)	https://www.laurenceanthony.net/software
2	AWSuM	Web-based writing assistant for academic writing support; annotated for rhetorical moves	Atsushi (2017)	https://langtest.jp/awsum/
3	COCA	Web-based corpus platform; Corpus of Contemporary American English; free; log-in required	Davies (2009)	https://www.english-corpora.org/coca/

(continued)

(continued)

No	Tool / Software	Description of the tool and underlying technology	Reference	URL if available
4	CROW	Web-based corpus platform; repository of learner writing; free; log-in required	Staples and Dilger (2018)	https://crow.corporaproject.org
5	English Corpora	Corpus overview portal; English language corpora	Davies (n.d.)	https://www.english-corpora.org
6	ICLE	Corpus databank; International Corpus of Learner English; commercial product (CD/DVD)	Granger et al. (2009)	https://www.i6doc.com/en/book/?GCOI=28001105280390
7	Lancsbox	Standalone software program for corpus analysis; downloadable; free	Brezina et al. (2020)	http://corpora.lancs.ac.uk/lancsbox
8	Ludwig.Guru	App and web-based interface (log-in required) for writing in English; sentence improvement options	Ludwig.guru (2022)	https://ludwig.guru/
9	Manchester Academic Phrasebank	Academic phrasebank webpage; English academic phrase lists; free	Morley (2018)	https://www.phrasebank.manchester.ac.uk/
10	Research Writing Tutor (RWT)	Annotated and pedagogically-mediated multi-disciplinary corpus; concordancer for rhetorical functions	Cotos (2014)	NA (Unavailable for external access)
11	ROGER	Web-based corpus platform; bilingual academic writing corpus for English and Romanian; novice academic writing; multi-disciplinary and multi-genre free; log-in required	Chitez et al. (2021)	https://roger-corpus.org/
12	Sketch Engine	Corpus query and management system; commercial product (annual user licences)	Kilgarriff et al.(2014)	https://www.sketchengine.eu/
13	Tools for Corpus Linguistics	Corpus tool portal; overview of corpus resources and their availability	Berberich and Kleiber (2020)	https://corpus-analysis.com/

(continued)

(continued)

No	Tool / Software	Description of the tool and underlying technology	Reference	URL if available
14	Thesis Writer	Online learning environment for bachelor or master thesis in either German or English. Offers various support functions (tutorials, phrasebook, corpus search, collaboration, feedback, project management…)	Rapp and Kauf (2018)	https://thesiswriter.zhaw.ch/
15	Wordsmith	Corpus analysis software; English language specific; commercial product (permanent user licences)	Scott (2020)	https://lexically.net/wordsmith/

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Investigating Writing Processes with Keystroke Logging

Åsa Wengelin and Victoria Johansson

Abstract Already in the 1970s, researchers in linguistics and psychology became interested in understanding how written language production worked, why students' texts ended up in a specific way, and whether writing instruction could be improved by an increased understanding of students' actual activities during writing - what happens "behind the scenes". They observed writing processes through video-recordings and think-aloud protocols, both of which required laborious manual analyses, but with the advent of affordable computers in the 1990s keystroke logging was developed. Keystroke logging records all keystrokes and mouse movements and provide them with a time stamp to allow playback and analyses. The purpose of this chapter is to introduce the reader to the concept of keystroke logging, explain briefly how it works, and give an overview of currently available software. First, we provide a short historical background. We then move into the core idea and functionality of keystroke logging in general before turning to descriptions of specific pieces of software. We summarise similarities and differences, aiming to show that choice of software should be governed by the research question. Finally, we discuss research that uses keystroke logging as a research tool, and provide examples of research about keystroke logging as a pedagogical tool.

Keywords Writing processes · Keystroke logging · Typing · Pausing · Revision

Behind each written text is a writer who wants to communicate something. He or she may have spent considerable time thinking about content and structure during the

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_25

writing process and meanwhile carefully formulated and revised sentences to create, for instance, an exciting story, a good argument, or a comprehensive message. These underlying processes are, however, invisible for the reader, perhaps a teacher who meets the product of those processes—the finally edited text. As pointed out by Chukarev-Hudalainen (2019, p. 126) “nobody stands behinds students’ shoulders and watches how they write their texts”. It has, however, been shown that the type and timing of fine-grained processes that writers engage in during text production, can account for up to 80% of the variance in writing quality (Breetvelt et al., 1994). Understanding students’ writing processes may therefore be of essence for teachers of academic writing.

Already in the end of 1970s and the beginning of the 1980s, researchers in linguistics and psychology became interested in understanding how written language production worked, why students’ texts ended up in a specific way, and whether the teaching of writing could be improved by an increased understanding of the students’ actual activities during writing. Independent of each other, but more or less simultaneously, Hayes and Flower (1980) in the US and Matsuhashi (1982) in the UK developed different approaches to achieve this.

Hayes and Flower, with a background in cognitive psychology, let writers think aloud about their processes while writing a text. Their main interest was to understand the major components of the writing process and the interaction between them, and the analyses of these self-reported data resulted in their seminal model of writing (Hayes & Flower, 1980). The original model, with planning, translation, and revision as the main components, has since been updated several times, and in 2014 Hayes & Berninger proposed a three-level framework consisting of a control level, a process level, and a resource level (Hayes & Berninger, 2014). The process level includes components of the writing processes and the task environment. The process components are the proposer (pre-linguistic idea generation), the translator (formulation), the transcriber (graphomotor planning and execution of handwriting or key-pressing), and the evaluator (checks whether ideas and produced texts will meet the goals of the topic, make the right impact on the audience etc., or whether this information could be improved to better meet those goals). The task environment includes collaborators and critics, task materials, and physical transcribing technology. The underlying assumption is that cognitive resources are limited—if one process requires more resources, there will be less available for others (McCutchen, 1996; Olive et al., 2002). Think-aloud protocols have been, and are still, used fairly extensively (Wengelin et al., 2019), because they are capable of providing rich information about the higher-level processes in text production. They have, however, been criticized both for relying on the writers’ subjective experiences and for being reactive.

The method used by Matsuhashi (1982), who had a linguistic background and was more interested in the lower-level linguistic processes, was less intrusive, and was inspired by spoken-language researchers such as Fromkin (1973), Goldman-Eisler (1968), and Hockett (1967). They viewed *pauses in speech* as a window to the linguistic and cognitive processes underlying language production. To capture *pauses in writing*, Matsuhashi video-recorded writers, zooming in on their hands, to register when they lifted and lowered their pens to think or to revise. This method offered no verbalised insights to the writers' minds, but provided more fine-grained and objective information, and was less reactive than think-aloud protocols.

Both these methods generated data which required laborious work and extensive interpretation by the analysts. With the advent of affordable and available personal computers, keystroke logging software, and later automatic handwriting capturing, were developed, both of which can be viewed as a modern and more automatized version of Matsuhashi's video recordings. Only keystroke logging is covered in this chapter. This technology provides (a) possibilities to capture the temporal dynamics of typing and revision with higher resolution than video recordings and (b) automatic analyses of these patterns. During the 1990s four programs became known among writing researchers—interestingly, once again produced more or less independent of each other: FAU-word (Levy & Ransdell, 1994) which was developed at Florida Atlantic University, USA; TraceIt (Severinson Eklundh & Kollberg, 1992), which was developed at the Royal Institute of Technology, Stockholm, Sweden; ScriptLog (Strömqvist & Malmsten, 1997) which was developed at University of Gothenburg, Sweden, and TransLog (Lykke-Jakobsen, 1999) which was developed at Copenhagen Business School, Denmark specifically for translation studies. Of these four, ScriptLog and TransLog are still being developed, in parallel with a few more recent pieces of software. We outline currently available programs, their main functionality, and similarities and differences between them in the tools list at the end of the chapter.

1 Core Idea of the Technology

The core idea of keystroke logging is to record all the events of the writing process and thereby enable researchers to observe writing processes and thus increase their understanding of what happens "behind the scenes" during text production. Each event—a keystroke or a mouse movement—is provided with a time stamp to allow playback and analyses. The example below shows the first two sentences of a text produced by a Swedish university student who participated in an experimental writing research project at her university (rough English translation is provided below).

> Fusk är ett av de vanligare problemen i skolor, och förmodligen långt vanligare än de flesta lärare vet om. I regel är det nog vanligare att pojkar fuskar än att flickor gör det, och om vi tittar närmre på könsrollerna så kan vi kanske hitta ledtrådar till hur barn (jag kommer utgå från barn i skolålder i denna text) förhåller sig till fusk.
>
> [Cheating is one of the most common problems in schools, and probably much more common than most teachers know. As a rule, it is probably more common that boys cheat than that girls do it, and if we look closer at the gender roles we may perhaps find clues to how children (I will children of school age as my point of departure) relate to cheating.]

After the writing session, the full text encompassed 16 orthographic sentences, 377 words or 2289 characters including spaces, punctuation marks, and line feeds. To produce her 2289 characters, the writer conducted 3504 key "events" (key presses including arrow keys and backspace but also mouse movements). Thus, her total her writing process included more than 1200 events of which the readers are not aware—probably mainly revisions but she could also have just moved around in the text, or even written and deleted gibberish as a thinking strategy. Possibly (hopefully) one reason for her thinking and revising was to adapt the finally edited text to the intended receiver.

The basic type of events generated by keystroke logging programs are keystrokes that change the text somehow—letters, numbers, punctuation, spaces, line feeds etc., but also keypresses/events, such as delete, backspace, arrow keys, cut and paste shortcuts etc. Further, most programs available today record mouse movements and, more recently, some have incorporated the possibility to synchronize the recordings with eye trackers. This enables investigations of writers' reading of their own emerging texts during writing. In common for all programs is that the events they record are saved in a log, which can be used both for generating various types of analysis files and for playback of the writing process. The table below shows a part of a simplified log file corresponding to the text fragment in 1a. Each line corresponds to a recorded event during the writing session. The left column shows the time stamp, and the right column the content of the event. We enter the scene just as the writer is about to finish the first sentence. The first line of the log file shows the full stop ending the first sentence. This is followed by a 'space'. Then–as the time stamp indicates–there is a pause of approximately 9 seconds after which the writer starts the second sentence with the words *Fusk har nog förekommit* ('cheating has probably occurred'). However, she changes her mind and deletes 26 characters by means of 26 consecutive presses of the BACKSPACE key. Instead of these, she writes the words: *I regel* ('As a rule') which are the two first words of the second sentence in the finally edited text.

Time stamp (event ended)	Event output
00:01:16.019	
00:01:16.219	SPACE
00:01:25.731	F
00:01:25.930	u
00:01:26.091	s
00:01:26.211	k
00:01:26.379	SPACE
00:01:26.563	h
00:01:26.747	a
00:01:26.923	r
00:01:27.019	SPACE
00:01:27.363	a
00:01:28.179	l
00:01:28.347	l
00:01:28.523	t

(continued)

(continued)

Time stamp (event ended)	Event output
00:01:29.058	BACK
00:01:29.250	BACK
00:01:29.434	BACK
00:01:29.650	BACK
00:01:30.811	n
00:01:31.139	å
00:01:31.978	BACK
00:01:32.443	o
00:01:32.578	g
00:01:32.803	SPACE
00:01:33.027	b
00:01:33.394	BACK
00:01:33.546	f
00:01:33.706	ö
00:01:33.866	r
00:01:34.211	e
00:01:34.499	k
00:01:34.618	o
00:01:34.882	m
00:01:35.018	m
00:01:35.164	i
00:01:35.298	t
00:01:35.434	SPACE
00:01:35.634	s
00:01:35.763	å
00:01:36.098	BACK
00:01:36.593	BACK
00:01:36.639	BACK
00:01:36.686	BACK
00:01:36.733	BACK
00:01:36.780	BACK
00:01:36.826	BACK
00:01:36.873	BACK
00:01:36.920	BACK
00:01:36.967	BACK
00:01:37.014	BACK
00:01:37.061	BACK

(continued)

(continued)

Time stamp (event ended)	Event output
00:01:37.108	BACK
00:01:37.155	BACK
00:01:37.201	BACK
00:01:37.248	BACK
00:01:37.570	BACK
00:01:37.810	BACK
00:01:38.034	BACK
00:01:38.226	BACK
00:01:38.418	BACK
00:01:38.578	BACK
00:01:38.730	BACK
00:01:38.898	BACK
00:01:39.082	BACK
00:01:39.258	BACK
00:01:50.658	I
00:01:50.826	SPACE
00:01:51.074	r
00:01:51.314	e
00:01:51.522	g
00:01:51.706	e
00:01:51.794	l
00:01:51.930	SPACE

Keystroke logging tends to generate massive amounts of data, and the readability of log files, even such a simple one as in the example above, is low. To increase readability, most program also generate a *linear file* which shows what is typically considered a static replacement of the playback. It shows the linear representation of how the text was produced:

<START><34.119>Fusk <4.463>är <10.543><BACKSPACE1>, <BACKSPACE2> ett s<BACKSPACE1>av de vanligare problemen i skolor, och förmodligen långt vanligara än de flesta vä<BACKSPACE2>lärare vet om. <9.511>**Fusk har allt<BACKSPACE4>nå<BACKSPACE1>og b<BACKSPACE1>förekommit så<BACKSPACE26**><11.399>I regel är det npog<BACKSPACE2>o<BACKSPACE2>og vanligare att pojkar fuskar<BACKSPACE2>ar än att flickor gör det, och om vi tt<BACKSPACE1>ittar närmre på könsro<BACKSPACE24> tittar närmre på ko<BACKSPACE1>önstr<BACKSPACE2>rollerna så ä<BACKSPACE1>kan vi npg<BACKSPACE2>og hitta en <4.423>ledtråf<BACKSPACE1>d till <3.391>hur <4.327>barn (jag kommer utgå från barn i skolålder i denna tes<BACKSPACE1>z<BACKSPACE1>xt) <2.879>förhåller sig till fusk.

Numbers in angle brackets show pauses in the writing process, here defined as keyboard inactivity longer than 2 seconds (but see for example Wengelin (2006)

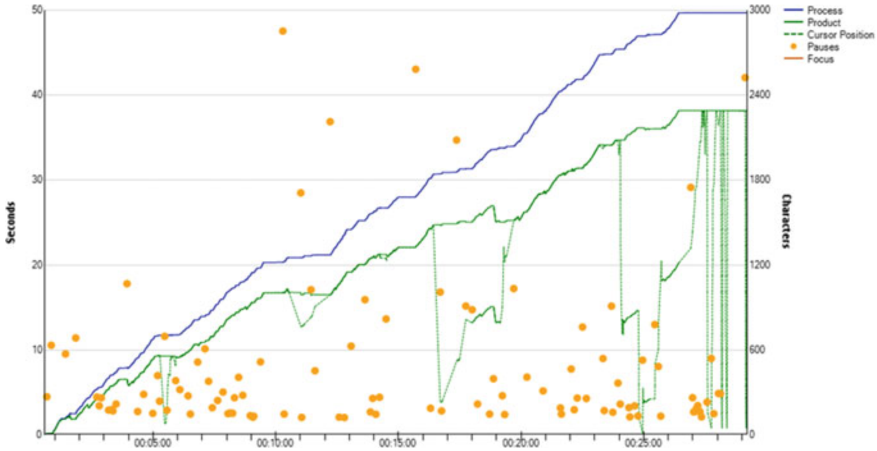

Fig. 1 A process graph

for a discussion about the complexity of pause thresholds). Angle brackets with BACKSPACE and a number (X) in them shows how the backspace key was pressed X times, for example 26 presses to delete the beginning of the second sentence.

As example of how the log file can be visualised and used for further analysis, Fig. 1 demonstrates a *process graph*. This illustrates the whole 29-min writing process that led up to the text which began with the sentences shown in the example above. The graph incorporates several aspects that could be of interest to a writing process researcher: pauses, revisions, and the dynamics of the process. The X-axis displays the temporal progression of the writing process, and the right Y-axis shows number of written characters. The blue line represents the total number of written characters, and the green line the number of characters left in the text at any given moment. Thus, the space between them represents number of deleted characters. Approximately 3 min into the writing session, we find the deletion of 26 letters as shown in the linear representation above, here represented by the "dip" in the green line. Pauses are shown as yellow dots and the left Y-axis shows their durations. The longest pause of this writer took place after about ten minutes and was almost 50 seconds long.

2 Main Products and Their Functional Specifications

There are two main types of keystroke logging programs: stand-alone programs with specialized editors for experimental research, and programs which can be used "behind" existing commercial word processers, such as MS Word. The latter type offers a more authentic setting than the first mentioned, but both require special software to be installed in the computer. These programs have to a large extent, but not solely, been restricted to laboratory-based research. Educational institutions, commercial companies etc. may not always be comfortable with—or have IT policies allowing—unfamiliar logging software installed in their computers. However, recently, web-based systems that could easily be deployed without having to install specialized software have started to emerge. See the descriptions of ScriptLog and CyWrite below.

To our knowledge, there are currently five programs available that have been developed for academic use and which are free of charge. While InputLog, ScriptLog and TransLog have been around for long, GenographicX and Cywrite can to a certain extent be viewed as "the new kids on the block" and they do indeed add useful functionality.

InputLog (Leijten & Van Waes, 2013) is probably the most widely known and used keystroke logging program at the moment. It was developed at the University of Antwerp, Belgium by Luuk van Waes and Mariëlle Leijten. InputLog logs data in all Windows applications but is particularly well equipped for analyses of text production in MS Word, which allows writers to format their texts as they would do in an authentic setting. It logs keystrokes, mouse activity, and Windows events, and offers a large range of process analyses, visualisations, and linguistic analysis (for Dutch and English). InputLog can be used with eye tracking but does not synchronize the output of the keystroke logging and the eye tracking automatically. The program also includes a report module specifically aiming to facilitate writing tutors in providing process feedback to their students (Vandermeulen et al., 2020). The analysis module of InputLog can import files from ScriptLog (see below). Researchers who want a more experimental and controlled recording environment, but still wish to have access to the rich variety of pre-programmed analyses offered by InputLog, can combine the two.

ScriptLog (Wengelin et al., 2019) was originally developed as a Mac program at the University of Gothenburg, Sweden, by Sven Strömqvist and colleagues (Strömqvist & Malmsten, 1997). The current version is platform independent (Mac, Windows, Linux) and was developed at Lund University by Johan Frid, Roger Johansson, Victoria Johansson, and Åsa Wengelin. The program offers several experimental settings, such as various elicitation formats (pictures, sounds, texts, the triple task paradigm, and opportunities to manipulate the text already produced during the writing session (e.g. Meulemans et al., 2022). To offer a controlled and replicable writing environment, the program has a simple built-in editor which logs keystrokes and mouse activity and offers full synchronisation with SMI eye trackers. A simple web-based version (without eye tracking synchronisation) is currently being developed. The analysis functionality is more limited in the current ScriptLog version than in previous ones. The program offers real-time playback, step by step playback and fast forward playback. In addition, it produces basic summary statistics, temporal data, and a linear file, but no revision analysis. The developers recommend exporting keystroke data to InputLog (and offers an export function to do so).

TransLog II (Carl, 2012) is a Windows-based program which was originally developed, by Arnt Lykke Jakobsen (Lykke Jakobsen, 1999) at the Copenhagen Business School, Denmark, for translation process research. The current version, which was developed by Arnt Lykke Jakobsen and Michael Carl, can, however, be used for any study of human reading and writing processes. It consists of a supervisor module in which experiments can be designed, and recordings replayed, and a user module in which the experiments are run. Translog records keystrokes and mouse activity and offers synchronisation with both EyeLink and SMI eye trackers. The program has no built-in analysis module but exports several tab-separated summary tables that can easily be processed by various visualization and (statistical) analysis tools.

GenoGraphiX-Log (Usoof et al., 2020) was developed by Gilles Caporossi, HEC Montréal, Canada, Christophe Leblay, University of Turku, Finland, and Hakim Usoof, University of Peradeniya, Sri Lanka. The program functions on both Mac and Windows computers and the idea behind it is to combine text genetics and graph-theory with keystroke logging. The authors state that "[t]he software is intended to be used by teachers, students, researchers and writing professionals." The recording module uses its own built-in editor and offers a choice of free writing, translation and editing translations. Both keyboard and mouse activity are recorded, but no synchronization with eye tracking is available. The analysis module offers a wide range of visualizations and the possibility to export log data in the form of (.tsv) files into spreadsheet or statistical software for ease of use.

CyWrite (Chukharev-Hudalainen, 2019) was developed by Evgeny Chukharev-Hudilainen, at Iowa State University, US, and differs from all the afore-mentioned tools in two ways. Firstly, the recording module is web-based, and secondly, it aims to include automated writing evaluation (AWE)—although the AWE modules have not yet (spring 2022) been publicly released. Having a web-based recording module is useful, in that no specialized software that could possibly be suspected to be a spyware needs to be installed in the computer. Moreover, a web application simplifies preparations for researchers who want to collect larger numbers of data. Like several of the other programs, CyWrite features a simple text editor that captures composition with the possibility to combine keystroke logging and eye tracking. Keystrokes, text changes, and eye fixations are recorded. Keystroke timings are obtained programmatically via event handlers in the JavaScript code running in the user's web browser. CyWrite's editor interfaces with a wide range of the eye trackers. The keystroke, text-change, and eye-tracking logs are streamed live to a server-based analysis module where they are analysed and persistently stored. The logged events are then rendered in a post-session viewer offering playback and visualization of the data.

In addition to the above-mentioned programs, all of which are more or less available to the research community—either via the web or by contacting the persons/groups behind them, there are also examples of "in house" software developed by various research groups to solve specific research problems. Perhaps the most well-known example is what in an early stage was called EyeWrite (Simpson & Torrance, 2007). It was originally developed by Mark Torrance at Nottingham Trent University, and Sol Simpson at SR Research. This is not a stand-alone program but rather code that provides a logging/eye tracking editor object within Experiment Builder and PsychoPy. When needed, the researchers/developers adapt the code to their current research questions. Because of this constantly changing functionality, the current Nottingham Trent team have stopped referring to it with a specific name, and just as in TransLog, there is no built-in analysis module. Instead, tab-separated data is generated for analysis in any spreadsheet software or through code written by researchers in Python or R on a needs-basis.

3 Research

As already mentioned, keystroke logging was developed as a research tool to enhance the understanding of the cognitive processes of written language production. It has mainly (but not solely) been used in experimental settings by psycholinguists, and cognitive scientists. Examples of research questions are: What can fluency and pausing in writing tell us about cognitive processes in writing, what are the challenges of writing for writes of different proficiency levels and what strategies do they use to meet those challenges, how does writing processes develop across ages, and how can awareness about writing processes be used to promote writing development. Many of these studies have had university students as their participants, because they are relatively easy to recruit, and usually have above average typing skills. However, such studies have rarely focussed on academic writing per se, but rather recorded short writing sessions (≈30 min) with specific experimental aims. Bowen (2019) is an interesting exception. He used keystroke logging to collect all writing episodes of four academic essays that were part of undergraduate assessment in the English language and literature subject and analyzed the revisions within the framework of Systemic Functional Linguistics (SFL). He could thus demonstrate how lexicogrammatical choice unfolds as text is being written.

There is no prescribed pedagogical use or single answer to what keystroke logging adds to academic writing, which is the focus of this book, but logging of writing can, undoubtedly, be useful in instructional settings, apart from just investigating various aspects of language development—which of course are of indirect pedagogical relevance. Direct pedagogical applications have been developed—first and foremost for observing, understanding, and reflecting upon writing processes—but there are also attempts of using keystroke logging for evaluation and intervention.

As regards observation and reflection, Rijlaarsdam and Couzijn (2000, p. 176) argued that "If students are not even aware of their writing strategies and their results, they can hardly be expected to evaluate—and thus deliberately change, maintain or abandon—them". Based on the idea that writers need to become aware of various processes of their own writing, but that it wouldn't be realistic to assume that they will be able to juggle their own writing processes—integrating language, topic, genre, and audience—and learn from them simultaneously, observational learning in writing typically involves the observation of another person (teacher or peer) carrying out a certain writing task (Rijlaarsdam et al., 2008). Keystroke logging can facilitate this by means of its playback function, where a keystroke log can be replayed an infinite number of times, which allows observation not only of other writers but also of one's own writing processes. Using this to direct students' attention to their processes, rather than the finally edited text, will enhance their awareness of their own writing (eg. Lindgren et al., 2011). As reflection and verbalization are crucial aspects of observational learning, pedagogical usage of keystroke logging typically involves commenting on and dialogue about the playback as it goes along. The writer is either asked to comment on everything that happens on the screen, or on more specific aspects such as long pauses or revisions. Van Waes, Leijten, Lindgren & Wengelin (2016) suggest that writers' playback of their own text production output transforms into new input, in terms of Swain's (2000) output hypothesis. Studies have shown that using keystroke logging as an awareness raiser have proven effective in writing classrooms of both adolescents (Lindgren, 2005; Lindgren & Sullivan, 2003) and adults (Sullivan & Lindgren, 2002), in both first and second language writing (Lindgren et al., 2017), in translation classes (Hansen, 2006; Schrijver et al., 2012), and in professional development (Ehrensberger-Dow & Perrin, 2013; Eherensberger-Dow & Massey, 2013; Perrin, 2013).

For writing teachers, the playback function of keystroke logging can also provide indepth knowledge about their students' writing strategies, what they struggle with, how they overcome challenges etc., and this may be a key to understanding how to support their writing development. Studies of writers with dyslexia have, for example, shown how their struggling with spelling and avoiding of difficult words influence their writing processes, "stealing" cognitive capacity from higher-level processes, resulting in lower-quality texts (Sumner & Connelly, 2019; Sumner et al., 2013; Wengelin, 2007). And in L2 research Smith (2012) combined keystroke logging with eye tracking to investigate what learners attended to during chat sessions with instructors who used corrective recast. They concluded that playback from these technologies can be valuable in helping to determine which features of the input are likely to be noticed by learners.

Another aspect of observational learning is modelling. Several studies have shown that observing models, either a teacher (Harris et al., 2006) or a peer (Fidalgo et al., 2008; Hillocks, 1986) is a successful strategy in writing instruction. In the classroom a teacher typically models a certain behaviour but using peers has also shown results in academic settings. For instance, Van de Weijer et al. (2019) carried out a short intervention study with small groups of university students with and without hearing impairment, to train their skills in argumentative writing. They found no consistent improvements, but the variation indicated that further research with longer intervention and larger groups would be of great interest.

Recently, researchers have also attempted to bridge the gap between writing process research and pedagogical applications by proposing that keystroke logging could be used for automatic evaluation of students' engagements in writing processes as well as for writing process interventions. For example, Dux Speltz and Chukharev-Hudilainen (2021) carried out an experimental study with the purpose of increasing fluency in students' text production by providing automated real-time feedback during the writing process and comparing that to a control condition with no feedback. Participants wrote more text, expressed more ideas, and produced higher-quality texts in the fluency-focused intervention condition. However, the cost of this was—both as shown in their text products, and according to their own statements in a follow-up survey—that they sacrificed accuracy.

4 Implications for Writing Theory and Practice

Keystroke logging was developed as an unintrusive approach to investigating how the writing process unfolds in real time. By analysing typing and its temporal characteristics, such as fluent and less fluent phases, pauses and revisions we can gain some insights into how writers orchestrate the different subprocesses of writing. This is useful not only for cognitive researchers but for writing instructors who are interested in understanding the challenges and strategies of their students. However, to interpret these activities in the light of more specific cognitive processes, additional information is needed, for example from eye tracking or stimulated recall interviews. While this may be viewed as a drawback in experimental research, it could be turned into a useful feature for writing instruction. By letting writing students reflect upon and comment on their own, or their peers', composition processes, their awareness about writing will increase, and they may possibly be able to improve their strategies. However, more research is needed on this, and on academic writing processes in general. Furthermore, researchers/writing instructors who want to try this should be aware that the available programs have been developed for slightly different purposes, and thus work on different platforms, have different recording functionality, and offer different analyses/playback functions.

5 Tools Table

Software	Original Purpose	Editor type	Access	Platform	License
CyWrite https://github.com/chukharev/cywrite	Writing processes	Built-in NotePad-like	Web-based	Any with a web browser	Free
GenoGraphiX-Log https://www.ggxlog.net/	Writing processes, and translation processes in combination with text genetics	Built-in NotePad-like	Local installation	MacOs, Windows	Free
InputLog https://www.inputlog.net/	Writing processes	MS Word, Google Docs	Local installation	Windows	Free, but you need to obtain a user code from the developers

(continued)

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Software	Original Purpose	Editor type	Access	Platform	License
ScriptLog Contact Johan.Frid@humlab.lu.se	Writing processes	Built-in NotePad-like	Local installation	MacOs, Windows, Linux	Free
TransLog-II https://sites.google.com/site/centretranslationinnovation/translog-ii	Translation Processes	Built-in NotePad-like	Local installation	Windows	Free

Acknowledgments Åsa Wengelin's writing of this chapter was supported by University of Gothenburg and Riksbankens Jubileumsfond, SAB20-0018.

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Implications

Writing and Learning: What Changed with Digitalization?

Ann Devitt, Kalliopi Benetos, and Otto Kruse

Abstract This chapter explores the relationship between writing and learning and reconsiders for the digital age some of the assumptions underpinning current conceptions of writing-to-learn and learning-to-write. We interrogate the mediating role of technology in connecting writing and learning. Our key argument is that through digitalization both writing and learning have transformed, resulting in many new kinds of interactions between them. In this chapter we focus on four new dimensions of the writing-learning nexus to exemplify and explore this constantly transforming relationship: (1) New spaces for writing and learning, (2) convergent trends in knowledge work, (3) collaborative learning/writing activities, and (4) the role of feedback and assessment. We conclude by looking to the future for some tentative predictions of how the relationship will develop as technology, writing, and learning continue to evolve. We explore how concepts such as creativity and critical thinking will remain as fundamentals of human activity within the digitally mediated relationship of writing and learning.

1 Introduction

Not only writing technology, but also educational technologies, and in particular online learning, have created new contexts for learning that offer various opportunities for writers to exchange papers, give feedback to each other, construct knowledge, and acknowledge the writings of others. Many of the technologies discussed in this book straddle writing and learning technologies. E-portfolios, authoring tools,

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_26

learning platforms, mind and concept mapping software, digital note-taking tools, annotation environments, feedback platforms, and automated feedback—none of these tools can be clearly or uniquely assigned to either the learning or the writing domain alone. Research on these tools is as often done within educational disciplines as within the writing sciences. Writing and learning technologies have melded into a large field that includes learning, writing, communication, publication, presentation, and research. It has become common to speak of "literate landscapes" to refer to the interconnectedness of media in integrated activity fields.

We will not be able to assess the entire scope of the new interconnections of writing/learning technologies as this is widely uncharted territory. We do, however, aim to demonstrate that the existing or upcoming transformations in selected areas mentioned in this book form hybrid arrangements in which learning and writing can no longer be separated. Today, learning contexts almost universally include writing in some form, and most writing tools supported or employed in those contexts have an open or underlying agenda that involves learning.

2 Traditional Views on the Connections Between Writing and Learning (the Past)

The connection between writing and learning belongs to the theoretical fundamentals of the writing sciences and bridges writing with education. A highly influential notion was Emig's (1977, p. 122) thesis that writing "represents a unique mode of learning-not merely valuable, not merely special, but unique." Her research (Emig, 1971) qualified writing as a self-directed way of developing, shaping and structuring knowledge. She highlighted the role of language, and in particular writing, as a mediating tool for learning. Her suggestion provides a justification for writing pedagogy despite critiques of the validity of writing as a driver for learning (Ackerman, 1993; Applebee, 1984).

The complementary concept to Emig's "writing-to-learn" has been seen in "learning-to-write," which stresses the domain-specific acquisition of disciplinary modes of writing rather than the domain-general learning processes as in writing-to-learn. It seems commonplace that these two kinds of learning cannot be fully distinguished but refer to different sides of the same coin.

In this chapter, we discuss writing and learning in more general terms, encompassing both variations. In this, we follow Klein and Boscolo's (2016, p. 312) description that writing:

> has shown a remarkable capacity to shape learning, from the relatively simple means of learning (where, for instance, writing aids memory), to its role in the solution of conceptual problems in a variety of disciplinary fields. […] Writing is not an all-purpose ability, but a pattern of activities which can have productive effects on knowing and thinking by interacting with different knowledge fields and learning contexts. (Klein & Boscolo, 2016, p. 312)

Understanding writing as a "pattern of activities" broadens the scope to include the many sub-actions and thinking processes that may be involved in writing and connects it in various ways to learning. These connections between writing and learning have been considered from several theoretical perspectives:

- Activity theory and socio-cultural approaches: positioning writing as an activity that connects the learner with action fields mediated by genres and writing technologies (Russell, 1997, 2009).
- Constructivist positions: stressing the self-generated and self-organized nature of knowledge by writing (Nelson, 2001).
- Socialization theories: connecting writers with their communities (Carter et al., 2007) drawing on theories such as Lave and Wenger's (1991) Communities of Practice or Duff's (2010) language socialization into academic discourses approach.
- Cognitive theories: focussing on mental processes (cf. Klein et al., 2016) and their gains for knowledge constitution (Galbraith, 1999) and transformation (Bereiter & Scardamalia, 1987) or symbol processing (Flower & Hayes, 1981; Hayes & Flower, 1980).
- Learning of disciplinary discourse: In a practical sense, learning-to-write has been used as a cover term for the learning of specialized disciplinary discourses and has become the reference field for WAC/WID programs (Anderson et al., 2015; Finkenstaedt-Quinn et al., 2021).

While these theoretical perspectives may need to be adapted in response to new digital contexts, we may assume that they maintain their validity through the current technological transformations. For instance: activity changes its nature when performed in networked and virtually structured cultures; self-organized learning as conceptualized in constructivist positions happens in many new ways in digital contexts; socialization takes place differently in virtual communities than in person-to-person contexts; cognitive processes involved in digital writing differ from those in using typewriters or paper and pencils; writing-to-learn in disciplinary discourses has been re-shaped by new opportunities to communicate, interact, and publish with digital media. The common factor here is the addition of technology to a writing activity and context. Therefore, the key question to address in order to begin to explore and understand these new digital contexts is technology's mediating effect in each of these that leads to a change in the nature of the activity. We explore this now by interrogating the ways in which writing in learning contexts is changing through digitalization today.

3 Current Dimensions of the Writing-Learning Nexus

The theoretical perspectives outlined above prioritise different dimensions of the writing-learning relationship. In this section, we examine four ways in which this relationship has been transformed through digitalization in recent years, drawing on all three sections of this collection. We use the notion of patterns of activities to consider how different aspects of writing and learning processes have changed and assess the affordances and opportunities these offer writers, learners and educators.

3.1 New Spaces for Writing and Learning

A fundamental change in both writing and learning accompanying digitalization is that both now happen in new virtual and physical spaces, contexts, and frames, breaking out of the traditional parameters and locations for these activities in the past. By the time Learning Management Systems (LMS) became the new virtual home for teaching, for the organization of pedagogy, and the exchange and communication of documents, writing was already firmly established in its own virtual home, the word processor, a space for text creation. In the early stages, LMSs were not yet able to make their users write and word processors were not yet able to make their writers communicate what they had produced. With the advent of the world wide web, the boundaries between these distinct and separate spaces became blurred and cross-overs became increasingly common. New spaces emerged where writing, text management, and learning were much more closely integrated. The most important among these are:

– Online word processors: Allow for joint text production and real-time interaction with others, including peers and educators (Rapp et al., "Beyond MS Word: Alternatives and Developments"). New technologies connect word processors in new ways with content management systems such as an LMS and make them accessible for synchronous group work (see Castelló et al., "Synchronous and Asynchronous Collaborative Writing").
– E-Portfolios: Make the exchange of texts, feedback, and the publication of texts possible (Bräuer & Ziegelbauer, "The Electronic Portfolio: Self-Regulation and Reflective Practice"). Various learning and reflective activities can be initiated in such writing/learning spaces.
– Feedback platforms: Allow writers to exchange, comment on, and grade papers of other students (Anson, "Digital Student Peer Review Systems").
– Specialized word processors and authoring tools: Writing platforms like Thesis Writer both instruct students in how to write their theses and offer them a writing space to develop their text individually or collaboratively (Rapp et al., "Beyond MS Word: Alternatives and Developments").
– Wikis: Writing and publishing collaboratively can be accomplished using Wikis. They connect individual work with collaborative endeavours to address an audience, often focused on learning tasks or projects (Cummings, "Writing Processes in the Digital Age: A Networked Interpretation").
– Shared annotation environments: Tools designed to read, annotate, and evaluate literature (Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing") that allow for joint acquisition of and reflection on a topic by

commenting and discussing the aim of such work can be related to both learning and writing.

Each of these tools or platforms provides a space in which writing and learning meld to new and potentially unique kinds of activities. Each of them demands its own pedagogical strategy and its own set of instructions as a writing tool. The term "space" in this context is used both metaphorically (as a place where people can work and get together) and literally (as a visually represented, interactive digital environment that can be manipulated by the user).

3.2 Convergent Trends in Knowledge Work

Both writing and learning aim to deal with intellectual activities such as accessing, acquiring, managing, applying, or constructing knowledge even if they traditionally approach knowledge from different angles. While learning in higher education was primed to strengthen analytic skills by reading written sources and decomposing them into learnable units, writing usually went in the opposite direction by synthesizing and linearizing knowledge from separate knowledge units into a coherent text. Today, digital technologies provide many opportunities to undermine this traditional division of labour in order to re-mix writing and learning activities.

There is a growing range of new tools and technologies to support knowledge work in much more detailed ways than before. Subprocesses of writing support knowledge construction through the elaboration of narratives, arguments, concepts and discussions. Similarly, learning proceeds through a process of construction and connection between prior and new learning which may be scaffolded by tools or educators within the learning environment. A number of chapters in Part 2 "Web Applications and Platform Technology" of this volume address these digital tools:

- Idea generation and mapping software: Kruse et al. ("Creativity Software and Idea Mapping Technology") highlight how this kind of software functions both as a creative tool to generate ideas and a structuring support to organise ideas. Such tools have applications for both writing and learning and for both simultaneously. They can be used for analytic activities (reducing theory or writings to core features) and also for synthetic ones (conceptualizing the content of one's own writing).
- Tools for argumentation: Benetos ("Digital Tools for Written Argumentation") explores the range of tools available to support the development of a discursive argument. This activity includes elaborating pro and con positions, providing justification for these positions, and generating a cohesive synthesis. Again, this is a process of organising and structuring ideas, layering in elements to bring depth and substance. This activity is a quintessential writing-to-learn process where through the development of a cohesive argument in writing, the knowledge of the context and content are deepened and connected.

– Electronic Portfolios: Bräuer and Ziegelbauer ("The Electronic Portfolio: Self--Regulation and Reflective Practice") examine the use of these tools for self-reflection where the digital tool serves as a scaffold for drawing meaning and constructing knowledge from one's own or other's experiences. These tools support the reflective process of identifying (what?), interrogating (so what?) and evaluating (now what?) critical moments of experience to generate new understandings and potential for action. In this case the reflective process is often, though not necessarily, undertaken as a written activity where understanding is developed and knowledge is generated through writing.

Chapters in Part 3 "Writing Analytics and Language Technologies" of this volume explore more techno-centric knowledge construction and generation through automated processes:

– Information retrieval: Benites ("Information Retrieval and Knowledge Extraction for Academic Writing") discusses the important role of automated information retrieval within the digital writing landscape in the era of Big Data. In many fields, the volume of content available as source or reference material has exploded. In this context, it is vitally necessary to automate processes of search and data extraction in order to make exploration of content feasible. The technology in this case mediates the process of knowledge discovery and even knowledge construction that can then be re-articulated or further developed through the writing process.
– Automatic text generation and summarisation: Benites et al. ("Automated Text Generation and Summarization for Academic Writing") explore the even more active role of technology as mediator in the role of automatic text generation and summarisation within the digital writing landscape. The degree to which the human is involved in this process can diminish from curation and re-construction of generated text to little more than copy-editing. This is an increasingly difficult issue in formal learning contexts where learning is often assessed through written outputs. However, both the process and product of text generation can be valuable for the writing process, requiring writers to set the parameters of the generation process as a kind of *chef de cuisine* managing the writing resources at their disposal. Still, much of the effect that formulation used to have on the learning process will probably disappear in favour of more analytic or evaluative kinds of text work.

3.3 *Writing and Learning as a Collaborative Activities*

Perhaps one of the most exciting developments of recent years has been the potential for collaboration afforded by more and more technologies within the writing landscape. With the expansion of the world wide web and the widespread use of cloud computing technology, there is much greater potential for writers and learners to operate within shared spaces, on shared documents and platforms towards shared objectives, both synchronously and asynchronously. This technological revolution has opened up new ways of producing shared thinking, creating, and writing that can be deployed to support learning as a social activity. A number of chapters in Part "Web Applications and Platform Technology" of this volume focus on harnessing the power of technology for collaborative activity during different aspects of the writing process:

– Synchronous and Asynchronous Collaborative Writing: Castelló et al. ("Synchronous and Asynchronous Collaborative Writing") highlight how the act of producing a collaborative written artefact has evolved over recent times from asynchronous collaboration afforded by early tools such as email to live synchronous fully collaborative writing which is possible within cloud-based tools such as Google Docs. The technology has shifted the nature of the collaboration from parallel and sequential activity to a fully reciprocal process.
– Content Management System or Wikis: Cummings ("Content Management System 3.0: Emerging Digital Writing Workspaces") explores the role of collaborative knowledge management, as evidenced in wiki creation. Similar to idea mapping software discussed by Kruse, Rapp, and Benetos, this inherently collaborative process supports both creation and curation of knowledge for writing and learning.
– Social Annotation: Hodgson et al. ("Social Annotation: Promising Technologies and Practices in Writing") explore the focused writing activity of annotation within a collaborative context and its role in learning and in learning to write. The social dimension provides a discursive environment to engage with and through text.
– Social Media for Writing and Learning: Bowen and Whithaus ("Multimodal Chat-Based Apps: Enhancing Copresence When Writing") examine multimodal chat which plays an overtly social and affective role within the process of writing and learning. They highlight how writers make use of the social support of others through social media while engaged in the challenging task of writing.

3.4 Writing, Learning and the Role of Feedback and Assessment

Here we turn our focus to learning-to-write and in particular how technology has transformed summative and formative assessment processes in this area. Today, technology routinely facilitates self, peer, teacher, and automated assessment with feedback on writing as evidenced in a number of chapters in this volume. The combinability of instructional prompts and assignments, writing genres, and different types of assessment provides a vast educational space that has not yet been fully explored. We offer two examples:

– Automated Assessment: While the goal of fully automated assessment, scoring, and feedback is still not fully attained, Banawan et al. ("The Future of Intelligent Tutoring Systems for Writing"), Link and Koltovskaia ("Automated Scoring of Writing"), Cotos ("Automated Feedback on Writing") and Shibani ("Analytic Techniques for Automated Analysis of Writing") each examine different aspects

of how automation can now bring value, accuracy, and efficiency to many aspects of the assessment of written outputs.
– Peer and Teacher Feedback Systems: Anson ("Teacher Feedback Tools" and "Digital Student Peer Review Programs"), on the other hand, examines how technology facilitates assessment carried out by humans, be they peers or educators.

4 Conclusions: What Are the Developments Pointing to (the Future)?

It is clear from this presentation of only four areas of writing and learning that technology has radically transformed how writing and learning processes can interact and complement each other. The breadth of bespoke and domain general tools available and in common use today across each of these four areas highlights the affordances that learners and educators have capitalised upon to scaffold complex and demanding writing and learning tasks.

The ever-increasing role of digital technology forces us to ask: in an age where Generative AI has succeeded in writing student essays of high quality, what remains for the writer and which aspects of writing should still be taught? What kind of learning will take place when writers are disburdened from content generation and formulation?

Furthermore, it would be remiss not to acknowledge the broader landscape of artefacts that learners can generate either as part of the writing process or parallel to it and not to consider the role of these artefacts in both learning and assessment. A written output is only one means of representing learning; taking the perspective of Universal Design for Learning (CAST, 2018), there is an imperative to offer learners multiple means of representing what they know and can do. The ecosystem of digital writing tools offers many options for alternative mechanisms to generate a written output and alternative outputs that can allow learners to demonstrate key aspects of the cognitive processes underpinning writing, even perhaps without generating a final written text. As regards generating written output, learners can make use of speech recognition software, for example, or even text generation software to generate a written output. As such, assessment may have to redefine what it recognizes as indicators of learning and to focus more on selection, curation, and organisation of information into meaningful (multimodal, non-linear) representations that include text, rather than a traditional textual page that aims to elicit a mental model of learners' acquired knowledge.

As regards writing to learn, programmes of learning may include learning outcomes that do not require a traditional full essay written output. The ecosystem of digital writing tools offers a range of options for representations of structured thinking other than written essay text, such as mind maps or other structured graphic representations, which could be used for the purposes of representation and assessment. These artefacts have at least some components of the core aspects of writing-to-learn noted by Applebee (1984) and discussed above: permanence, explicitness, conventional discourse forms, and active nature. This can allow learners to produce valid and persistent representations of their knowledge and skills which can then be assessed by instructors without having to produce a full written text. In terms of inclusion, this allows access to the curriculum for diverse learners, some of whom may have difficulties with text-based media for a range of physical, cognitive, or affective reasons.

Not only can tools within the digital writing ecosystem be used to capture valuable dimensions of the writing (and writing-to-learn) process, other multi-modal digital technologies now offer valid alternative options to achieve the four core characteristics of writing noted above without producing written text. In particular, the proliferation of digital image, audio and video capture and editing tools in recent years puts the production of multimodal artefacts of learning well within reach of learners of all ages across a range of contexts. While access to these tools may still be more restricted than those required for writing, with the ubiquity of the smartphone this may become more widely distributed across populations. With the exponential growth in the ability to create, edit, and share multimodal content, the long-dominant position of the written word may well be in jeopardy.

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Towards Defining Digital Writing Quality

Stephanie Link, Elena Cotos, and Andreea Dinca

Abstract This chapter provides a description of current views towards writing quality and promotes a move toward a definition of *digital* writing quality. We argue that, because new digital affordances have changed how writing is learned, taught and delivered, the nature of written products has become increasingly multi-dimensional and interactive. Traditional perspectives toward writing quality offer a foundation for understanding the textual features that are essential to defining digital writing quality, but these views largely disregard non-textual and non-linguistic abilities needed to effectively communicate in digital spaces. We thus address contemporary realia to stimulate discussion about how to consolidate various domains of knowledge for defining digital writing quality. Aligning contemporary writing demands to form a comprehensive definition of digital writing quality can help transform the design and development of future writing technologies and curriculum for an increasingly technology-adept learning audience.

Keywords Digital writing quality · Genre innovation · Multimodality

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_27

1 Introduction

Twenty-first century digital innovations offer new affordances that arguably enhance writing spaces, foster writing processes, and enrich writing development and production opportunities. At the same time, the ubiquity of digital writing technologies challenges traditional perspectives towards writing quality, which commonly tend to focus on textual aspects, linguistic accuracy, and rhetorical conventionality. *Digital writing quality* encompasses a much more complex interplay between textual and non-textual elements, metacognitive processes, sociocultural knowledge, and technical abilities. Therefore, defining this concept can be controversial and thus necessitates careful deliberation.

Working towards a contemporary definition of digital writing quality is important for a number of reasons. This concept is central to how writing should be theorized, researched, taught, and learned in the era of digitalization. It is a substantial indicator of the competencies that present-day and future writers need to acquire. Understanding what constitutes digital writing quality is also imperative for supporting those who teach and formally evaluate written communication. Awareness of what makes writing effective in digital contexts is essential for students as well, especially because they are already producing diverse forms of writing in new digital spaces for various audiences. Social media, for example, is filled with avenues for exchanging ideas and knowledge, developing authentic writer identities, strengthening awareness of audience and authorship, and promoting self-confidence and motivation to write (Ware et al., 2016). Disregarding the writing that takes place within these digital contexts would thus restrict writers' opportunities to practice and produce writing in creative, authentic ways.

Given the predicament of there being little consensus about what constitutes writing quality in general, the 'digital' attribute of writing quality certainly needs time and interdisciplinary input to gestate. The rich spectrum of affordances provided by digital writing tools and platforms poses uncharted potential, for every single tool has its own inherent ways of impacting quality. For instance, the digitalization of writing expands access to multimodal semiotic resources (text, audio, visual), digital spaces (e.g., web interfaces), and new audiences (e.g., bloggers), disrupting traditional conceptualizations of writing quality. This, in turn, compels professionals to rethink writing instruction and evaluation.

In this chapter, we discuss traditional views toward writing quality, exploring theory-driven perspectives that help to define expectations of writing. We then shift to contemporary views to discuss how new digital tools and digital genres challenge traditional notions of writing quality and require practitioners to evaluate what writing practices are most appropriate for reaching today's audiences. We end by posing key questions that will help to move towards a definition of digital writing quality, which can set a foundation for understanding how our digital world affects those who teach, construct, and evaluate writing.

2 Traditional Perspectives on Writing Quality

A lack of a unified view of writing quality has long been noted in first and second language writing research (Huot, 1990), creating an imbalance between theoretical perspectives and writing practice (di Gennaro, 2006), especially when multilingual writers are involved. Collating traditional perspectives from first and second language writing studies can strengthen connections between domains of knowledge and provide a springboard for discussing writing quality expectations in digital contexts. According to those perspectives, writing quality is dependent on several features including (but not limited to):

- complexity, accuracy, and fluency
- task dependent features, and
- genre conventions.

Complexity, Accuracy, and Fluency (CAF) measures are often used in second language studies to replace subjective and sometimes vague delineations (e.g., beginner, intermediate, advanced) of learner performance and development (Ellis & Larsen-Freeman, 2006). In short, complexity refers to the elaboration of the language that is produced, accuracy as the ability to produce error-free language, and fluency as the ability to rapidly produce language (Lennon, 1990). Complexity and accuracy are most commonly evaluated as part of the quality of a written product. Fluency has its place in both quality of process and quality of product. Technologies (e.g., corpus-based technologies in Chitez & Dinca "On Corpora and Writing") have impacted the detection of CAF, offering means for immediate and reliable evaluation of writing quality, which in turn enables evaluators to account for the effects of task-internal features (e.g., task complexity) on writing quality (Robinson, 2011; Skehan, 2016). Evaluating CAF, however, is exclusively based on the linguistic realizations writers use to convey ideas, with a disregard for multimodality.

Task dependent features may include content or prompt relevancy and rhetorical quality or coherence. Models of writing have established that writing quality is dependent on an appropriate selection and management of content and rhetorical aspects of writing (Bereiter & Scardamalia, 2013; Flower & Hayes, 1981; Hayes, 1996). These features focus on writers' abilities to contribute relevant information appropriate for a task, build logical and orderly discussion of content, and communicate ideas effectively to the reader. Tools for automated scoring of writing (see Link & Koltovskaia "Automated Scoring of Writing") and automated feedback on writing (see Cotos "Automated Feedback on Writing") can help to evaluate many of these features by utilizing various computational techniques, such as latent semantic analysis for analyzing the content of a text (Landauer & Dumais, 1997; Landauer et al., 1998). These tools offer opportunities for technology to mediate the writing process so that writers can manage choices leading to higher quality written products. The type of mediation, or form of formative and summative automated feedback that is available, is dependent upon developers' expertise and beliefs about what features are important for heightening writing quality, and again is absent of multimodal representation.

From the perspective of genre, which refers to the socially recognized ways of using language in a context where a text is created and utilized, genre conventions are described as relating a text to a similar group of texts and to the choices (or constraints) acted upon writers (Hyland, 2003). Genre theorists posit that successful writing entails a writer's awareness of the audience and purpose of communication in a target context (Kress, 2009). This idea resounds across three main schools of thought that value different dimensions of genre: New Rhetoric (NR), English for Specific Purposes (ESP), and systemic functional linguistics (SFL). NR highlights the functional relationships between text type and rhetorical situation in which genres are employed (Coe, 2002; Freedman & Medways, 1994). The field of ESP gives prominence to the analysis of communicative events within a discourse community whose members share social purposes (Swales, 1990) and whose rhetorical choices impact the way texts are structured and composed content-wise (Johns, 1997). SFL, in turn, accentuates the ways language is systematically linked to a writing context through lexico-grammatical patterns and rhetorical features (Christie & Martin, 1997). Regardless of these theoretical differences, it is through genre theory that multimodal research has made the most headway in the field of digital writing studies. That said, how digital genres are constructed and evaluated by digital audiences in new digital spaces warrants continued discussions in order to inform the definition of digital writing quality from a contemporary perspective.

3 Contemporary Realia of Digital Writing

The quality of writing produced using digital tools in and for heterogeneous environments cannot be devoid of multi-dimensionality, so a forward-thinking notion of digital writing quality should be multi-dimensional across multi-platforms for authentic and collaborative multi-audiences. To produce successful modern century writers capable of integrating new literacies and technical abilities to create manyfold genres, teachers will need to equip their students and themselves with skills responsive to an expanded view of digital writing quality—a view that comprises textual, non-textual, and non-linguistic aspects of written communication. This view would acknowledge ways in which writers can maximize the effects of digital affordances throughout the writing process to successfully achieve the expectations of contemporary audiences. It would also help formulate guidelines for evaluating the effectiveness of digital communication products as well as for researching the multiple facets of writing in compelling and dynamic ecosystems.

Consolidating both traditional perspectives and contemporary realia is vital for tailoring a theoretically and empirically grounded understanding of digital writing quality for teaching and learning. In other words, given that genre, task dependent, and CAF features of writing quality are essential to the effectiveness of any text, digital writing quality needs to be defined such that these traditional criteria remain (especially because most are amenable to automated analysis and already integrated in digital writing tools) but are rectified in view of new developments. Audiences, for example, have broadened significantly in recent years. Students are taking on new real-life roles, such as social justice advocates, which are way beyond content creation. Some audiences take on second or alternative identities to shadow or amplify their voices across the internet. The web has become an expanded context for sharing factual content as much as beliefs and interpretations, while also providing new means of interaction. Commenting features and chat rooms, such as those in fan fiction sites, empower writers to accomplish new communicative purposes including writing to get likes/shares or to boost a digital marketing scheme. All these realities present motives for researchers to obtain a better understanding of digital writing quality, which should then be translated to writing pedagogy and assessment, whether traditional or technology-assisted. There is an undeniable need to help educators teach the writing traits and distinguishing conventions that are pertinent to the quality of divergent multi-dimensional genres.

As a starting point, conceptions such as genre innovation, multimodality, hybridization, resemiotization, and translingualism would need to be conjoined. Genre innovation refers to "departures from genre convention that are perceived as effective and successful by the text's intended audience or community of practice" (Tardy, 2016, p. 9). Innovation can be realized at a stylistic level using modal variation, at the structural level through reordering and changing a text in unconventional ways, and at the discourse level by uniting different genres or discourses. Technology has added to the potential for genre innovation by offering new modes for communicating meaning across diverse communicative platforms. The interplay between multiple representational modes (e.g., visuals, spoken and written text), or multimodality (Kress & Van Leeuwen, 2001) afforded through digital tools can bolster genre innovation by offering a range of semiotic resources that go beyond textual and language features and, consequently, impact digital writing quality. Associated with that is hybridization, which refers to "all kinds of blending, mixing, and combining that occur in genres and texts" (Mäntynen & Shore, 2014. p. 738). These processes can contribute to endorsing multimodal and hypertextual features for online texts in digitized spaces, potentially changing conventional texts such that they reach expanded audiences (Bhatia, 2010; Tardy, 2016). Furthermore, resemiotization as an analytical means for determining how meaning making can shift from context to context and across multiple practices and stages of the writing process should be accounted for as well. It allows writers to consider choices in how semiotics are translated and why certain semiotics (over other semiotic resources) may be mobilized to communicate certain meanings (Iedema, 2001). Making logical choices in these shifts is important for enhancing digital writing quality. Finally, translingualism is a fundamental notion, as it connotes that communication occurs through language as a vehicle for all linguistic and nonlinguistic semiotic resources, such as color, images, symbols and sound, to enable multilingual writers to negotiate cross-language relationships (Canagarajah, 2013). In this practice- and process-oriented view, a genre shifts focus from the 'grammar' of the genre to considerations of the performance. Thus, the quality of digital products should be negotiated between writer and educator, as well as audience whenever possible. Educators should consider evaluating learners' awareness of writing quality, degree of reflexivity, and learning trajectories instead of only the quality of the written product (Canagarajah, 2013).

Methods for evaluating multi-dimensional genres have not evolved as readily as classroom practices. It is often the case that, while engaging students in multimodal writing tasks, assessments tend to focus on text quality, to a great extent reflecting educators' discomfort with evaluating anything other than written text (Sorapure, 2006). Applying the aforementioned conceptions can help alleviate some uncertainties and concerns in writing pedagogy and assessment. Moreover, this can cardinally contribute to devising new methods that would foster extended forms of agency– the "power to control one's situation, be fully heard, be free from oppression, and have choices" (Oxford, 2003, p. 79). Agency in digital spaces should enable writers to make personal choices, create new means of expression, and act against social constraints to foster self-concept, i.e., their self-descriptions of competence and evaluation of self (Dörnyei, 2005). In other words, through new digital spaces, writers should know how and be able to control their sense of self by mediating interactions with new audiences and challenging power hegemonies that tend to standardize the evaluation of writing quality.

As we deliberate on the digital writing realities of our contemporaneity, our intent is not to dismiss the importance of established features of writing quality; those will remain the foundation of writing as a measurable construct and of writing quality standards in personal, professional, and academic contexts. Building on that, we argue that accounting for the multi-dimensional aspects of digital writing has the potential to bind measurable textual and linguistic features to contemporary expectations by which digital writing quality could be more comprehensively and inclusively defined.

4 Towards a Definition of Digital Writing Quality

Despite the advent of technological innovations and the pervasiveness of digital writing tools, educators remain unsure of what exactly digital writing is and how it should be taught and evaluated. Therefore, theorists, researchers, and practitioners should embark on a joint endeavor aimed to define digital writing quality because it is integral to the art and goal of writing better. Leveraging different levels of expertise and aligning interdisciplinary perspectives is key in this rather challenging (perhaps even daunting) yet high-stakes endeavor. Acknowledging potential hurdles and ethical considerations is also important, as these concerns may impact judgments of writing quality in unexpected ways. Emerging writers, for instance, may be highly influenced by language use in forums and chats. McKolloch (2019) noted that people who first used the Internet for socialization tend to adhere to writing conventions that coalesce online (e.g., irony punctuation as in ~*~* to show enthusiasm or word lengthening as in "sameee" when sharing agreement); less frequent Internet users, on the other hand, often use offline communication styles online (e.g., sending texts with punctuation patterns that younger recipients may instead replace with line breaks).

While the influence of the Internet on the typographical tone-of-voice system is evident, its impact on writing quality for formal and informal digital contexts is relatively unknown, challenging how or to what extent educators can address digital writing quality in writing classrooms.

Furthermore, the social impact of online interactions and collaborative spaces (see Castelló et al., "Synchronous and Asynchronous Collaborative Writing" on collaborative writing) enables collaborative thinking and knowledge sharing. Digital collaborative writing has been shown to improve accuracy and critical thinking (see Talib & Cheung, 2017, for a review) and may boost motivation to improve writing quality. Collaborative writing, however, calls into question notions of ownership attributions. Ownership of writing has long been a point of discussion within professional communication (see Rehling, 1994), with contributions to writing quality traditionally being a top factor in how workplace writers attribute ownership. Modern writers can challenge this belief by altering audience perceptions about what high quality writing entails.

Finally, new forms of writing can also raise academic integrity concerns given the widespread access to information that can be misused as stimuli for academic misconduct (e.g., plagiarism and *e-cheating*, see Dawson, 2021). Modern writing is often data driven, based on research, but burgeoning information across the web has stimulated many writers to draw on falsifications of information that spread more rapidly and more expansively than ever before. Misinformation can be an insurmountable problem and should be of high regard when evaluating digital writing quality.

These hurdles and ethical considerations, along with both traditional and contemporary views towards digital writing quality are important for equipping the field with a comprehensive and inclusive characterization of the concept, or even phenomenon, of digital writing. The research territory is wide open; we only provide here several questions in an attempt to suggest a few directions and to spark interest.

- To what extent should domains of knowledge be expanded, taught, and assessed to cover multi-/digital-literacy development and performance as dimensions of digital writing quality?
- How can digital writing quality be evaluated for communicative success and genre efficiency when multidimensional digital products are divergent from conventional genres?
- How can educators be prepared to evaluate digital writing quality given long-standing concerns about the non-stable development of technology across time?
- How does the digitalization of writing change the social nature of the writing process and feedback provision? In other words, is text composition and evaluation of writing quality only meant for individuals?
- How can students and educators best work with Artificial Intelligence-informed writing systems to improve writing quality?

With these questions in mind, product versus process, expression versus substance, complexity/accuracy/fluency versus meaning, generic versus genre diversity are all assumptions about writing practices that warrant unpacking, if assumptions should be made at all. Otherwise, what is valued and/or assumed in regard to writing quality may not be what is operationalized when designing digital classroom tools, many of which integrate formative and summative assessments of writing. While much is yet to be uncovered, what seems to be known is that researchers, teachers, and other professionals must technologize their views towards writing quality in light of digital affordances. In turn, the developers of tools and assessments need to integrate what is known and valued about writing in digital environments as they design and develop the next generation of digital innovations.

5 Final Remarks

For all writing studies audiences, the progressive rise in digital spaces and telephony via mobile devices and tablets have transformed written performance, reshaping and repurposing sociality (how writers form personal relations) and spatiality (where writers form personal relations). These platforms offer new opportunities for extensive social engagement, enabling writers to develop their agency and self-concept. As a writer's agency grows, so might the influence of technology on the choices made to produce high quality digital products. These days, we see the influence of technology grow exponentially through advances in corpus-linguistic and computational perspectives. On one hand, these perspectives suggest that twenty-first century digital advances can provide experimentation in evaluating writing quality while controlling for extraneous contextual factors, as much as possible but in efficient ways. On the other hand, traditional perspectives have under-explored the essence of twenty-first century writing skills where multi-dimensional competencies and digital literacies are pertinent to engaging new audiences in new digital spaces. Moving forward, our understanding of digital writing needs to include the interplay between modes to foster genre innovation, multimodality, hybridization, and resemiotization. Multilingual and translingual views also recognize multimodality as serving populations where semiotic resources offer extended opportunities to not only reach new audiences and purposes but support the creation of meaning as a negotiated experience between a writer and reader. As traditional and contemporary perspectives begin to unite within writing studies, clarity in how digital writing quality can be defined can begin to form. This discussion about the nature of writing will move the field toward a future where educators are the drivers in producing and evaluating products with high digital writing quality in a world where writing is fully digitalized.

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Finding the Right Words: Language Technologies to Support Formulation

Otto Kruse, Madalina Chitez, and Christian Rapp

Abstract This chapter explores the ability of digital technologies to provide language support for writers. With such ability, technologies directly intervene into the productive act of language creation, which we refer to by the traditional term *formulation*. Formulation here is defined as the kind of thinking that happens when a writer tries to linearize thought by using language. In written communication, formulation happens during interaction with an inscription tool and is strongly influenced by the kind of technology used. In this chapter, we look into some of the changes in formulation and language crafting that followed the introduction of digital technologies. We attempt to estimate where the developments are heading by addressing four issues: (1) support for the preparation of formulation, (2) real-time support during inscription, (3) support for the choice of words and collocations, and (4) support for language use at the revision stage by automated feedback and intelligent tutoring. The contribution concludes with some thoughts about future directions.

Keywords Formulation support · Inscription · Written communication · Automated feedback

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_28

1 Introduction

No matter through which theoretical lens we look at academic writing, it always involves crafting language so that the resulting text carries the message that an author wants to communicate. Writers know that words matter, and they usually spend time and effort to get the selected words into the right form and order. They know that the same thought can be expressed in different words and languages, but are also aware that meanings may change with every word replaced and every phrase altered. Writing is both expressing meaning and creating meaning (Wrobel, 2002). Some experienced writers even claim that they do not know what they think unless they read what they wrote. The written text feeds back into thinking and expands the options for creating meaning.

Formulation is defined as the kind of thinking that happens around the moment when words are linearized to a language string (see Kruse & Rapp, "Word Processing Software: The Rise of MS Word"; Kruse & Rapp, 2023). When the formulation activity is finished, writers may assume that what they have in mind is what they find expressed in their text. If not, they may change or accommodate their thoughts to what they wrote. Alternatively, they may continue revising the text until it conveys what they have in mind.

Writing tools are enabling technologies, without which the activity of writing cannot happen. Writing technology enables the inscription of letters and words on a writing surface (Baron, 2009; Bazerman, 2013, 2018; Haas, 1996; Mahlow & Dale, 2014; Ong, 1982). Formulation, in contrast, is a purely mental activity which, however, is not independent of inscription, as writers usually develop their text in interaction with the writing tool where they can re-read and re-think what they wrote. If the tool allows, they can revise the wording to reshape or extend their thoughts. It must be noted, however, that behind written formulation we can still see traces of the historically and ontogenetically earlier skill of oral formulation with its own rhetoric, registers, and formulation strategies.

Due to the various capabilities of digital technologies, the writing tools have become active agents in crafting language, making it necessary to re-consider almost anything we knew about formulation. In this chapter, we will look at formulation in the light of the many digital tools that currently make it easier for writers to process language. These technologies started with the development of grammar and spell checkers in the 1970s (see Smith et al., 1984), which, for the first time in media history, enabled writing tools to exert considerable influence on language production and text composition. This was only the first step. Today, Natural Language Processing (NLP) and computational linguistics are advanced enough to not only support but actually appropriately assemble language pieces into different text types such as essays or business news. They are able to master complex formulative, grammatical, and evaluative problems, as has been shown in Part "Writing Analytics and Language Technologies" of this book. We will examine these technological developments from the perspective of formulation support they can provide for writers and will discuss the conceptual changes in formulation theory that the technologies ask for. For any conclusive deliberations, we have to challenge the traditional rhetoric assumption that language capability is an exclusively human characteristic. Today, language has fallen prey to the computer, and sometimes it seems that computers outwit the human brain with regard to grammatical, rhetorical, and terminological abilities. Then, the questions that arise are: What is it that will remain for the humans? And how can humans make use of the computer in the best way to boost their linguistic performance?

2 Traditional Views of Formulation (the Past)

Formulation, a topic grounded in psycholinguistics, has attracted attention from many researchers throughout the past centuries. One of the starting points was Wilhelm Wundt's (1900) monumental 2-volume work *The Language*, which presented thorough considerations about creating utterances and forming sentences (see Levelt, 2013, for a review). While Wundt treated formulation primarily in relation to the thoughts expressed, Bühler (1927) pictured it in a communicative frame where the sender, the receiver, and the message were specified, all three of them being part of a given context. The message, in his view, is not only tied to the thought of the writer but also to the receiver it is meant for. Thus, the message has representational meaning, but it also conveys the internal state of the sender and may be seen as an appeal to the receiver (see Nerlich & Clarke, 1998). To address formulation, several alternative terms have been used, such as 'sentence production' or 'sentence formation,' 'language production,' or 'language generation,' all referring to the activity of producing meaningful chains of words.

Only a few studies have dealt with written formulation (e.g., Keseling, 1993; Wrobel, 1995, 2002). The cognitive model by Hayes and Flower (Flower & Hayes, 1981; Hayes, 2012; Hayes & Flower, 1980) introduced the term 'translation' for 'formulation.' This model was built on the idea that content is first created cognitively and then translated into language. This assumption led to numerous discussions about how such a process could take place (e.g., Alamargot & Chanquoy, 2001; Fayol, 2016; Fayol et al., 2012; Galbraith, 1999, 2009). Recent revisions of the model (Galbraith, 1999, 2009; Galbraith & Torrance, 2004) have tried to push it into a dual process approach, understanding "writing processes as an interleaving of dispositional content generation and rhetorical structuring" (Galbraith & Torrance, 2004, p. 63). Instead of a successive creation of content and language, as the original model suggested, they proposed a parallel processing of content generation as both cognitive and linguistic. Content, here, is not created first and then translated, but it is assumed that "ideas form as the language is produced" (Torrance, 2016, p. 80). This opens the door to considering language as a part of, if not a leading force in knowledge creation and meaning-making. This shift in perspective would, consequently, afford an additional theoretical step towards an operational view of language telling us how language is related to ideas and what exactly writers do with words and grammar.

Knowledge cannot be constructed and cannot be thought of without language, but it needs a linguistic theory to say how language does this and how writers use language for the expression of intentions and the creation of thought (see more in Kruse & Rapp, 2023). The quality of thinking and writing depends, for instance, on the size of the mental lexicons of the writers, as well as of their mental phrasebooks. Limited word and collocation knowledge make writing difficult and would allow formulation on a basic level only. Words are the building blocks for sentence construction and the basic elements of meaning-making. Faber (2015) sees words and terms as units of specialized knowledge as much as of a specialized language and considers them as "access points to larger knowledge configurations" (p. 14). Common languages and their rich vocabularies form the core of formulation activities and frame the use of special terminologies associated with different professional, cultural, or educational domains.

Even if language generation of adult writers is automatized to a large degree, they still make deliberate and purposeful choices of terminology, word order, phrases, rhetoric, parts of speech, etc. After about 12 years of school, beginner academic writers have enough training to understand a good deal of the linguistic and rhetorical means of text production for transformative writing strategies (Kellogg, 2008). They are aware of linguistic decisions and know of the need to be precise in language use. They also have a mental lexicon large enough to address the most important issues in academic thought but still have to extend their mental lexicons considerably to keep up with the vocabulary and knowledge of their disciplines. Word learning in the disciplines is usually not independent from acquiring knowledge, and it is a rather slow process of familiarizing with words (Wolter, 2022) including their morphological, collocational, semantic, and pragmatic aspects.

3 Current Transformations of Formulation Induced by Technology (the Present)

The new ways of digital writing have made formulation a much more comfortable activity mainly because of improved options for inscription and revision (see Heilmann, "The Beginnings of Word Processing: A Historical Account"; Rapp & Kruse, "Word Processing Software: The Rise of MS Word"; Kruse & Anson, "Plagiarism Detection and Intertextuality Software"). Corpus studies have led to a wide array of information on the lexical, collocational, grammatical, rhetorical, and genre-specific dimensions of texts that can be operationalized for writers, even though not for all languages alike (Chitez & Dinca, "On Corpora and Writing"). The key to language technologies is automatic text analysis, for which a large number of methods have been developed (see Part "Writing Analytics and Language Technologies"). The items below encompass a birds-eye-view of what language technologies have to offer for formulation support.

– Automated spell, grammar, and style checkers (Cotos, "Automated Feedback on Writing"; Link & Kolovskaia, "Automated Scoring of Writing")
– Sentence completion and word prediction features for real-time text production support (Kruse & Rapp, "Word Processing Software: The Rise of MS Word")
– Synonym finders for word level support (Kruse & Rapp, "Word Processing Software: The Rise of MS Word")
– Built-in corpora along with search tools and query platforms (Chitez & Dinca, "On Corpora and Writing") for inquiries on research language
– Phrase books for collocation level support (Chitez & Dinca, "On Corpora and Writing")
– Rhetorical and discipline-specific automated feedback for genre writing support (Cotos, "Automated Feedback on Writing")
– Intelligent tutors for guided individualized learning (Banawan et al., "The Future of Intelligent Tutoring Systems for Writing"; Cotos, "Automated Feedback on Writing")
– Preparing formulation by idea and concept development (Kruse et al., "Creativity Software and Idea Mapping Technology")
– Key stroke logging for 'behind the scenes' analyses of inscription and revision processes (Wengelin, "Investigating Writing Processes with Keystroke Logging")
– Reference management systems for quoting and evaluating literature (Proske et al., "Reference Management Systems")
– Plagiarism-detection systems for checking intertextuality and relations to other publications (Anson & Kruse, "Plagiarism Detection and Intertextuality Software")
– Argument mining or mapping for argument construction support (Benetos, "Digital Tools for Written Argumentation")
– Information retrieval and knowledge extraction systems connecting automatic content generation with linguistic framing (Benites, "Information Retrieval and Knowledge Extraction for Academic Writing")
– Automatic text generation producing almost perfect linguistic surface structures with minimal human involvement (Delorme Benites et al., "Automated Text Generation and Summarization for Academic Writing").

With these technologies, formulation has become a collaborative human-computer issue and, eventually, more parts of it are done by the machine than by the human writer. Digital technology provides formulation provision on all levels, be it at the word, phrase, grammar, or document level. NLP developments have decoded the productive aspects of language and are advancing the support not only for language usage but also for content development.

In the remainder of this contribution, we will focus on four functional aspects of the technological abilities listed above to demonstrate and discuss in more detail what impact digital technologies can have on formulation processes:

1. Support for preparing and guiding formulation processes: Making writers collect and create meaningful bits of verbalized thought and knowledge either in the form of mind or concept maps without the constraints of linearization, or in the form of notes and summaries.
2. Real-time support during inscription: Aiding inscription with linguistic support such as sentence completion or grammar and spell checkers to unburden writers from elementary constraints of sentence construction.
3. Support for the choice of vocabulary: Search tools to scan through digital corpora which can provide direct access to linguistic information such as word use, collocations, rhetorical choices, or synonyms.
4. Support through automated feedback and intelligent tutoring: Complex analytic tools can offer formulation support for relevant linguistic and rhetorical traits such as cohesion/coherence, focus, style, structure, connectives, moves/steps, and more.

It is worth noting that most of these developments are happening in English; the transfer to other languages is not always a given.

3.1 Support for Preparing Formulation Processes

Writers may follow different strategies regarding the onset of inscription in a writing project. They may prefer to do the reading and note-taking first to acquire enough knowledge for their paper before they start formulating their ideas and developing content. They may also begin writing right away from what they already know and then do the reading. For formulation, not only knowledge about a topic must be available but also knowledge of disciplinary vocabulary. Some of these prerequisites can be acquired before formulation actually takes place, especially if supported by tools for:

3.1.1 Mind and Concept Mapping

These tools operate at the concept level, where concepts are represented by words, expressions, or interconnected words (see Kruse et al., "Creativity Software and Idea Mapping Technology"). They help prepare formulation by singling out the thoughts to be expressed and the relations between those thoughts, which serve as initial framing for the linearized text. In mind mapping, the resulting tree can be transformed into an outline that contains the central ideas/words to be filled in with text. Concept mapping, in contrast, focusses on the interrelation of single thoughts or bits of knowledge including the relation that connects them.

3.1.2 Note Taking and Summarisation

Such tools are built on the idea that the best preparation for a text is to write small texts in advance (e.g., notes summaries), which later can be used either as a flexible basis for the expression of own ideas or as the basis for the literature report (see Pitura, "Digital Note-Taking for Writing"). Although note taking and summarisation are traditional forms of academic work, they have been integrated in new ways of accessing texts and organising text excerpts. Summarized text can be easily reused, thus offering basic textual units for the formulation process.

3.1.3 Annotation and Social Annotation

Annotation tools in general aim to foster the connection between reading and writing by relating own thought with printed text. In social annotation, where several users are involved, annotations can be commented on, answered, or extended (Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing"). This allows for acquiring a deeper understanding of the topic at hand, along with an extension of the expressive abilities to write about it.

These three types of tools account for the fact that activities focused on preparation of formulation need to intertwine, not separate, the linguistic and content-related elements. There is no abstract preparation by language learning through memorizing certain language features, studying word lists, or trying to remember collocations and phrases. Also, memorizing content is not an effective strategy because formulation means making sentences move, and this kind of sequentiality is created by linguistic elements such as connectives, sentence structures, and grammar.

3.2 Real-Time Support for Formulation Activities During Inscription

Formulation processes are tied to the short time span when words are written down. Writers may prepare this short moment of inscription by activities such as reading, summarising of literature, or thinking ahead of what they might want to say. Still, most decisions are made in the moment of inscription, and, ideally, formulation support has to be squeezed into the short time slot that inscription offers. Supporting formulation activities at the very moment of inscription needs technologies that are fast enough to enter the microprocesses of inscription without distracting writers too much or disturb their thought processes.

3.2.1 Grammar, Style, and Spell Checkers

Grammatical accuracy is an essential aspect of most writings and has both an operational aspect in terms of text construction and a conventional aspect in terms of the compliance to established norms. The fact that digital inscription tools not only passively preserve letters and words but also actively inform the writers about various dimensions of inacurate language use or sentence construction, has been a millennial invention. Still, to this day, grammar checkers are far from being perfect (Cotos, "Automated Feedback on Writing"). Yet, while inadvertently missing out on some aspects of writing, they still have a similar success rate in detecting textual problems compared to teachers. For a thorough discussion of reliability and validity of automatic scoring and text evaluation, see Link and Koltovskaia ("Automated Scoring of Writing") and Cotos ("Automated Feedback on Writing").

The first grammar checker, called Writer's Workbench, was developed in the 1970s (see Smith et al., 1984) but became publicly available only in the mid-1980s. It was created by Lorinda Cherry and Nina McDonald from the Bell Labs and was based on NLP technology. It involved mainly lists of words and lists of common errors that the program marked in the text. Grammar checkers cannot simply rely on the rules of a consistent grammar, which they would "use" or "apply." Languages simply do not work consistently as rule-based; rather, languages exhibit multidimensional usage patterns of which only some are reflected in grammar books. For more technical information on NLP and grammar checkers, see Dale et al. (2000).

3.2.2 Automatic Word Division and Hyphenation

A writing problem that seems to have been solved is word division, as word processors do this automatically, and no decisions have to be made by the writer. In inflexible inscription systems such as typewriters, the number of words fitting into one line was a problem, at least in languages where separation was restricted to syllables. Not only was knowledge of hyphenation necessary, but also the space left for the last word in a line had to be calculated (at least when typewriters were used). Hyphenation works on the basis of word lists, in which the division points are marked and applied when the text approaches the margin. There are also formulas in use for syllable separation when words on the list are missing. Automatically set hyphens are considered 'soft' hyphens in contrast to self-set hyphens which are considered 'hard.' The soft hyphens disappear when the text is reformatted and the hyphenated word does not hit the end of the margin, while the hard hyphens remain in such a case. For formulation activity, automatic hyphenation is another help function freeing the writer from a lower-order concern that, in typewriting, not only demanded constant attention but was also a source of errors.

3.2.3 Autocompletion and Word Prediction

Perhaps the most straightforward approach to supporting inscription processes is autocompletion, which aims at what is essential in formulation: deciding on the next word(s). Autocompletion software offer potential completions to a sentence beginning; they can offer single words or chains of words such as phrases or collocations. It can offer several suggestions from which the writer can choose. This software type is mainly used in mobile devices and for search engines, but it is also an option in Microsoft Windows. Next to a large vocabulary, a collocation dictionary is needed for word prediction. Individual shortcuts for autocompletion are possible so that a user-based dictionary for completion can be created and, for instance, 'thank you' is automatically offered when typing 'tha'. Autocompletion can be based on a general dictionary or on individual word usage built from previous texts.

3.3 Support for the Choice of Vocabulary

Approaches from corpus and computational linguistics provide features allowing to search for appropriate words, word usage, or collocations. These measures are not as immediately tied into the inscription process as the aforementioned ones but need a certain search action on the part of the writer. The action may be as quick as right-clicking the mouse to open the synonym finder, or it may be a more extended action like querying a corpus-based search tool to look for collocations. Let's consider some prominent examples of digital tools offering vocabulary-level support.

3.3.1 Synonym Finders

Synonym finders, as included in Microsoft Word and similar word processors, are good examples of support features for formulation during inscription. They work only on demand and not automatically like autocorrection (once 'activated'). The technology of synonym finders is comparatively simple, having developed from word collections in dictionaries and then made available as searchable electronic documents. All it takes is to choose the right word that corresponds to the text.

In Microsoft Word, right-mouse-clicking on any word launches the synonym function, usually providing five alternative words. When an alternative word is clicked on, it replaces the original word in the text. In some instances, antonyms are also displayed. The thesaurus, which is available from the same menu in Microsoft Word as the synonym finder, has a different organisational form. It is a structured, alphabetically ordered list of interconnected words. Each term is clickable to retrieve a new list of synonyms, so that variations in meaning of similar terms can be readily assessed.

A more complex system of synonym finding is offered as a Microsoft Word add-on by https://www.synonyms.com. It offers more synonyms and antonyms than

Microsoft Word and it is available in six languages. Additionally, this tool offers word usage examples and is more creative in graphically representing word relations. The same company STANDS4 running the synonym finder also offers an abbreviation and acronym finder at http://www.abbreviations.com, which is a useful addition to the synonym finder.

3.3.2 Phrasebooks

Connecting phrasebooks with word processors is uncommon. Phrasebooks have been created for various languages, domains, and research fields. In general, phrasebooks support writers according to the idiomaticity of the domain/genre by offering complex phrases. In academic writing, the Manchester Academic Phrasebank is the best-known tool, pioneering not only in collecting phrases for numerous topics, but also in providing clarity through presentation in tabular format (Davis & Morley, 2015).

A bilingual (German and English) phrasebook is integrated within Thesis Writer (Kruse & Rapp, 2019; Rapp et al., 2022), which is a specialised platform designed to instruct and guide thesis writers focusing on their extended research papers. Thesis Writer offers a template-based outline generator to create a thesis proposal. Each step (e.g., 'state your research question', or 'describe the state of the knowledge to your topic') is supported by a list of 10 commonly used phrases. Additionally, Thesis Writer offers a large, open phrasebook similar to the Manchester Academic Phrasebank. It contains phrases, relevant for thesis writing, distributed into 16 categories related to research writing and 63 sub-categories, each of which corresponding to a particular communicative aim, similar to Swales' (1981) moves and steps. For each of the 63 categories, 20 distinct phrases are presented–all derived from a large corpus of academic research papers, dissertations and expert statements.

3.3.3 Concordancers and Collocation Finders

Corpus linguistics and computational linguistics have contributed several technologies to offer writers real-time support through text-based evidence (Chitez et al., 2015; Cotos, 2017; Cotos et al., 2017; Flowerdew, 2015; Hsieh & Liou, 2009). In second language teaching, providing lexical support directly from corpora forms an important grounding (Sinclair, 1999, 2004) that expands to more complex linguistic phraseology and rhetorical functions (Flowerdew, 2012, 2015).

L2 learners and writers, however, differ from L1 users who, at least passively, know most words and phrases and therefore look for the most appropriate lexical choice rather than considering rhetorical effectiveness. Whilst for L1 writers, synonym finders (for words) and phrasebooks (for phrases) seem advantageous, there is still a need to provide support for special terminology or more complex expressions, which requires individual corpus searches. The values of these offers likely depend on the size and specific focus of available corpora.

One of the most straightforward approaches to provide access to corpus data is offering writers an accessible or integrated concordance tool such as AntConc or ConcApp to search a corpus of selected documents for language use. Thesis Writer (Kruse & Rapp, 2019) has an integrated concordancer, through which users can explore an embedded English and German corpus. Searches can be performed for single words or word connections (collocations), with the tool searching for all instances where the words or collocations have been used in the corpus and then displaying them in a list. The number of words preceding/following the search term can be selected, and writers can check how the respective word/collocation is used in an authentic sample of documents. Whilst little is known about how much such tools are utilised and what their gain is, it seems that users require training in order to profit from them (Hsieh & Liou, 2009).

A far more differentiated collocation finder is offered by Philip Edmond (http://www.just-the-word.com), which presents search results in a clearly arranged tabular format. Here is an example of a search query on the term "risk":

> 'accept risk' (45); 'carry risk' (96); 'concern about risk' (15); 'cover risk' (31); 'involve risk' (59); 'take risk' (680)

The bracketed numbers refer to the number of entries found in the British National Corpus. Collocations with verbs, adjectives, and other nouns are presented separately. Here, a three-page list of collocations only for the word 'risk' provides a systematic account of all word connections. Even though collocations are a main issue in formulation, it is not clear how such a linguistic offer would serve writers without reducing the amount of information to a manageable size.

3.4 Support Through Automated Feedback and Intelligent Tutoring

Many modern language technologies make use of algorithms that can analyse deep structures of texts and, from there, can help generate automated feedback and provide tutoring for writers (see Part "Writing Analytics and Language Technologies" this volume). Such feedback is usually not given during the initial inscription but rather at a later stage when the text or a considerable part of it exists as a draft or seems finished. Revision means to reformulate parts of the text in order to adjust it to various demands of the content, structure, flow, genre, or audience. None of such changes can be accomplished without altering the wording and re-shaping the linguistic surface. For the writer, this kind of revision means to change the perspective from a text producer to a reader and evaluator of the text. Similarly, writing software has to transpose into an educational technology specifying what and how writers should learn. The tools we are looking at below give feedback not only at the language level but address a much broader range of deeper textual issues such as content development, focus, coherence and cohesion, organisation, rhetoric, flow, and structure. Each of them touches upon a different layer of text development and relates differently to language. Feedback on any of these measures necessarily leads to changes of the wording of the text and forces them to engage in reformulation. In what follows, we give examples of how automated feedback and intelligent tutoring influence formulation. We hope to demonstrate that reformulation needs more attention as a necessary part of revision, as it is connected to a large number of meta-communicative, meta-discursive, or meta-linguistic aspects demanding learning and re-orientation from the writer.

3.4.1 Rhetorical Support: Move Analysis

Move analysis is grounded on Swales' (1981) analysis of research article introductions, which connects the rhetoric of the text (expressions, phrases) with the communicative intentions of the writer (moves and steps) and the overall Introduction-Methods-Results-Discussion (IMRD) structure of the research article. Scholars analysing discourse in the Swalesian tradition identify phrases that serve as functional language, which is distinguishable from content-based language. To communicate effectively, research writers tend to use such functional language to make their intentions clear and avoid ambiguities. Beginning academic writers, on the other hand, are often not aware of the need to compose their research reports based on genre-specific rhetorical elements and instead try to express themselves creatively yet unconventionally.

The most elabora te Automatic Writing Evaluation (AWE) tool using move analysis to instruct writers is the Research Writing Tutor (RWT) (Cotos, 2014; Cotos, "Automated Feedback on Writing"; Cotos et al., 2020). It is based on the evaluations of a carefully collected 900-document research article corpus containing 30 papers from 30 disciplines. The documents were analysed along the categories of the Swalesian move analysis (Cotos, 2018; Swales, 1981) which, for this purpose, was extended beyond the introduction to cover all IMRD/C sections.

The core feature of the RWT is an algorithm that operates based on a collection of functional language (n-grams) related to specific moves/steps, which allows to identify the IMRD/C rhetorical traits, make them visible by color-coding, and generate feedback comments on them. Numerous examples of alternative language choices characteristic of individual moves/steps may be accessed vis a functional concordancer. A similar automatic feedback system is the AcaWriter, which developed move/step-like detection systems for expository and reflective student genres (Knight et al., 2018, 2020; Shibani, "Analytic Techniques for Automated Analysis of Writing").

Both tools, the RWT and the AcaWriter, provide scaffolding features for writers that are built around an automatic detection of phrases and offer support for their selection, interpretation, and eventually replacement. "Scaffolding", here, means that text construction and learning about academic writing are equally involved. Learning about formulation takes place while developing own paper. The pedagogical problem of such help functions for formulation activities is to offer appropriate word combinations without necessarily constraining the rhetoric of the writers. Making all writers use the same wording would be a rather odd practice for a scaffolding system. Rather, the selection process of wordings is tied to the aims of a particular textual step and can be optimized when it becomes clear what the aim is and which formulative options are available.

3.4.2 Cohesion and Coherence

The concepts of coherence and cohesion offer another opportunity to connect structural aspects of text organization with linguistic text elements such as transition markers, forward and backward references, and connectives. Coherence refers to the logical dimension of thought organization in a text while cohesion denotes the linguistic connectedness between stretches of text (Halliday & Hasan, 2013; Taylor et al., 2019; van Dijk, 1977). Coherence and cohesion depend on each other, and writing usually involves aligning topic development with linguistic organizers of text flow.

A critical element for coherence and cohesion are connectives or connectors. They serve both as syntactical bridges between clauses and as indicators specifying the relationship between thoughts (e.g., causal, temporal, additive, conclusive, conditional, etc.). In academic writing, precise thinking depends on the selection and usage of connectives. What makes them difficult to learn is their sheer number. The web-based multilingual lexical resource at http://connective-lex.info/ lists 142 English, 274 German, 328 French, and 173 Italian connectives (for more information see Stede et al., 2019). Learning to distinguish and use them takes time. Determining the right connective is not a matter of grammar but rather a matter of thought organization.

What can automated feedback do to support the use of connectives and how can it help writers understand deeper levels of coherence? There are a number of tools that focus on cohesion and include connectives; we will refer here to only two. The first is Coh-Metrix (http://cohmetrix.com) by McNamara et al. (2013, 2014), which is an analytical system using algorithms for a high number of different indicators describing linguistic and discourse representations of a text (McNamara & Graesse, 2012; McNamara et al., 2014). These algorithms have been applied in an online tutoring platform called Writing Pal (Banawan et al., "The Future of Intelligent Tutoring Systems for Writing"; Roscoe & McNamara, 2013") which hosts many analytic, tutorial, and gaming features for learning writing strategies. Coh-Metrix provides five different indices to evaluate uploaded text (Dowell et al., 2016, p. 78): narrativity, deep cohesion, referential cohesion, syntactic simplicity, and word concreteness. What do the coherence measures offer? "Deep cohesion" considers the number of different kinds of connectives and conceptual links while referential cohesion refers to the "words and ideas that overlap across sentences and the entire text, forming explicit threads that connect the text for the reader (p. 78)."

The second tool is the Writing Mentor, an NLP-based tool (Burstein et al., 2018) available as a free-of-charge Google Docs add-on (https://mentormywriting.org). It is designed to provide feedback on four relevant essay parameters: convincing, well developed, coherent, and well edited. 'Coherent' is defined as indicating the flow of ideas (highlighting topical words), transition terms, long sentences, pronoun usage, and titles. Topical words that mark the flow of ideas are highlighted. For 'coherence', the user has to choose from several feedback types such as transition terms, sentence length, section headers, pronoun reference, and indicators of topic development. Feedback is specified for the genres of essay, letter, narrative, and other. Tutorials are connected to each evaluative dimension connected with the respective advice, thus making the transition from automated feedback to intelligent tutoring.

Both tools, RWT and Writing Mentor, may be characterised as a language-awareness tool, directing the writer's attention to relevant linguistic and rhetorical issues and explaining their significance to textual construction principles. Much of the evaluative activity is left to the writer, as are the conclusions for text revision. Tutorial advice for complex linguistic issues such as coherence has limits. Automated feedback does not guide the writers' pen but points at the factors that matter and makes them think about language.

4 Conclusion: What Are the Developments Pointing at (the Future)?

Language assistance and formulation support have received comparatively little attention in writing theory. Although digital language technologies exist for more than 50 years and have been recognized for their rapid and revolutionizing results, their effects on formulation have not been analysed and theorized systematically. Perhaps one of the reasons is the lack of linguistic underpinning in writing theories and, to some extent, the nature of teaching writing in L1 contexts. Although no one would seriously doubt that language skills are necessary for writing, there is no consistent operational language theory that would explain what writers do with language (see Kruse & Rapp, 2023).

Technologies supporting formulation activities have arrived at an advanced stage of development, with many of them now regularly used in word processors or other digital environments, and more are still to come. We can no longer think of writing without these technologies, but we have to accept that the nature of formulation has significantly changed. The inscription environments of today's word processors and editors made formulation a more comfortable task, with few lower-order constraints that formerly occupied a large part of a writer's attention. Newly developed technologies, such as automated feedback, intelligent tutoring, argumentation support, or corpus-based search tools, address the writers' higher-order concerns, particularly when connected to a certain genre or domain of writing. In natural language generation supported by artificial intelligence, formulation may be completely executed by the computer while the writer's activity would be reduced to the control and revision of wording and content. We have to assume that summarization, reformulation, and editing would be executed automatically by digital technologies so that much of the formulation activity will be delegated to the computer.

Acknowledgements The research of Christian Rapp was financially supported by the ZHAW DIZH Fellowship Call 2020.

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Writing and Thinking: What Changes with Digital Technologies?

Otto Kruse and Chris M. Anson

Abstract The relationship between writing and thinking explicitly or implicitly runs through all the contributions to this book. There is no writing without thinking and there is no new writing technology that does not alter the way thinking in writing happens. Many layers of the relationship between thinking and writing await conceptualization. Four of them that seem most widely affected by the currently unfolding transformational processes are described in more detail in this chapter: (1) the connection of inscription and linearization to thinking; (2) the relation of sub-actions of the writing processes to thinking; (3) the influence of digital technology on connected thought, networked thinking, and collaborative writing; and (4) the challenges of higher-order support for writing, including automatic text generation for the conceptualization of the writing-thinking interplay. We close with a short statement on the necessity to adopt human-machine models to conceptualize thinking in writing.

Keywords Writing and thinking · Orality and literacy · Effects of digital technology on thinking

1 Introduction

Writing and thinking, particularly in academic contexts, are so closely related to each other (see, for instance, Langer & Applebee, 1987; Oatley & Djikic, 2008; Bereiter & Scardamalia, 1987) that Kellogg (2008) suggests we think of them as twins:

> Writing an extended text at an advanced level involves not just the language system. It poses significant challenges to our cognitive systems for memory and thinking as well. . . . Thinking is so closely linked to writing, at least in mature adults, that the two are practically twins.

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_29

> Individuals who write well are seen as substantive thinkers, for example. (Kellogg, 2008, p. 2)

Writing depends on thinking skills, and is, in turn, an activity that trains and develops various intellectual abilities such as conceptual, systematic, or critical thinking. Writing and thinking depend on both cognitive and linguistic skills and, additionally, on the quality of their interaction. We assume that the human mind runs on language as much as it runs on cognition. Thinking needs the lexical symbols, the grammatical forms, and linguistic connectors to create thought units as well as it needs the cognitive operations to process the flow of thought.

In this contribution, we consider the effects of the latest generations of digital technology on the relationship between writing and thinking. We start from the idea that writing is a way of linearizing thought into a chain of words that ideally are organized cohesively and coherently to make their content comprehensible for readers. Writing technology, in all its previous and current variations, allows for a step-by-step crafting of language, thus offering more control over the production of thought than speech alone. In its developed forms, writing has been called a way of restructuring or transforming knowledge (Kellogs, 2008; Bereiter & Scardamelia, 1987). We will also discuss what digital technology offers for the transformation or restructuring of thought beyond traditional writing media.

2 Traditional Views

How exactly does writing support or influence thinking? This was a much-debated question, particularly in the 1980s and 1990s, to which no simple answer was and still is possible. In a thorough survey of research, which can serve as a starting point for our purpose, Applebee (1984) summarized the common assumptions of his time about what it is that writing adds to thinking:

- "The permanence of the written word, allowing the writer to rethink and revise over an extended period;
- the explicitness required in writing, if meaning is to remain constant beyond the context in which it was originally written;
- the resources provided by the conventional forms of discourse for organizing and thinking through new ideas or experiences and for explicating the relationships among them;
- the active nature of writing, providing a medium for exploring implications entailed within otherwise unexamined assumptions." (Applebee, 1984, p. 577)

At the time, these assumptions seemed intuitive and probably still are. They were, as Applebee showed, less grounded in research than in the general assumptions of literacy theory. In particular, the historical and anthropological comparisons of literate and illiterate societies (Goody, 1977; Levi-Strauss, 1962; Ong, 1982) had provided assumptions that were transferred to the field of writing. However, several confounding variables mediate the relationship between writing and thinking development such as writing practices, schooling, and course design, which obscured a clear-cut causal influence of writing on thinking (see, for instance, Chandler, 1994; Finnegan, 1988; Street, 1984). Scribner and Coles' study of the Vai (1981), some of whom used a writing system but did not experience the additional effects of schooling, pushed against the conclusion of Ong and others that written literacy restructures thought. It is difficult to come to general assumptions of how the interconnection of both actually works and several levels or layers of theory building and research have to be distinguished:

Microprocesses of inscription and formulation: Language creation in writing happens in interaction with a writing tool that fixates words on a writing surface. It also mediates the inscription of sound to sight, thus making language visible. When writers see what they write, they can align the expressed thought with the thought they have in mind, or formulate the thought through the process of inscription (see Blau, 1983; Marcus & Blau, 1983 for accounts of what happens when writers cannot see what they are writing) today, such fine-grained processes of formulation are best studied by keystroke logging technologies that display the words inserted and changed in relation to the text development (Wengelin & Johansson, "Investigating Writing Processes with Keystroke Logging"). Most research comes from cognitive studies in the tradition of Hayes and Flower (1980), Hayes (1996), and Hayes (2012), but also from earlier psycholinguistic research on formulation and language production (see Levelt, 2013). At the micro-level, it is essential for an evaluation of thinking quality to understand how usable the technology is for the inscription of words, as this is related to the fluidity of the writing and thinking process (Kruse & Rapp, "Word Processing Software: The Rise of MS Word"; Kruse et al., "Finding the Right Words: Language Technologies to Support Formulation").

Writing processes and the sub-actions of text production: Writing demands many separate intellectual activities that traditionally add up to what is called text production. Most scholars today agree that writing is a recursive activity involving an ongoing reconsideration and revision of what has been written and successively improving the content, language, and structure of the text. Preparatory activities such as idea generation, source reading, summarising, structuring, and outlining may precede the more formulative activities of word choice and sentence construction. However, the extent to which writers engage in such prewriting activities has been the subject of debate. Early theories of "incubation" posited periods of unconscious rumination about an upcoming or ongoing text. Lauer (2004), pointing back to the work of Young et al. (1970), explains the process of inquiry "as beginning with an awareness and formulation of a felt difficulty followed by an exploration of that unknown, then proceeding through a period of subconscious incubation to illumination and verification" (p. 9). Further inquiry found that writers plan in a variety of ways, some with a general sense of exigency or purpose but with reliance on the emerging text to discover ideas, others with an explicit process of mapping out or outlining the structure and content of their writing (Baaijen et al., 2014; Isnard & Piolat, 1994). Prior to the development of digital planning tools, writers were urged to use various invention strategies before beginning to formulate their ideas into words.

Educationally, instructors incorporated activities into the writing process such as looping, tree diagramming, and listing. These invention heuristics were perhaps best exemplified in McLelland's textbook, *Writing Practice: A Rhetoric of the Writing Process* (1984), which included a chapter on invention with exercises such as brainstorming, cubing, starring, personifying, and creating metaphors. More sophisticated invention strategies based on linguistic tagmemics, such as the use of the particle/wave/field heuristic earlier developed by Young et al. (1970; also included in McLelland) became popular as a way for writers to brainstorm ideas. At their core, these strategies relied on categorizing or taxonomizing thought through a combination of linguistic and visual/diagrammatic representations or through questioning strategies (Larson, 1968), some of which drew on principles and methods from classical rhetoric (see Enos & Sypher, 1977; Young, 1976). The results were said to spark memory, extend thinking, reveal gaps in knowledge needing to be filled, and create structural outlines for whole texts (each category of information, for example, constituting a paragraph or section of text).

Writing as a way of student learning: When writers think about a topic or problem, writing may help them organize their thoughts and gain clarity about their intentions, arguments, and conclusions. Emig (1971, 1977) showed the similarities between writing and learning and noticed that revision of student papers leads to self-directed learning and thinking. Students carrying out writing or research projects use writing for documenting the information they have gathered and for connecting them to coherent papers or theses. Writing and thinking in such contexts are connected with literature searches, reading and reviewing literature, synthesizing knowledge, developing arguments, structuring a paper, and more. Here, writing is a way of learning about a topic by thinking it through. This kind of thinking by writing depends on the genres used and the assignments given (Anderson et al., 2015). It is also key to learning disciplinary epistemologies and thinking styles (see Devitt et al., "Writing and Learning: What Changed with Digitalization?").

Epistemological and intellectual development: Moving to a higher level of the organization of thinking abilities, the dimension of intellectual development comes into focus and the question arises as to how writing affects the growth of thinking abilities and of epistemological beliefs (see Baaijen et al., 2014). Here, the focus changes from the process or course level to one that tries to assess the overall thinking competencies and skills that result from writing. The connections of writing to the internet and web become salient as they position writers and thinkers differently than before with respect to the thoughts and writing of others. The relations of thinking to digital or computer literacy become relevant but also how digitalization influences critical thinking as Bean and Melzer (2021) conceptualize it.

The interactive and intertextual dimension: Writing is a seemingly isolated activity but by its nature it is also a thoroughly social activity, encouraging writers to use the thoughts accumulated in a discipline or in an activity field. Writing offers different kinds of interactions with other writers and their writings than oral communication does; intertextuality is an essential attribute of academic discourse where what is thought and written is related to what others have already said and where the origins of ideas have to be specified when recoverable or when they are common knowledge or tacitly learned (see Bazerman, 2003). Thus, writing may be seen as enculturation into the thinking habits of a discipline or group of users. Bruffee (1999) pointed out that writing is one of the roots of collaboration both among students and within disciplinary knowledge groups. Feedback is seen as a necessary practice to foster writing development as well as text development.

Even if there is considerable overlap between these levels, they should be distinguished to arrive at consistent theories and valid research. Another theoretical development explored the highly contextualized nature of literate practice, suggesting that writing can have different effects on thinking at each of the five levels depending on a host of factors such as genre, purpose, rhetorical situation, disciplinarity, and the affective states of the writer.

An equally persistent problem as that of different levels of analysis arises from the vagueness of the term "thinking" and the lack of appropriate theories that avoid cognitive or linguistic reductionism. Thinking can neither be reduced to cognitive activity (no academic thinking without language), nor can it be made equal with inner speech (no thinking without cognitive activity). Also, thinking cannot be reduced to automatic routines that can be processed in a computational way, any more than it can be reduced to conscious processing of thought or logical reasoning, as Kahnemann (2012) has pointed out. To better understand thinking, Kahneman suggests that we consider both the automaticity of thinking subroutines and the linear, controlled, effortful, and conscious part of sequential thinking. Thinking relies on myriad automatic processes, both linguistic and cognitive in nature; but in academic writing we practice a more linear, step-by-step process of thinking that is needed for knowledge construction.

3 Current Transformations of Writing Induced by Technology

With the invention of the computer, the hope of improving thinking was expressed at an early stage of development (Bush, 1945; Engelbart, 1962; Licklider, 1960; Rheingold, 1985). The expectation that the computer would foster thinking has been one of the great promises of the digital age. This was not only proposed in the context of word processors but more so of the computer as a whole and its potential uses, even if word processors became a main application (Heilmann, "The Beginnings of Word Processing: A Historical Account"; Kruse & Rapp, "Word Processing Software: The Rise of MS Word") to align the computer with human thinking.

In digital writing, the computer is more than a passive inscription tool for letters and words as the typewriter and other media once were, but has become an interactive agent (see Baron, 2009). Word processors have become work benches for the creation of text, offering many tools for writers to apply. The tools guide the writers' thinking in various ways, not only by assisting with lower-order concerns like line feeds, grammar checking, hyphenation, and pagination but increasingly by taking care

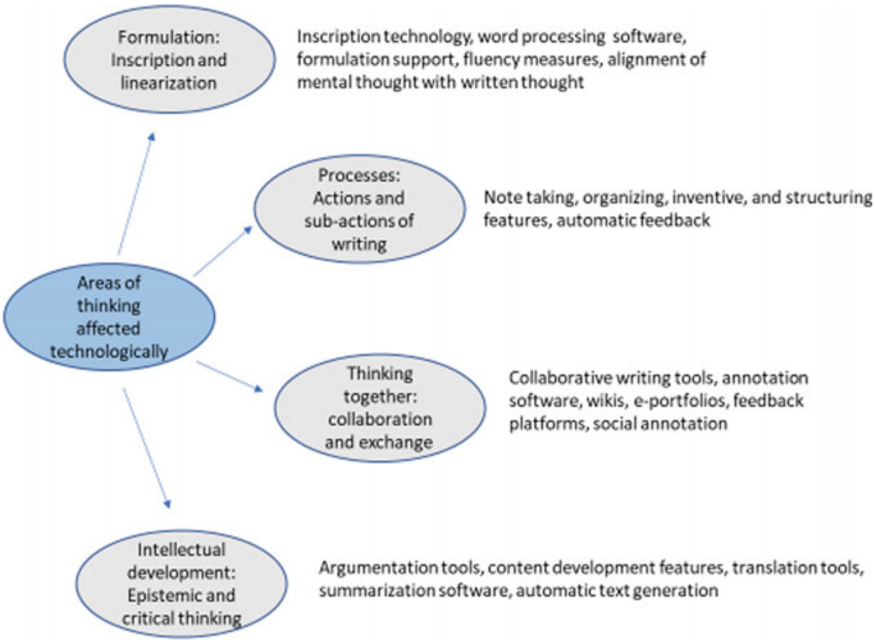

Fig. 1 Main areas of thinking influenced by writing technology

of higher-order thinking activities such as structuring, formulating, searching, and synthesizing. The influence of such technologies on human thinking cannot be seen only as a form of tool usage or of a supportive assistance of the computer but also in the way that they substantially change the demands on human thinking. We will suggest some hypotheses at the end of this contribution as to how this can be conceptualized.

Figure 1 provides an overview of four kinds of thinking we see supported by technology use and the kinds of technologies on which this support is based. We will consider each of them individually.

3.1 Thinking, Inscription, and Linearization

If writing and thinking are twins, as Kellogg (2008) has put it, then the question arises of what digital technology adds to a smooth and productive interaction between the two. Thinking and writing are, after all, substantially different processes; synchronizing them means adapting digital technology to the peculiarities of human thought production as it, conversely, means adapting writers' thought processing to the word processors' working principles. That is, there is no linear influence of technology on thinking because of the recursive nature of writing and because users must adapt to the tools. In turn, the tool developers have to keep the users' minds in view it they want to optimize usability.

The most basic function of writing technology is to provide a way for the inscription of letters and words, which means assembling lines of words that eventually reach permanence and can be transmitted to readers (Kruse & Rapp, 2019; Kruse & Rapp, 2023; Kruse et al., "Word Processing Software: The Rise of MS Word"). To match writing and thinking, the inscription procedures must be similarly flexible as the thinking processes but still be able to ensure the permanence of the inscribed content. Typewriters were comparatively inflexible, producing fixed text lines only partially revisable. To arrive at a usable text, writers usually needed to produce several draft versions because of the medium's limited options for the removal of inscribed text until autocorrection-enabled typewriters were available. In digital technology, insertion of characters is as easy as deleting, changing, relocating, rearranging, or formatting them (see Kruse & Rapp, "Word Processing Software: The Rise of MS Word"). Word processors compress the operational space between writing, revising, designing, editing, and publishing the text to the use of a single tool. Many parts of the writing process have been automated by digital tools, unburdening the writer from some aspects of inscription in favor of focussing on the content of the emerging text. All these aspects free the writer from lower-order and often trivial activities.

Next to the lower-order aspects of handling a writing tool, another aspect makes the creation of lines of words difficult and distracts attention from the conceptual issues of content creation: the constraints of linguistic forms, orders, and conventions (Bazerman, 2013). The writer must attend to many syntactic, morphological, lexical, and rhetorical demands. Words cannot be attached to each other like Lego pieces. When a noun is exchanged, the verb usually has to be adapted. When a tempus form is changed, other tempus forms may need modification as well, and when a connector is replaced, the meaning may change and must be reconsidered and possibly rephrased. What keeps them together is a high number of different syntactic, collocative, lexical, and rhetorical conventions that are intertwined with logical structures in an often confusing way.

Digital writing tools support the assembly of words into meaningful units of thought, allowing the writer to test the connections between language and thought. Writers do not have to decide in advance about the sentence to be inscribed, as in handwriting or typewriting, but can flexibly modify the sentence in real time. Writers can also alter the chosen line of linearization flexibly, both within a sentence and between sentences and paragraphs. The writing tools have adapted to the needs of thinking-for-writing and enable the use of language for various purposes. Several tools support writers during inscription, such as synonym finders, grammar checkers, sentence completion programs, phrasebooks, or internet search tools. In addition, various tools support the revision phase of writing such as automated feedback systems or those that support human feedback; style and grammar checkers; and so on.

Digital inscription technology has offered new ways of thinking which, as Heim (1987, p. 27) has claimed, revolutionize the "transcendental intimacy of thought, word, and reality," thus reconfiguring thinking, language, and experience in a new way. Although Heim's argument is a philosophical one, we can also use it to refer to changes in writing processes. Digital tools give way to new forms of thought development when a writing space supports the alignment of mental representations with linguistic expression. Whether we see the textual forms of thought as primary or as mentally constructed, word processors are writing spaces mediating the mental and the literal.

Van Waes and Schellens (2003), for example, studied the processes of 20 writers who wrote two texts, one by hand and one on a computer. Extensive analysis of keystrokes and recordings of the handwritten episodes revealed significant differences in the writers' processes, including the length of the pauses between moments of inscription and subsequent revision of already produced text. As the 20 participants switched modes (from handwriting to writing on the computer), the profile of their composing processes changed. This and other evidence demonstrates differences in the way that writers produce text on the computer but also gives us a window into changes in thinking processes, which are revealed by changes in text production.

Thus, what explains Heim's quality of an "intimate" relation between thought, word, and reality is probably the increasing loss of a clear border between the mental activity, the content, and the writing space in which thought is shaped. The word processor becomes an extension of the mental thinking space and successively enlarges its natural capacities. The word processor is, however, not a passive medium like the chessboard is for the players but is an agent that virtually thinks back. It not only supports thinking activities and makes the thought production smooth but increasingly adds to the production of thought and content itself (see Benites, "Information Retrieval and Knowledge Extraction for Academic Writing"; Benites et al., "Automated Text Generation and Summarization for Academic Writing").

When we consider word processors as "thinking tools," then we address this quality of using the virtual writing spaces to make thought accessible for conscious and deliberate processing. Thinking in writing depends, first, on the inscription technology and the way writers can see and manipulate their own thought by changing what they wrote. However, many technological features extend the word processor's range of activities by connecting it to the internet, to platform engines, and to the writing spaces of other writers with activities such as importing thought from external sources, checking existing material, getting and giving feedback, co-authoring papers, and bringing thought into line with other writers' ideas and statements.

3.2 Actions and Sub-actions of Writing Processes

Text production follows, as most human working processes, a temporal logic of steps to be carried out such as planning, source reading, data gathering, outlining, formulating, revising, giving and receiving feedback, formatting, editing, and publishing. Such a sequence leads from the first idea or assignment to the finished, submitted, or published text. Different from many other working processes, writing is seen as a recursive and iterative process, as Emig (1971) and Hayes and Flower (1980) have shown. This means that the order of steps or stages is not fixed but can vary. Several steps may be carried out repeatedly and each part of the text can be revised several times. Writers learn while writing and this makes it necessary for them to adapt what is already written to what they continue to discover until the text is coherent. The arrangement of sub-actions can be adapted to individual writing strategies and thinking preferences.

The best-known process model (Flower & Hayes, 1981; Hayes, 2012; Hayes & Flower, 1980) sees writing as a sequence of cognitive activities (planning, translating, revising, transcribing), thus reducing writing to mental activities without reference to tool use or manual actions. If we look at writing processes through the lens of word processors and other digital tools, we find an increasing number of functions that support various sub-actions of the writing process (Lockridge & van Ittersum, 2020). Van Ittersum and Lawson Ching (n.d.) suggest on their website (http://cconlinejournal.org) that the writing process is not so much a static cognitive structure as a set of complex interactions among writers, their tools, and their objectives. What is called the "writing process," they add, is a system of activities that is made and re-made every time a writer writes.

Slightly simplified, understanding the writing process today means specifying which digital tool to use to perform any of the various sub-tasks. Each of the sub-tasks is connected to a certain thinking activity that once had to be performed mentally without computer support or as a paper-based activity. Candidates for a closer consideration are the following sub-actions of writing with the respective technologies supporting them:

Idea generation and invention: Even though mind and concept maps existed before the digitalization of writing, today they can be included seamlessly into the writing process and the results can easily be transferred from the tool used to the word processor (see Kruse et al., "Creativity Software and Idea Mapping Technology"). The interest in invention processes spurred the development of digital tools to aid in the composing process. These included brainstorming programs, mind maps, and concept maps. Mind maps and concept maps provide the most direct access to conceptual thinking (Kruse et al., "Creativity Software and Idea Mapping Technology") and also provide an operational model of what concepts are. Although both concept maps and mind maps reach back to the pre-digital age, they have changed their accessibility and connectedness to writing considerably post-digitalization. Both technologies are based on the idea that collecting and connecting ideas (thoughts, terms, conceptual units) is a worthwhile activity to get access to conceptual thought without being bothered by the linguistic embedding of the ideas into linear arrangement of the text.

Planning and project management: Planning tools such as Thesis Writer have been developed in the context of project management and have been imported into word processors only recently (Rapp et al., "Beyond MS Word: Alternatives and Developments"). They can be used to both draw a plan for a writing project and monitor its progress. When using planning software, thinking shifts toward the methodological meta level, forcing writers to look at their working process from the outside, and maintain focus on the temporal issues of their projects.

Outlining and structuring: Creating hierarchical outlines was one of the early functionalities of word processors. They organize headlines hierarchically and allow the creation of tables of contents. Outline generators support structuring content and organizing them both logically and thematically. Blocks of content can be moved up and down along with the respective headlines to allow for a flexible rearrangement of content. Outline generators are of great help to master the structural demands of academic papers and offer substantial support for thinking by making outlines visible and adaptable.

Literature searches, source reading, and annotating: Reference management systems revolutionized the way writers handle literature. While initially these tools copied the library card drawer with references and summaries, today they include increasingly more functionality and have expanded the opportunities for writers to engage with the relevant literature (Proske et al., "Reference Management Systems"). Writers can "collect, select, analyze, interpret, organize, and connect information of different sources," as Proske et al. explain (p. 2). Reference management systems do much more than organizing the reference section of a paper, particularly since they do not only collect references themselves but also the respective papers, usually as PDFs. They also can guide the production of the literature review and the state-of-the-art sections. These actions connect knowledge of content with rhetorical knowledge and relate both to the aim of a paper or research project. It is unclear to what extent the new technology has changed thinking along with the activity itself; disregarding the technology used, the relationship between emerging content and rhetorical knowledge is one of the most demanding of the writing process, requiring many kinds of thinking. New options for creating intertextuality are offered by plagiarism detection software (see Anson & Kruse, "Plagiarism Detection and Intertextuality Software"). Particularly when not used to find improper quotations but to inform writers about the ways they have incorporated outside literature, this kind of technology may be helpful as an aid for creating literature reviews.

Summarizing and note-taking: Reference management systems and notetaking tools have overlapping functionalities even though notetaking starts from the reading process and is less grounded in knowledge management than in the knowledge reception. As Pitura, ("Digital Note-Taking for Writing") points out, notes are elementary information units, usually of private nature, which can be used to transfer knowledge from a source into the frame of personal usage for the purpose of learning or writing. Notetaking is a basic activity for academic learning and writing alike and trains receptive abilities of text comprehension and idea generation.

Quoting, referencing, and intertextuality: Although not considered a stage of writing, the role of intertextuality is a core feature of academic discourse and was one of the early targets of digitalization (see Proske et al., "Reference Management Systems"). Access to intertextuality can be provided by plagiarism detection software which indicates all sources taken from the internet (Anson & Kruse, "Plagiarism Detection and Intertextuality Software").

Formulating: Writing is always concerned with finding the next word. Linearizing thought also means linearizing the chain of linguistic signs and interconnecting them (Kruse & Rapp, 2023). As both activities have to be carried out simultaneously, formulating is seen as a strenuous activity. As inscription and revision can be carried out almost simultaneously, the cognitive load of formulating has been reduced, affecting thinking (Kruse et al., "Word Processing Software: The Rise of MS Word"). Tools include grammar and style checkers, digital phrase books and corpus search tools (Chitez & Dinca, "On Corpora and Writing"), and summarizing software.

Editing, publishing and submitting: Many tools and platforms offer services for checking grammar, spelling, style, coherence, and other aspects of text quality. It is an important learning task for writers to employ such digital tools to improve a text and make it publishable. Writers are not only relieved of attention to certain language features but have substantial support for them (see Shibani, "Analytic Techniques for Automated Analysis of Writing"; Link & Koltovskaia, "Automated Scoring of Writing"). In addition, digital technology along with the internet offer intermediate forms of publication, such as portfolios, that address small or medium-sized groups instead of open, unlimited audiences (see Bräuer & Ziegelbauer, The Electronic Portfolio: Self-Regulation and Reflective Practice).

Formatting, visualizing, and designing: Although it may not seem related closely to thinking, writing cannot really be dissociated from its graphical appearance. Early on, multimodality held promise for digital writers, and even if it has not fulfilled all expectations, it does provide affordances for the use of graphics, pictures, sound recordings and videos to enrich alphabetic text. What once had been the task of a professional field of graphic designers, typesetters, and printers can be done in passing by the writer.

3.3 Thinking Together: Connected Thought and Networked Thinking

While traditionally, writing was considered a rather solitary activity, digital technology has made its social dimensions more visible, accessible, and available. Activities that previously could be performed by a single writer now may be carried out collectively, with equal access to the text production process for every participating writer. But even for individual writers, digital tools offer new ways of relating to the thoughts of others and connecting to them in different ways than the traditional quotation systems.

While thinking together in pre-digital technologies happened only when a text existed as a consistent draft, today collaboration and co-authoring can start at a much earlier stage. First steps such as exploring a topic, generating ideas, and searching the literature can be produced collaboratively. More broadly, writing can be composed collectively with various roles and distributions of labour among the writers. This may lead to completely new configurations of interconnected individual and networked thinking. For a more extended discussion of collaborative writing software, see Castelló et al. ("Synchronous and Asynchronous Collaborative Writing").

While the technologies in the last chapter support activities that have always been part of writing, in this chapter we deal with technology that enables completely new kinds of actions compared to those in the pre-digital age. Synchronous collaborative writing, joint publication in wikis, or social annotating are relatively new developments and need considerable extensions of our conceptualizations of writing.

Collaborative thinking in online word processors: The social dimensions of collaborative writing have been extensively covered in existing scholarship (for instance, Posner & Baecker, 1992; Sharples et al., 1993), which were using early digital technologies with hard-wired LAN networks to induce collaboration. With wikis and the launch of Google Docs in 2006, collaborative writing and document sharing became accessible to a large public (see Castelló et al., "Synchronous and Asynchronous Collaborative Writing", for a summary). Although asynchronous collaboration predates digital technology and has been enhanced by it, synchronous collaboration is more recent. To further support collaborative writing, advanced online word processors usually include a comment function to discuss or give feedback; visualization to highlight certain content; version control and revision history to allow the writer to go back to previous iterations; standard author roles such as "editing," "suggesting," "viewing," and "reading"; and integrated communication channels such as chat and video streaming that help coordinate the writing process.

While collaborative word processors and other tools allow for joint usage of the same digital working space, writers have to organize working processes differently than when writing solo. Issues such authorship and writer identity in digital collaborative writing conditions also deserve deep attention in research, especially in professional contexts (see Reid & Anson, 2019, for a representative case study). Next to the newly emerging roles, coordination is an essentially new demand of such tools and a group writing synchronously has to develop new collaborative writing strategies that differ from traditional writing processes (Olson et al., 1993; Olson et al., 2017; Yim et al., 2017; Wang et al., 2017). We have to assume that a considerable portion of the thinking activity has to be directed to the coordinative needs of the group situation. Writers experience themselves differently in synchronous collaborative contexts and have to adapt to the new social challenges which include a struggle for roles, competition, influence on the product, and choice of a strategy. In addition. the social nature of collaboration may lead to affective and emotional responses that are part of thinking while writing.

Wikis: As Cummings ("Content Management System 3.0: Emerging Digital Writing Workspaces") explains, wikis are CMS designed for writers to develop content and write text together. Unlike earlier wikis, today they are more flexible and can be customized as well as adapted to individual tasks by every user. They are, as Cummings explains, "no longer just about collecting and organizing information but cultivating new connections for ideation and content creation—both personally and collaboratively". Wikis are web-based working spaces that include different kinds of content, both formal and informal, connected by bidirectional links. Various kinds of knowledge visualizations are offered and shared publishing is possible. From the perspective of thinking processes, Cummings notes that

> In these spaces, some aspects of our cognitive processes become visible through links and graphs. Because most of these digital workspaces allow users to shape and transform the space, cultivating these CMS becomes a form of thinking itself, often preceding the ideation phase of invention. As a result, our thinking can become much more visible by making it tangible. Instead of just thinking about our ideas, we can actually see the process of how our ideas came to be.

Next to the visibility of thought, the interconnection and the joint shaping of content are of interest in conceptions of the relationships between digital technologies and thinking. It seems promising for theory building to follow the idea of externalizing thought through digital writing spaces.

Portfolios: Similar to wikis, electronic portfolios are CMS designed to exchange text and offer new ways of interacting with others (Bräuer & Ziegelbauer, "The Electronic Portfolio: Self-Regulation and Reflective Practice"). Their original intention was to make student papers visible and document or communicate their development (see Yancey, 1992). In digital contexts, the interconnection to other texts, and the affordances for sharing, commenting, and reflecting, provided initial innovations. Portfolio use offers many opportunities for networked thinking and learning, as well as for group engagement in class, connecting individual text work with communication, learning, and presenting.

Social Annotation: Hodgson, Kalir, and Andrews ("Social Annotation: Promising Technologies and Practices in Writing") describe social annotation as a "type of learning technology enabling the addition of notes to digital and multimodal texts for the purposes of information sharing, peer interaction, knowledge construction, and collaborative meaning-making." Similar to the function of wikis, social annotation brings writers together in a digital working space and allows them to interact by commenting on papers of various kinds. This is primarily used for the reading and evaluation of sources which typically precedes (but may be concurrent with) the writing process to prepare and enrich the knowledge base on which a paper may be grounded. It also may be used as a reading tool for learning, not only for writing purposes. Social annotation produces a kind of interactivity between users supported by "social reading, group sensemaking, knowledge construction and community building" (as Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing", note with reference to Zhu et al., 2020, p. 262). The nature of such digital tools deepens the construction and interpretation of meaning more than any other previous writing or knowledge media.

3.4 Computers as Content Developers, Thinking Tutors, and Co-authors

Recently, computers have started to support the core features of academic writing: content production, argumentation, and summarization (see, for example, Cotos, 2014, 2015) Beyond this, they are at the edge of becoming co-authors and independent agents of text generation, thus expanding their competencies beyond supporting sub-actions to become text producers of extended and elaborate drafts (see Benites et al., "Automated Text Generation and Summarization for Academic Writing"). What does this mean for human thinking? Writers can request a document from one of the available text generation tools such as GPT-3 and will receive a fully fleshed text on a chosen topic. With this AI-based programming, the computer can move beyond a tutoring or supporting role to become a co-author mimicking what humans consider a stance or position embedded in a coherent text. Although AI-based text production systems do not "think"—in their current iteration, that are, as Bender, et al. (2021) have described them, "stochastic parrots"—they demonstrate how computers can still produce artifacts that appear to have been created by human writers, taking over the processes of text production and challenging traditional linguistic craftsmanship.

Argument construction and argument mining or mapping: Argumentation is an intellectual activity that seemed to be exclusively in possession of humans, until it was made accessible for computation (see Benetos, "Digital Tools for Written Argumentation"). Argument mining or mapping refers to technologies that scan text corpora for the rhetorical signs of argumentation, delve deep into the logic of argumentation, and make the extracted arguments available for learning and writing. They also help to design arguments and prepare argumentative writing. Computer-enhanced argumentation has challenged software developers because of its multi-faceted and discipline-specific forms but seems to be successful when reduced to its generic forms and graphically supported by diagrams (Benetos, "Digital Tools for Written Argumentation"). Although few of these digital tools have made it to the market so far, they strike at the heart of rationality and scientific inquiry. Argumentation is one of the most complex thinking activities and is key to critical thinking. Cracking its code for computation or at least for computer supported instruction would be another key aspect of the human-computer interplay that needs conceptualization and research.

Automatic text generation: Currently expanding AI-based natural language production systems will rapidly change writing and intellectual development. Like the games of Chess and Go in which computers easily outsmart world champions, text generators will eventually produce papers of higher quality than those written by university students. Even though computers do not understand what the words they use mean, they can gather relevant knowledge, make decent summaries, and excel rhetorically (see Benitez et al., "Automated Text Generation and Summarization for Academic Writing"). There is reason to fear that the interaction with the computer will lose Heim's (1987, p. 27) notion of the "transcendental intimacy of thought, word, and reality." Automatic text generation is not about the word-for-word interaction with a word processor that gently supports the writer's development of ideas. Automatic text generation puts the writer into the role of a reader of a self-generated text and, depending on satisfaction with the produced text, a possible editor. Texts are not written in the writers' own words, even if the writer initiated the process and has to make sense of its results. Language production becomes part of the computer's skills and when the need to formulate and struggle with words, collocations, and rhetoric is passed on to the computer, an important area of language learning and meaning making is subverted. The alignment of writing and thinking made possible by the word processor will dissolve again in favour of patterns connected to the handling of complete texts with the option of revising them. It has yet to be known what the new role of humans in text production will be under these circumstances and how they can be performed, although some suggestions have already been proposed for accommodating AI-based language production systems in the classroom (see Anson, 2022; Anson & Straume, 2022).

4 Conclusions

Through digital technologies, thinking itself has become technologized and is at the edge of becoming industrialized. Opening a laptop, we find plenty of "tools for thought" (Rheingold, 1985) that support, augment, expand, or even replace human thinking. The share of automatically processed sub-tasks of writing is growing, thus transforming writers into tool users who know which button to press in order to accomplish a complex thinking activity. Digital technology changes not only the basic language and formatting skills like hyphenation, spelling, grammar, and typesetting but also higher-order processes such as translation, argumentation, and summarization. It is unclear, however, whether and to what degree writers will still know what the computer does in the background.

The computer is not only a tool that enhances writing, it changes writing itself and forces writers to adapt their thinking to a wide range of new technology-supported activities. Today, digital technology enables writers to produce text in new ways, to cooperate and communicate with more ease, and to access knowledge within seconds from myriad sources. All this upends the production logic of texts and pushes the cognitive, linguistic, social, and emotional components of thinking-for-writing in new directions. The computer, thus, is not only a supporting and comforting agent but also a challenging one. Keeping up with technological development and readjusting to new tools, platforms, and networks has become a constant task. A considerable part of thinking activities for future writers will be to explore this constant change and adapt to it.

Finally, the computer is about to take over the writing professions by becoming an agent of text production itself, thus initiating the industrialization of text production. This again forces writers to adapt to a completely new reality of academic work and thinking. Meta-skills of communication and evaluation will become necessary for supervising the computer and controlling its products.

In summary, four new dimensions surface as core issues for an understanding of the relationship of thinking, writing, and digital technology:

New thinking skills: Making use of the new technological opportunities requires a new level of digital literacy and technology awareness. Teaching and critically evaluating these new technologies, and adjusting thinking skills to them, will be equally needed.

Loss of skills: Digital writing technology may have deteriorating effects on the development of certain thinking skills, particularly because automatic computer support, such as spelling, grammar, hyphenation, collocation, choices of style or register, etc., may lead to a loss of the respective linguistic and cognitive skills that are no longer needed when the machine takes care of them. It is not clear yet how to respond to these losses and whether they can and should be replaced by new technological skills.

Cooperative interaction with the machines: It is still a challenge to conceptualize thinking as an interactive process with the computer. Licklider (1960, p. 4) was the first to write of a [hu]man-computer symbiosis as part of a cooperative interaction between both in which computers do the "routinizable work" while humans "set the goals, formulate the hypotheses, determine the criteria and perform the evaluations." Bazerman (2018) has suggested focusing on "socio-cyborgian activity systems" for human thinking, where the computers take over what humans cannot do equally well.

> This changing distribution of work means that human skills also must change. While machines will come to do what machines do best, humans must reallocate their attention and skills to do what humans do best in these socio-cyborgian activity systems. Further, humans need to develop new skills to understand, direct, and make choices about these complex networks. (p. 205)

Bazerman's conceptualization suggests a need for balance between the human and the digital, focusing on what humans can do best rather than on their deficits or disappearing skills. His metaphor helps to avoid an evaluation of digitalization in terms of wins or losses for the humans in favour of a productive collaboration or interaction between both.

New access points to intellectual development: Currently, computers are unable to perform certain aspects of human thinking, such as conceptualization, rationality, logic, disciplinarity, intentionality, epistemological reflectiveness, and metacognition. We like to group these features under the term "critical thinking"—those parts of thinking that the computer at best mimics. Critical thinking does not develop in a single course and does not result from writing a single paper but is the result of longer and more sustained educational experience and intellectual development. Relating thinking in writing to this development should be a way to arrive at new perspectives for the teaching of writing alongside whatever technological developments accrue to us.

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Writing Processes in the Digital Age: A Networked Interpretation

Lance Cummings

Abstract The concept of writing processes is clearly useful for the study of digital writing when we see writing as a complex, integrated set of actions that are organized in time and integrated into both digital and physical spaces. With the increased digitalization of writing, the processes of writing are becoming more integrated into a variety of tools, workspaces, and platforms, adding new layers to how we perform writing. This chapter explores how writers and researchers can conceptualize digital writing activities as new platforms and software continue to evolve, changing the way writers adapt processes to complex writing situations. The proliferation of digital spaces and tools also raises the visibility of writing processes formerly difficult to assess and evaluate due to their cognitive nature. This chapter will summarize primary approaches to writing processes and several heuristics currently used to understand and analyze writing as a dynamic and networked activity. These tools are useful for examining the new ways digital technologies make writing processes visible for both research and reflection. The chapter will also discuss some implications for theory, pedagogy, and research.

Keywords Writing process · Workflow · Ecology · Activity · Networks

1 Introduction

The digitalization of writing has not only distributed writing activity across space but also across time, making writing processes more complex. The digitalization of the writing process highlights the adaptability and flow of writing activity, where each step can take place at any point in time and can occur independently or in relation to other actions within a variety of digital spaces. Because many of these activities now happen in new and developing platforms and tools, like those discussed in this book, processes are more accessible to both researchers and writers, increasing opportunities for research and innovation in the writing process. Though writing

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6_30

processes can be difficult to map, both researchers and writers can better reflect on writing activity as the use of digital tools becomes more ubiquitous throughout all the processes of writing.

In writing studies, process has always been shaped by the available writing technology and the historical and cultural contexts in which they exist and interact. How we think about process is often informed by not only shifts in technologies, but also in cultural movements. For example, the idea of a single writing process emerged from the industrialization of manufacturing and influenced all aspects of education, not just writing (Gee et al., 1996; Henry, 2006; Slack et al., 1993). The technologies available to researchers and scholars will ultimately shape how we construct the various activities and processes involved in writing. One goal of this book is to clarify these contexts to better understand writing processes, how they are changing, and how we can better reflect on how they function in complex writing situations.

This chapter will explore how researchers and writers can conceptualize writing processes in the digital age. To do so, the chapter will review primary approaches to thinking about writing activity and then look at how these processes are visible throughout the technologies discussed in this book. Both researchers and instructors will need to think about the ways these shifts alter how writers conceptualize and adapt writing activities as they become more distributed and complex.

2 Traditional Views of Writing Processes

Since its inception in the mid-twentieth century, writing studies has used the idea of writing processes to develop both research and teaching. The shift from final products to developing the skills and abilities required to produce texts revolutionized how we research and teach writing in academic contexts (Anson, 2014). Writing became no longer defined as a final product, but as a series of activities that take place in specific spaces and environments. Since the emergence of the process paradigm, scholars have viewed writing activity through various lenses, which are always historically situated and influenced by technologies.

Understanding the digitalization of writing means understanding how new technologies influence the way we frame the activities around the production of text. Since this paradigm shift, writing activity has often been understood as not only sequences, but also a collection of choices and social interaction.

Process paradigms	Theoretical focus	Dominant technology
Sequenced steps	• Final product • Linear connections • Editing & Polishing	Analog
Collection of choices/cognitive or mental models	• Revision • Recursivity • Reflection	Word Processing

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Process paradigms	Theoretical focus	Dominant technology
Social activity	• Collaboration • Audience interaction • Participation	Web 2.0
Workflow	• Networked ecologies • Activity theory • Distributed tools	SaaS, CMS 3.0

Many of these concepts find their way into the newer approaches to writing processes in the digital age, even as we adapt to new technologies. The next few sections will detail these approaches and how they fit into the digitalization of writing.

2.1 A Sequential Set of Steps

The most basic view of writing sees process as a set of sequential or interrelated steps that lead to a final product, usually by an individual writer. These processes have been typically broken into six stages: planning or prewriting, drafting, revising, editing, reflecting, and publishing or sharing. How we explain these activities is often determined by the tools and spaces we use to make them happen (Bernhardt, 2013; Porter, 2002). For example, writing on paper or with a typewriter emphasizes the linear nature of writing, both as the generation of text and in the organization of ideas. This sequential view of the writing process emerged in the early twentieth century with the increased use of mass-production models in factories and schools. This model became the predominant definition of process during the 1960s and 1970s, when writing processes in schools and universities became an alternative to product-based writing instruction. Much of writing studies research into process is centered around researchers and teachers examining them as more dynamic and interconnected as new technologies become integrated into our writing.

Early on in the process movement, scholars cast writing as a sequential set of steps meant to help writers better develop their thoughts and rhetorical awareness. For example, Corbett (1999) organized the writing process around the canons of rhetoric to emphasize audience and purpose. Rohman (1965) conceptualized various stages in order to highlight writing activity underemphasized in research and teaching (like pre-writing). How writers plan and organize ideas became a key moment of intervention where teachers could improve student learning and thinking, while researchers could better understand how writers think by observing them, instead of just analyzing their texts (Perl, 1979). Because much of writing was analog at that time, many of these writing activities were invisible or underemphasized in the writing classroom. Researching writing processes helped bring important writing activities to the front of mind.

Approaching writing as process helped teachers and researchers look beyond the text itself to see how writing processes could be improved, taught, or simply understood. For example, the revising and editing stage became a key element in most writing classes. This stage involves making changes to a text to improve its clarity, coherence, and overall quality, but also helps writers develop meta-awareness of how their processes work. Emig (1977) made the case that writing processes and learning processes work together to help writers develop knowledge, not just communicate what they know. Writers' own reflections and self-assessments on these processes can help students improve how they handle complex writing situations (Anson, 2000; Howard, 2000). This meta-awareness can lead to a better understanding of the choices writers make. As digital technologies became more available and connected, a greater emphasis was placed on the role of editing and revising digital artifacts. Revision becomes a key moment of intervention for teachers, particularly as working with digital technologies gives them clear visibility into revision history and allows for greater reflection on the choices writers make.

2.2 A Collection of Choices

In both teaching and research, tracking and analyzing writers' choices became a key part of understanding writing activities as more dynamic. Before the advent of computers, access to the writer's thought process was difficult to access, requiring lab-like observations and speak-aloud protocols (Flower & Hayes, 1977). Researchers have often been limited to the written text, with little access to the writer's thought process, as well as the environment and tools that the writer uses to create the text (Anson and Kruse, "Plagiarism Detection and Intertextuality Software"). With word processors and cut/paste tools, both writers and researchers could see more of the choices they make while writing, not just when revising or editing (Kruse & Rapp, 2019; Liu, 2011). As a result, writing processes are not just seen as a series of steps, but as a constant revision and repositioning of ideas, as well as the re-examination of values, purposes, and audience. New computer technologies encouraged a more recursive view of the writing process (Collier, 1983; Selzer, 1983). For example, writers can re-order, delete, and add elements to a text in ways that may not fit into a linear view of writing (Sommers, 1980).

As the field of writing studies grew, many scholars and teachers looked at writing processes as more than just communication, but a way of thinking and learning. Researchers like Flower and Hayes (1981) used process as a way to explore the thinking behind composing. Writing activities became a series of choices that writers make as they develop their ideas, not just their texts. Breaking down writing activities into these decision points allows scholars and teachers to focus on specific kinds of activities that cultivate ways of thinking. Flower and Hayes recast process into a more dynamic and iterative process focused on better understanding what criteria govern writer choices. Effective writers plan what they have to say, translate or communicate these ideas, then review and evaluate the result. Instead of a linear process, though, this model became a way to track writers' choices and thought patterns.

This became one way to help writing teachers to increase student awareness of implicit expectations in academic writing, a common approach to first year writing classes in the university. Writing activities become opportunities for student reflection, often leading to increased awareness of how academic discourse works. Consequently, these opportunities provide teachers with an effective way of helping students increase their efficacy when composing complex text like academic essays and research papers. When combined with technology, tools, and feedback strategies, understanding writing processes as a series of choices creates more agency for individual writers as they enter into communities of discourse.

2.3 Social Activity

Ultimately, this led researchers and teachers alike to think about writing activity within more social contexts (Collins, 1995). Instead of focusing on individual learning and writing, researchers and instructors began to focus more on collaborative learning and peer feedback as an integral part of the writing process (Bruffee, 1999). Using technology to increase student agency, interaction, and collaboration became a way to open up academic discourse to more social approaches to knowledge-making, especially with the rise of more collaborative tools like Google Docs, wikis, and blogs (Bradley, 2014; Tzu-Ching Chen, 2012). This provides students with the opportunity to read and provide feedback on each other's writing, while also interacting with audiences in-class and online, raising awareness of audience and purpose.

In many ways, understanding writing activity in more social contexts has encouraged researchers and teachers to go beyond the linear models of composing, understanding writing as more ecological and networked (Kent, 1999). This social turn in writing studies eventually led to a pushback against the writing process as a set of discrete steps that writers go through to complete a text. Writing is more than just a cognitive process or a series of individual choices (Cooper, 1986; McComiskey, 2000). Even so, postprocess arguments focus on the social nature of text, not on the social nature of the individual or invention process (Fraiberg, 2010). In short, producing text is not about following a set of pre-written rules, but a series of dynamic interactions between the writer and the world around them, which includes technology and the digital world.

Though not necessarily a central theme, composition's social turn parallels the rise of more accessible technologies for writers like Web 2.0 and social media, where users participate in the creation of content (instead of passively consuming). Writers begin interacting with others in different ways, using a range of tools, platforms, and genres inside and outside the classroom. Social media networks (like Facebook) and Enterprise Social Networks, like (Slack and Microsoft Teams) become important spaces for brainstorming, exploring, and drafting (Cummings, 2016; Cummings et al., 2017). Even virtual reality expands how we understand social interaction around writing (DeWinter & Vie, 2008). Many new collaborative spaces, like digital whiteboards and collaborative mind mapping tools, are also changing how writers work together visually and across networks (Hewett, 2006; Lin, 2019). Going beyond the individual processes of writing, the social turn in composition studies helped focus writing activity as an act of making meaning with others.

Understanding these interactions opens up a multi-faceted understanding of the writing process that provides a richer picture of how writing works and an openness for adapting it to new environments and technologies that understand writing activity in more dynamic and socially situated contexts. With the growth of digital tools, writing processes are now seen as a series of choices within a complex network of individual and social activities that can be observed within a variety of contexts, both online and off. While the emphasis on observing individual choices is still important, writers are now seen to participate in broader social activities. Writing activities become networks of social exchange, with feedback and support from peers, teachers, and other writers essential to successful writing. In this way, writing activity no longer needs to be seen as a solitary activity, but instead a part of a collaborative and recursive process of meaning-making.

3 From Process to Workflow Models

The increasing digitalization of writing in this century creates even more possibilities for both exploring and adapting the writing process to new digital contexts, especially as writing activity is distributed through more networks, both human and digital. While there is still a great deal of research about how writing is done in digital contexts, most current scholarship takes a multiliteracies approach, or the idea that there are many different forms and processes of writing (Khadka, 2018; Selber, 2004). For example, computers networks have expanded the range of social and textual spaces writers can use to produce and share text, like blogs and wikis. Digital technologies have also facilitated alternative forms of writing activity that are social, corporal, and multimodal, often described as networked ecologies (Hawk, 2007).

This shift has led to what Lockridge and Van Ittersum (2020) call workflow thinking or a more ecological approach to understanding process. Lockridge and Van Ittersum re-articulate the writing process as workflow, or a set of malleable activities connected to specific technologies or tools used to accomplish specific tasks. This can be a useful way of understanding the digitalization of writing processes, which tends to de-articulate the notion of individual writers outside of space and shows how our consciousness as writers emerges from the activity and interactions around various tools, spaces, and people. In this sense, postprocess scholars were correct. Workflow is not a codifiable process. It is not a set of steps that run in more or less the same order. Rather, workflow is an activity that moves through various tools, apps, and physical spaces in different ways and at different times.

The workflow approach to understanding the writing process reframes the study of writing to include both the technological and social components of writing. Instead of a linear or discrete process, writers are now seen as engaging in a set of interconnected activities, drawing on multiple resources to produce texts. In this way, writing is not seen as a single process, but an ecology of activities, tools, and spaces. Theories and pedagogies about writing need to take into account how tools are used and integrated into the writing process in these complex networks. This understanding of writing processes has the potential to open possibilities and create more flexibility to respond to changes that come with new technologies and forms of communication.

3.1 Towards Networked Metaphors

One major influence of digital technology on writing is the development of more networked metaphors to explore collaborative and distributed forms of writing. The metaphors used to understand the writing process are moving beyond the written page, the book, and the office space (Heilman, "The Beginnings of Word Processing: A Historical Account"). As these metaphors shift, our assumptions about how text and knowledge are created will have to adapt. Researchers and teachers need to develop methods for understanding how this shift in knowledge production occurs, what it means for teaching, and how writers engage with these changes. Network metaphors map the complexities of digital writing onto the idea of interweaving threads, rather than circles or straight lines.

Instead of thinking about writing processes in discrete steps or choices, using ecologies as a metaphor can help writers and researchers identify how writers intertwine writing activities in digital spaces. For example, using mind maps or social annotation tools is not just a pre-writing exercise, but also can be an important part of the drafting or revision stage. These activities might occur in digital spaces, physical spaces, or some combination of the two. Here are some questions that might help think about how the various spaces and technologies in this book might interrelate:

- How are different spaces and tools connected? What happens between these?
- How do the various writing activities that comprise the writing process change and adapt within the various tools and spaces?
- What kinds of physical spaces, environments, or infrastructures lie beneath the digital networks and technologies that now make up the writing process?
- How do these ecologies change over time?

An ecological view of writing helps writers and researchers examine the writing process as an emergent set of activities that is dynamic and ever-changing. How we put together writing activities in changing environments is a more useful way to approach the digitalization of the writing process.

Lockridge and Van Ittersum's workflow mapping can be a helpful way for writers and researchers to think about the writing process and how they may change in various technological and digital contexts. To better understand how a writing process can be tweaked, writers can map out the digital spaces and tools to see how workflows might be adapted. These maps are not meant for describing a static reality, but to provide a snapshot of a dynamic system with specific points of agency that can increase writing quality or efficiency using these primary questions:

- What tasks make up the writing process, and how do they relate in space and time?
- What technologies do writers use to accomplish the tasks on the map?
- How does changing tasks, technology, or position benefit or influence the workflow?
- How do writers shuttle between tools and platforms?
- How do writers understand their activities?
- What is the relation between inscription and revision?

These questions, along with workflow maps, are useful for a more holistic perspective at the digitalization of the writing process. Tinkering with apps and adjusting workflow is now an important part of the writing process, requiring both writers and researchers to think about how the writing process can be shaped and reshaped in different contexts.

3.2 Expansion of Invention

The proliferation of invention spaces within these complex networks allows writers and collaborators to linger longer in the invention stage and experiment in deeper ways (Kruse et al., "Creativity Software and Idea Mapping Technology"). The invention phase of the writing process can also expand to include other ideas writers might consider when making meaning, as well as new modes of knowledge creation. When students can experiment with other modes of inquiry, they also learn that writing is one way of making meaning, but not the only way.

New annotation and note-taking tools allow for easier capture of new ideas and more experimental approaches to organizing those ideas (Pitura, Digital Note-Taking for Writing). As new tools become available, so do new forms of thinking and organizing knowledge. This includes new forms of understanding information, the ways in which we use new tools and technologies to think (Kruse & Anson, "Writing and Thinking: What Changes with Digital Technologies?"), and the ways in which we think about how we can best use the tools that are available (Anson & Kruse, "Plagiarism Detection and Intertextuality Software").

Many of these tools also use various hypertext methods to connect text and ideas in different ways (Cummings, "Content Management System 3.0: Emerging Digital Writing Workspaces"; Lang & Baehr, "Hypertext, Hyperlinks, and the World Wide Web"). When writing is used as a means of exploration, writers learn that they have the power to control their own learning by linking ideas in new ways. Writers can actively choose how the information they consume in the classroom connects, even across disciplines and contexts. When writers are given the opportunity to build and revise their own learning, they are learning that there is always another way of thinking about a problem or concept (McKinney, this volume).

Even plagiarism detection might be considered a part of various writing activities invention and revision process, helping students understand intertextuality in its early forms (Anson & Kruse, "Plagiarism Detection and Intertextuality Software"). As the invention process expands in terms of media and modes of inquiry, there is an opportunity to create a learning environment where students see themselves as creators and not just consumers of knowledge. New media tools enable us to track and report plagiarism in much more detail and provide more complex analyses of source material than is possible with traditional document writing. In addition to reporting plagiarism, these tools enable more nuanced analysis of the relationship between student text and source material.

3.3 Increased Collaboration

One of the main advantages to writing in the digital age is that it allows for easier integration of writing with other content areas and learning activities (Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing"). Writing is often confined to a single classroom and a single teacher. New tools and technologies allow for a much more flexible and dynamic approach to writing and writing assessment. Though new writing platforms like OneDrive and Google Docs have increased collaborative options in the drafting phase (Castelló et al., "Synchronous and Asynchronous Collaborative Writing"), these affordances extend beyond writing production. The digitalization of the writing process allows for more tailored and idiosyncratic approaches to writing and invention, and collaborative tools have also increased opportunities for more social approaches to knowledge management, invention, and the writing process.

Social annotation tools, new note-taking tools, CMS 3.0 tools allow for more social approaches to knowledge management and invention … not just drafting (Cummings, Content Management System 3.0: Emerging Digital Writing Workspaces; Pitura, "Digital Note-Taking for Writing"). These tools also provide new ways for instructors to involve themselves in the writing process (Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing"). Digital peer review platforms take this a step further, allowing instructors to systematize their feedback procedures in the classroom, even to the point of incorporating tutoring activities (Anson, "Digital Student Peer Review Programs"; Banawan et al., "The Future of Intelligent Tutoring Systems for Writing"). The digitalization of the writing process has also enabled new and previously impossible collaboration opportunities, going beyond just peer editing and review (Anson, "Digital Student Peer Review Programs"). They can share ideas, notes, and sources. As these tools become more common and their affordances become more socially understood, writers will begin to experiment with these tools in their own work.

3.4 Observing the Writing Process

With these new digital spaces, both writers and researchers will have more opportunities to observe and analyze writing activities that have not always been visible or emphasized in writing studies. Before the digital age, observing the writing process or workflows was difficult, requiring lab conditions or self-reporting. Writing is now increasingly visible through new and emerging tools and technologies, as described in this book.

Metrics such as time elapsed between drafts, the speed, duration, and intensity of text editing, and the amount and types of external sources consulted are all key metrics that can be tracked through new tools. Teachers can also use these tools to collect, organize and present documentation of writing activity for both research and student reflection. This can include the organization of writing artifacts like drafts, notes, and student portfolios (Bräuer & Ziegelbauer, "The Electronic Portfolio: Self-Regulation and Reflective Practice"). Similarly, the digitalization of the writing process has also made it easier to track types and sources of feedback, such as peer review, annotations, and comments (Anson, "Digital Student Peer Review Programs"; Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing").

New digital tools, such as social annotation, note-taking and next-gen CMS technologies, also provide opportunities to observe and research the invention process in new ways (Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing"; Kruse & Rapp, "Word Processing Software: The Rise of MS Word"; Pitura, "Digital Note-Taking for Writing"). The use of automated plagiarism detection can provide a window into the ways students are incorporating external content into their writing (Anson & Kruse, "Plagiarism Detection and Intertextuality Software").

New technologies will also help researchers organize and analyze larger, yet more detailed chunks of data. The digital availability of academic text, along with automated analytical tools, will allow researchers to more easily identify patterns in writing activity, not just in published journals, but in other spaces as well (Shibani, "Analytic Techniques for Automated Analysis of Writing"). Keystroke logging (Wengelin & Johansson, "Investigating Writing Processes with Keystroke Logging") can help us observe how writers develop their writing not just in drafts, but in prewriting spaces like notetaking tools and emerging digital workspaces.

4 Conclusion: Future Developments

With the onset of digital writing, writing processes have become dependent on a variety of technologies and tools. We cannot assume that writing is still a consistent pattern of activities. The choices writers make are guided by individual decisions and the availability of tools. What works today may be outdated tomorrow, or what works for one content area may not work for another. In addition, new approaches to managing the digital writing process may require new types of hardware and services. Conventional word processors like Microsoft Word or Google Docs constantly add new functionalities which can be used optionally. All of these variables may make the process of adapting to and integrating new technologies into teaching, research, and writing more nuanced and difficult to define. Researchers and teachers must understand the technological tools available to writers and what is possible in these spaces to more fully understand the choices writers make.

Researchers should continue to think about how writers and technology work together co-constitutively to shape our writing workflows. Neither the technology nor the writer is in full control of the writing process; each shapes the other. Writers do not exist in a vacuum, but within a complex environment that is more and more digital, but never entirely so. But new technologies provide artifacts for the study of the writing process. The digitalization of the writing process means that we have access to a wider range of artifacts than ever before. We can now trace the evolution of a particular artifact over time and space and how writing is used by different people in different contexts. This suggests that writing is a complex, integrated set of actions, not just putting words together on paper or in a Word Doc.

As the visibility of writing activities increases in different ways, scholars should also think about what new aspects of the writing process might be accessible to research, while also thinking about what elements of the process are still hiding. For example, keylogging makes self-editing more available for research, but perhaps makes rhetorical choices less visible in the research process.

In this contribution, I have explored the various ways in which the digitalization of the writing process is affecting the writer and the production of content. We have seen how writing tools and spaces are being redesigned to meet the needs of writers and how the design of these tools and spaces affect how writing is produced. The idea of a dynamic, technologically mediated writing process is useful when we see writing as a complex, integrated set of actions that are organized in time and integrated into both digital and physical spaces. Even a quick glance through the chapters in his books shows many opportunities for researching and reflecting on the writing process in new ways.

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Glossary

Term	Definition	Referencing Chapter
Add-In	An additional software component that is permanently installed in a main application and usefully extends its previous functions. Does not belong to the default package of a software and can be subsequently added to the software by the user	Chapter "Digital Tools for Written Argumentation"
Analogue note	A note produced in a paper notebook, on a piece of paper, a printed text, a post-it note, a whiteboard, a flipchart, etc.	Chapter "Multimodal Chat-Based Apps: Enhancing Copresence When Writing"
Annotating	The act of adding short comments, summaries, explanations or notes to source material	Chapter "Digital Tools for Written Argumentation"
Annotation	Note added to a text, or the process of providing additional information (e.g., part of speech categories) to the linguistic data in the corpus by using manual or automatic tagging systems	Chapters "Content Management System 3.0: Emerging Digital Writing Workspaces", "On Corpora and Writing"
Automated essay scoring (AES)	"Computer technology that evaluates and scores the written prose" (Dikli, 2006, p. 4)	Chapters "Automated Feedback on Writing", "Analytic Techniques for Automated Analysis of Writing"
Automated transcription tools	(See voice-to-text programs)	Chapter "Digital Note-Taking for Writing"
Beta version	Early version of a programme that is already functional but not ready for professional or regular use. Beta versions are offered to outsiders not involved in the development for testing and feedback	Chapter "Beyond MS Word: Alternatives and Developments"

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6

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Term	Definition	Referencing Chapter
Bibliographic information	Words that describe a publication (for example title, authors, abstract, keywords)	Chapter "Digital Tools for Written Argumentation"
Bibliographical database	An organized collection of references with bibliographic or publication records that have been quality controlled. Provides an index of journal articles from multiple journals, and includes citations, abstracts and often a link to the full text	Chapter "Digital Tools for Written Argumentation"
Bidirectional links	New wiki features that enable writers to not only create new pages while writing, but to link pages both ways (from the page where the new page was created and back to the originating page)	Chapter "Creativity Software and Idea Mapping Technology"
Bitmapped display	A display composed from an array of individual pixels which are stored in memory and can be modified rapidly (all modern computers screens are bitmapped displays). Bitmapped displays make possible complex GUIs, WYSIWYG and high-resolution text and graphics. They replaced vector displays as the main video output device of computers during the 1970s	Chapter "The Beginnings of Word Processing: A Historical Account"
Blocks	Refer to the basic editable units in new wikis or CMS. A block can be a paragraph, but also can be an image, table, video, or any other media	Chapter "Creativity Software and Idea Mapping Technology"
Bookmarking	Storing the address of a website, file, etc. to enable quick access in the future	Chapter "Digital Tools for Written Argumentation"
Browser plug-in	A small computer program that makes a larger one work faster or have more features	Chapter "Digital Tools for Written Argumentation"

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Term	Definition	Referencing Chapter
Chat-based app	Emerging from programs such as ICQ and mobile phone texting capabilities, as cross-platform technologies became increasingly present on mobile devices, laptops, and desktops, chat-based apps became a primary mode of synchronous communication. The next evolution in these tools was the development of multimodal chat-based apps that enabled both synchronous and asynchronous forms of communication (e.g., WhatsApp and Discord). Later collaborative tools (e.g., Gather.Town) incorporate elements from chat-based apps but also create a fuller place-based simulation	Chapter "Reference Management Systems"
Citation information	A standard set of information that allows readers to easily identify, search, and retrieve a source	Chapter "Digital Tools for Written Argumentation"
Citation style	A set of rules on how to cite sources in academic writing. Citation styles differ in the layout of the in-text citations, the reference list and (sometimes) the formatting of a paper	Chapter "Digital Tools for Written Argumentation"
Cloud-based file storage	With online editors, cloud-based file storage was needed (Dropbox, Google Drive, and One Drive offer such services). Their vast background storage capacity has become the basis for a large-scale file-sharing ability, which is a prerequisite for collaboration across teams or companies	Chapter "Beyond MS Word: Alternatives and Developments"
Cloud-based writing	With server-based word processors, there is no longer a need to install and continuously update the software on a local computer. It can be executed on a server and accessed through the web browser (software as a service (SaaS)). "Saving" documents is no longer necessary as the cloud-based software stores every input immediately and, additionally, saves a text's history, enabling any former version to be restored. Documents, too, are stored on the server rather than locally. Google Docs still is the prototype of this kind of online word processing	Chapter "Beyond MS Word: Alternatives and Developments"
Collaborative asynchronous writing	Collaborative writing where contributors write and amend a document from different places at different times	Chapter "Social Annotation: Promising Technologies and Practices in Writing"

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Term	Definition	Referencing Chapter
Collaborative writing	Distribution of the task of writing across multiple participants	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Collaborative writing coordination (parallel, sequential, reciprocal)	In parallel coordination, each person writes a different part of the text. Sequential coordination is a production line, where each writer in turn hands over a partially-completed text the next person. In reciprocal coordination all the partners work together on a shared document, watching and mutually adjusting their activities to take account of each other's contributions	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Collaborative writing software	Computer-based tools to support production, revision, commenting, annotation and sharing of text	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Collaborative writing spaces	Refer to cloud-based user interfaces which can be accessed by several writers simultaneously. All writers can adopt an active author role as readers, writers, editors, or commentators, even though most collaborative tools make it possible to restrict authorization for any of these roles	Chapter "Beyond MS Word: Alternatives and Developments"
Collaborative writing strategies	Deliberate and goal-oriented decisions, either individual or collective, that allow for writing collaboratively. Those decisions refer at least to purposes (why), modes (how) and timing (when) of collaborative writing	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Collaborative writing technologically supported	Collaborative writing is the generic term, with the additional implication that today it is supported by technology	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Collocation	A string of two or more words commonly used together	Chapter "On Corpora and Writing"
Coming to writing	A way of naming the combined mental, conceptual, and physical process for preparing to write	Chapter "Reference Management Systems"
Concept map	A diagram that shows relationships between ideas expressed as words or pictures, sometimes with labelled links to indicate how the ideas are related	Chapters "Social Annotation: Promising Technologies and Practices in Writing", "Synchronous and Asynchronous Collaborative Writing"

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Term	Definition	Referencing Chapter
Concordance	A concordance is generated by corpus support software programmes and represents the display of every occurrence of a searched word / string, with its context of use	Chapter "On Corpora and Writing"
Content Management System (CMS)	A content management system allows users to individually or collaboratively create content. Such systems (e.g., WordPress) do not contain any learning capabilities, such as quizzing software or other tools for purposes other than creating content. Such systems can allow creators to publish, edit, and change their own web or digital content without code	Chapters "Creativity Software and Idea Mapping Technology", "Teacher Feedback Tools"
Contract cheating	Obtaining newly composed text from ghost writers and submitting it as one's own	Chapter "Plagiarism Detection and Intertextuality Software"
Copresence	The capacity to access the presence (and guidance) of others for information gathering and sharing through networked digital technologies	Chapter "Reference Management Systems"
Corpus Linguistics (CL)	The discipline (or methodology, by some scholars) where computer-processed collections of linguistic data can be analysed using either computational methods or specific corpus query and frequency software	Chapter "On Corpora and Writing"
Creativity tools	Tools supporting procedures to disburden the mind temporarily of logical and linguistic constraints in favour of a rapid production of ideas of any kind (usually about a topic for a paper). Creativity tools usually also contain functions to help writers select the best items and organize them in a linear way as part of a text	Chapter "Synchronous and Asynchronous Collaborative Writing"
Criterion	A standard (for a genre, assignment, or textual feature) considered during peer review	Chapter "Learning Management Systems (LMSs)"
CSS (Cascading Style Sheets)	Describes how web pages are to be displayed on screen, on paper, and other media and can be used to format multiple web pages at once	Chapter "Hypertext, Hyperlinks, and the World Wide Web"
Data-Driven Learning (DDL)	A student-centred discovery approach in language teaching, characterised by the use of authentic linguistic data, such as corpora, for self-directed learning	Chapter "On Corpora and Writing"

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Term	Definition	Referencing Chapter
Debugging	The task of correcting errors in the code of computer programs. The increasing difficulties in debugging ever more complex software was one of the reasons that led to the first text editors around 1960	Chapter "The Beginnings of Word Processing: A Historical Account"
Desktop application / Desktop app	A software program that can be run on a standalone computer to perform a specific task by an end-user	Chapter "Digital Tools for Written Argumentation"
Desktop publishing programmes (DTP)	DTP programmes are designed for the computer-aided layout and typesetting of documents. They generate digital files for professional print publications and integrate text and images of books, magazines, and catalogues. At the heart of graphic design-oriented DTP is a workstation computer with a graphical user interface and software for the visual creation (WYSIWYG) of a layout and the output of a digital print template to a printer or print shop. Although not designed for writing and editing text, applications like Adobe InDesign nevertheless play a pivotal role in the digital production of printed text	Chapter "Beyond MS Word: Alternatives and Developments"
Digital annotation tool	An interface that allows the user to make comments on a text, website, other onscreen material using a variety of tools (text boxes, stickies, arrows, etc.)	Chapter "Digital Note-Taking for Writing"
Digital badge	In peer review, a notice of completion, accomplishment, or skill development assigned to a student	Chapter "Learning Management Systems (LMSs)"
Digital note	A note requiring the use of an electronic device, enabled through a keyboard, digital ink or voice	Chapter "Multimodal Chat-Based Apps: Enhancing Copresence When Writing"
Digital workspace	Refers to any digital space that transfers multiple physical use spaces or multiple apps into one space	Chapter "Creativity Software and Idea Mapping Technology"
Digitial Portfolio	Also called electronic (e-) portfolio, is a network-based hub (folder) that integrates various digital media and services, with which the owner of the portfolio can quickly respond to changing purposes and audiences of the genre	Chapter "The Electronic Portfolio: Self-Regulation and Reflective Practice"

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Term	Definition	Referencing Chapter
Digitial Reflective Writing	When reflective writing moved into the digital sphere, some of the procedural steps changed its character, e.g., the gluing of text fragments in paper-based portfolio changed into drag/drop, shift, and hyperlinking of fragments of text. As a result, digitally based reflective writing can respond much faster than paper-based reflection to changing purposes and audiences	Chapter "The Electronic Portfolio: Self-Regulation and Reflective Practice"
Distraction-free text editors	Refers to writing software downplaying the visualization and formatting of a text on the screen and reducing the options for changing its appearance (layout, typesetting) in favour of a simplified presentation and interface. Reduced functionality and ease of use make them the antithesis of the GUI and WYSIWYG models of writing embodied by MS Word. Writers are not bound by the logic of the printed page and conventional typography. Instead, they can use the computer screen as a writing space to construct linguistic text, enabling them to indulge in "pure" digital writing	Chapter "Beyond MS Word: Alternatives and Developments"
Document-based annotation	A form of annotation technology that allows users to upload files, such as PDFs, into a platform whereby documents are converted for annotation. These technologies require users to bring the object-to-be-annotated (e.g., PDFs) to the platform	Chapter "Content Management System 3.0: Emerging Digital Writing Workspaces"
Domain model	The Intelligent Tutoring System (ITS) component that represents the target knowledge elements and skills, also referring to the ITS' curriculum of topics	Chapter "The Future of Intelligent Tutoring Systems for Writing"
DTP/Desktop publishing	The use of a PC with GUI to create typographic-quality documents such as brochures, magazines, books etc. DTP is typically done on WYSIWYG systems which let you visually control the page layout of a document. Pioneered by Aldus PageMaker for the Apple Macintosh in the second half of the 1980s	Chapter "The Beginnings of Word Processing: A Historical Account"
English for Academic Purposes (EAP)	A field within Applied Linguistics that focuses on the use of English in academic settings for study, teaching, or research	Chapter "On Corpora and Writing"
English for Specific Purposes (ESP)	A field within Applied Linguistics that focuses on the use of English in specialized fields of knowledge such as medicine, law, or business	Chapter "On Corpora and Writing"

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Term	Definition	Referencing Chapter
Eye tracking	Recording of eye movements and visual attention	Chapter "Investigating Writing Processes with Keystroke Logging"
false negative (plagiarism)	When a plagiarism-detection tool fails to identify text that matches another source and could be plagiarized	Chapter "Plagiarism Detection and Intertextuality Software"
false positive (plagiarism)	When a plagiarism-detection tool falsely identifies a piece of text as plagiarized when it is not	Chapter "Plagiarism Detection and Intertextuality Software"
File management	Any text produced in the computer's working memory can and must be saved as a document or it will be lost. For this purpose, the operating system enables the creation of directories in which a file name can identify the document. Files can be opened and edited at any time. In contrast to printed matters, electronic storage takes only a fraction of the space it would take in a physical setting. This is because writing and storage happen on the same device. For writers, creating consistent file structures is an integral part of the writing, learning, and working processes	Chapter "Word Processing Software: The Rise of MS Word"
Final text	The finally revised text in the shape that it would normally reach the reader	Chapter "Investigating Writing Processes with Keystroke Logging"
Formulation	Formulation is a summarizing term for the mental activities that govern text production, oral or written. Formulation in writing always happens in interaction with a writing tool. With digital tools, formulation activities are supported by various linguistic support measures at the level of words, collocations, grammar, and textual organization. Formulation is closely related to the type of thinking connected with the selection, connection, linearization, and linguistic appearance of thought	Chapter "Word Processing Software: The Rise of MS Word"
Grammar checker	Software that automatically analyses a text to display grammatical correctness. Beyond grammatical rules, grammar checkers contain lists of typical language errors which they highlight	Chapter "Word Processing Software: The Rise of MS Word"

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Term	Definition	Referencing Chapter
Graphic organizers	Tools that represent knowledge in a graphical arrangement by separating it into distinct units which may be placed in differently shaped "containers" and then connected by lines, arrows or connecting terms this providing a "conceptual skeleton" of a knowledge field	Chapter "Synchronous and Asynchronous Collaborative Writing"
Graphical user interface/ GUI	An interface for interactive computing that allows for direct manipulation of graphical elements on a screen (windows, icons, menus etc.) with keyboard, pointing device or fingers (in the case of touchscreens). A user interface is "graphic" when the handling of the computer is done by manipulating graphical elements rather than inserting the code of a computer language. Graphical interfaces have made computers easily accessible and user-friendly	Chapters "The Beginnings of Word Processing: A Historical Account", "Word Processing Software: The Rise of MS Word"
Holistic score/scoring	"Using automated tools to produce a score that is intended to be equivalent to a human score on the same essay for the purpose of some decision, such as admission or placement" (Weigle, 2013, p. 41)	Chapter "Automated Feedback on Writing"
Hypertext Markup Language (HTML)	A standardized system for tagging text files that enables them to be viewed in a web browser	Chapter "Hypertext, Hyperlinks, and the World Wide Web"
Human Computer Interaction	A field linked to user-centred and interaction design that focuses on usability of computer technology often measured in terms of efficiency, effectiveness, ease-of-use, and satisfaction	Chapter "The Future of Intelligent Tutoring Systems for Writing"
H yperlink	A feature in a hypertext that allows the user to navigate from one portion of a text to another, or from one text to another, by clicking on the text or image that designates a link	Chapter "Hypertext, Hyperlinks, and the World Wide Web"
Hypermedia	The range of multimodality possible with hypertext, in that content can be static or dynamic, asynchronous or synchronous, audio or video, passive or interactive in nature	Chapter "Hypertext, Hyperlinks, and the World Wide Web"
Hypertext	Linked text on the internet or in digital spaces	Chapters "Creativity Software and Idea Mapping Technology", "Hypertext, Hyperlinks, and the World Wide Web"

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Term	Definition	Referencing Chapter
Idea mapping technologies	Graphic procedures to collect and connect ideas related to a certain topic or aim in order to make the multitude of ideas visible and arrangeable	Chapter "Synchronous and Asynchronous Collaborative Writing"
Inscription	In digital writing tools, inscription is done by connecting letters and symbols with a digital code that makes it identifiable and processible. A standardized code, the ASCII code (American Standard Code for Information Interchange), was created to ensure interoperability among digital tools, followed by more extended codes such as Unicode. Digital inscription is the prerequisite for linearizing letters and words into a text	Chapter "Word Processing Software: The Rise of MS Word"
Intelligent Tutoring Systems (ITS)	Computer software used in educational settings that simulate tutor-tutee interaction and provide customized instruction and immediate feedback	Chapter "The Future of Intelligent Tutoring Systems for Writing"
Interactive computing	Using computer programs while they run. An interactive computer system accepts user input (through GUI or other interface) and reacts with corresponding output in real-time. This is the dominant computing paradigm for PCs (as opposed to non-interactive computing like batch processing of jobs on mainframes)	Chapter "The Beginnings of Word Processing: A Historical Account"
Interface or user interface model	The ITS component that represents a human computer interface designed to facilitate communication and interaction between the ITS and the students	Chapter "The Future of Intelligent Tutoring Systems for Writing"
Interkey Interval (IKI) or transition time	The time between two consecutive keystrokes. Sometimes the term "pause" is used synonymously, but "pause" is frequently also used to describe interkey intervals that are longer than could be expected in fluent text production, i.e., for interruptions of the process. A writer's average IKIs provide a rough measure of their typing speed	Chapter "Investigating Writing Processes with Keystroke Logging"
Intertextuality	The relationships between different linked content chunks or sections, which share semantics	Chapter "Hypertext, Hyperlinks, and the World Wide Web"
JavaScript	An advanced programming language used to make web pages more dynamic and interactive	Chapter "Hypertext, Hyperlinks, and the World Wide Web"

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Term	Definition	Referencing Chapter
Key logging	Programs recording all input into the word processor by the keyboard and mouse. Data are stored separately from the word processor and all entries relate to a time stamp in milliseconds. Data can be analysed using various statistical methods	Chapter "Word Processing Software: The Rise of MS Word"
Keystroke log/log file	The most basic output file from a keystroke logging program. A chronological list of all keystrokes (and mouse movements) that were captured by the software during a writing session and the exact time that they occurred. Other information, such as where in the text the result of the keystroke turned up, or a categorization of the keystroke (for example, letter, number, arrow key etc.) is also often included	Chapter "Investigating Writing Processes with Keystroke Logging"
Keystroke logging software/program	Software that is used to record keystrokes (and frequently also mouse movements) to capture the dynamics of the writing process	Chapter "Investigating Writing Processes with Keystroke Logging"
Knowledge component	A general term used to describe concepts, facts, or skills related to the domain-specific tasks or problems, which usually represents the students' decision-making during problem-solving	Chapter "The Future of Intelligent Tutoring Systems for Writing"
Knowledge graphs	Visualizations of ideas, content, and notes that are automatically generated by a CMS	Chapter "Creativity Software and Idea Mapping Technology"
Label	Term assigned to a snipper in a text expander application	Chapter "Digital Note-Taking for Writing"
Language model	Usually, a Machine Learning Model which was trained to predict words in certain context. It is a base component in many NLP systems	Chapter "Information Retrieval and Knowledge Extraction for Academic Writing"
Latent Dirichlet Allocation (LDA)	An unsupervised method for automatically identifying the key themes/ topics in a set of documents. It generates a probability distribution of topics for a given text based on the word occurrences in the whole set of documents using an algorithm called Gibbs sampling	Chapter "Analytic Techniques for Automated Analysis of Writing"
Latent Semantic Analysis (LSA)	A statistical representation of word and text meaning which helps calculate the semantic similarity of texts by applying singular value decomposition to reduce a large word document matrix to a smaller number of functional dimensions	Chapter "Analytic Techniques for Automated Analysis of Writing"

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Term	Definition	Referencing Chapter
Learning Management System (LMS)	A learning management system enables storage and management of content for courses. It also tracks learners' progress through the material. Early iterations of such systems did not allow for internal content generation. More recent iterations, occasionally referred to as Learning Content Management Systems (LCMS), do allow users to create content within the system	Chapter "Teacher Feedback Tools"
Learning Portfolio	Shows primarily the student's effort in learning, his/her ability to self-assess and monitor learning development based on both predefined institutional standards and own values and beliefs. Reflective writing in learning portfolios needs to provide the story of the owner's journey as a learner and his or her future endeavours	Chapter "The Electronic Portfolio: Self-Regulation and Reflective Practice"
Levels of reflection	Are rhetorical moves that help to focus reflective writing on individual aspects such as documenting & describing, analyzing & interpreting, assessing & evaluating experience or planning more efficient action in the future. These levels of reflection can also be seen as a way of scaffolding in order to reach deeper insight in an action to be reflected upon	Chapter "The Electronic Portfolio: Self-Regulation and Reflective Practice"
Linear note-taking	The process of developing notes that resembles conventional text writing	Chapter "Multimodal Chat-Based Apps: Enhancing Copresence When Writing"
Linear text	A simplified description of the process, showing all keystrokes (including arrow keys, carriage return etc.), mouse movements, pauses (according to a pause cratering set by the researcher), and revisions, linearly in the order they happened	Chapter "Investigating Writing Processes with Keystroke Logging"
Linearity	A basic principle of languages is the sequential arrangement of letters and symbols into a readable line of words. Computer code is also linear and can be read in one direction only	Chapter "Word Processing Software: The Rise of MS Word"
Linearization technology	Tools that enable writers to inscribe letters and words on a writing surface. Most common today are word processors which allow for a comfortable, and error-permissive inscription. Characters can only be added one after the other, forming words, sentences etc. enforcing a linear string	Chapter "Synchronous and Asynchronous Collaborative Writing"

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Term	Definition	Referencing Chapter
Machine Learning	An application of artificial intelligence which uses statistical models and learn from data fed for training to predict future unseen data. Many different algorithms are available, with the most common ones used for supervised and unsupervised machine learning	Chapters "Analytic Techniques for Automated Analysis of Writing", "Automated Feedback on Writing"
Macro generator	See text expander	Chapter "Digital Note-Taking for Writing"
Markup editor	Refers to editors specially designed for using a markup language to format texts (See also "markup language")	Chapter "Beyond MS Word: Alternatives and Developments"
Markup language	A language for describing the visual and/or logical properties of text (font size, logical structure etc.). Markup is typically inserted into text by authors in the form of control characters, commands or tags. One of the most popular markup languages today is the HyperText Markup Language (HTML) for describing the structure and look of webpages	Chapter "The Beginnings of Word Processing: A Historical Account"
Markup language	Formatting and structuring in markup editors are not achieved by manipulating a text visually via WYSIWYG but by placing control characters and signs into the text. The programme will thus execute the formatting in a second step. In Markdown, for example, text can be *enclosed in asterisks* to emphasize it, or a # sign can be added to a line of text to denote it as a section heading. The separation of content and layout enforced by markup languages helps authors concentrate on the text by not having to deal with matters of appearance and graphic design while writing and editing. Learning a complex markup language takes time, similar to learning a programming code	Chapter "Beyond MS Word: Alternatives and Developments"
Markup program	See digital annotation tool	Chapter "Digital Note-Taking for Writing"
Meta-data	Data about data, in the context of reference management for example bibliographic information about a source	Chapter "Digital Tools for Written Argumentation"

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Term	Definition	Referencing Chapter
Microcomputer	A computer based on microprocessor technology. In the 1970s, advances in semiconductor technology by Intel and other manufacturers made microcomputers like the MITS Altair 8800 and Apple II possible and popular. All modern personal computers are microcomputers, but the term has fallen out of usage since the mid-1980s	Chapter "The Beginnings of Word Processing: A Historical Account"
Microcontent	A unit of text smaller than a page, but can be anything like a paragraph, sentence, image, video clip, etc	Chapter "Creativity Software and Idea Mapping Technology"
Mind map	"A mind map is a multicoloured and image centred, radial diagram that represents semantic or other connections between portions of learned material hierarchically" (Eppler, 2006, pp 203.)	Chapter "Synchronous and Asynchronous Collaborative Writing"
Minicomputer	A class of general-purpose computers made possible by transistor and core memory technology in the 1960s. Smaller and considerably less expensive than mainframes, minicomputers helped advance the interactive computing paradigm in the 1960s and 1970s. With the advent of microcomputers, the market for minicomputers began to disappear	Chapter "The Beginnings of Word Processing: A Historical Account"
Multimodal	Ways of communicating that draw on visual, linguistic, aural, gestural, and/or spatial modalities rather than only alphabetic text	Chapter "Reference Management Systems"
Natural Language Processing (NLP)	A computational method and sub field of artificial intelligence that helps manipulate text automatically. It uses computational linguistics to understand, interpret and extract meaning from analyze large amounts of natural language data	Chapters "Analytic Techniques for Automated Analysis of Writing", "Automated Feedback on Writing", "The Future of Intelligent Tutoring Systems for Writing"
Non-linear note-taking	Note-taking that involves graphical representation of information while developing a note	Chapter "Multimodal Chat-Based Apps: Enhancing Copresence When Writing"
Note	An information unit that is stored externally; the outcome/product of note-taking	Chapter "Multimodal Chat-Based Apps: Enhancing Copresence When Writing"
Note-taking system	A system in which diverse information is stored, managed, and retrieved, for example, for writing	Chapter "Multimodal Chat-Based Apps: Enhancing Copresence When Writing"

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Term	Definition	Referencing Chapter
Note-taking tool	Software (application/app) that allows to store, manage, and retrieve notes, for example, for writing	Chapter "Multimodal Chat-Based Apps: Enhancing Copresence When Writing"
Open web annotation	A form of web-based annotation that relies upon an interoperable data model, generates publicly accessible data, supports Creative Commons licensing of annotation content, and aligns with open-source software and educational movements. These technologies bring the annotation platform to the object users want to annotate	Chapter "Content Management System 3.0: Emerging Digital Writing Workspaces"
Paraphrasing	Restating material from a source in one's own words without summarizing, for example by changing the grammar, word order, and/or main words used	Chapter "Digital Tools for Written Argumentation"
Patchwriting	"Restating a phrase, clause, or one or more sentences while staying close to the language or syntax of the source" (Jamieson & Howard, 2011)	Chapter "Plagiarism Detection and Intertextuality Software"
PC/Personal computer	1) The generic term for multi-purpose microcomputers operated, and typically owned, by non-professional users. Conceptually 'invented' in the late 1960s and technologically developed since the early 1970s, PCs became available to the public in the late 1970s. 2) The name for IBM's model line of personal computers released in 1981. Often used to designate the de facto industry standard set by IBM and to differentiate compatible machines from other PC platforms like Apple Macintosh computers	Chapter "The Beginnings of Word Processing: A Historical Account"
Pedagogical agents	A user-interface object often present in ITSs, which simulates human-like characters that play a role in the delivery of instruction or content	Chapter "The Future of Intelligent Tutoring Systems for Writing"
Peer review	A process in which students provide feedback on their peers' drafts to prompt revision and improvement and to learn by evaluating specific aspects of the drafts	Chapter "Learning Management Systems (LMSs)"
Personalized Learning	A pedagogical paradigm that is characterized by customized or adaptive learning as appropriate to each student's needs, strengths, and skills	Chapter "The Future of Intelligent Tutoring Systems for Writing"

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Term	Definition	Referencing Chapter
plagiarism anxiety	A condition among student writers when they fear being caught plagiarizing but haven't been taught the skills necessary to identify or avoid it; also known as plagiarism paranoia or plagiarism phobia	Chapter "Plagiarism Detection and Intertextuality Software"
plagiarism detection software	Software that searches text databases to determine matches that could be the result of plagiarism or uncited sources	Chapter "Plagiarism Detection and Intertextuality Software"
Plagiarism	A form of academic misconduct. The act of (intentionally or unintentionally) taking someone else's words, ideas or writings as one's own without acknowledgement	Chapter "Digital Tools for Written Argumentation"
Portfolio	Can be defined as both mode and medium of reflective writing with regard to learning and instruction. In education, finance, the arts and elsewhere it has also become a new genre for presenting the outcomes of learning development and work processes (e.g., in writing projects) to a predefined audience	Chapter "The Electronic Portfolio: Self-Regulation and Reflective Practice"
PostScript	A programming language developed by Adobe in the early 1980s used typically to describe the pages of a document for display and printing. PostScript supports typographic-quality fonts and graphics and thus made possible desktop publishing. Today, it has been largely replaced by Adobe's Portable Document Format (PDF)	Chapter "The Beginnings of Word Processing: A Historical Account"
Presentation Portfolio	Shows primarily the student's outcome of learning, his/her ability to showcase specific competences and concrete products. Reflective writing in presentation portfolios needs to present the owner's strengths and potentials	Chapter "The Electronic Portfolio: Self-Regulation and Reflective Practice"
Prewriting	Seen as activities that students and writers engage in before starting a formal writing task in classic writing process theories. As writing theory and research has evolved, prewriting and brainstorming have remained important steps; however, the recursive nature of writing processes have been recognized in writing process research since at least the early 1990s and–as we argue in this chapter–changes in information technologies have increasingly blurred the boundaries between distinct stages in the writing process	Chapter "Reference Management Systems"

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Term	Definition	Referencing Chapter
Publishing platform annotation	A form of annotation features that are built into online publishing platforms, requiring that both the users and the object-to-be-annotated go to the platform	Chapter "Content Management System 3.0: Emerging Digital Writing Workspaces"
Quoting	Using the exact words copied from a source	Chapter "Digital Tools for Written Argumentation"
Recursive	A returning to or circling back to an "earlier" stage in the writing process in order to refine or develop the piece of writing	Chapter "Reference Management Systems"
Reference Management System	A reference management system (reference/ citation managers, bibliographic management systems or software) allows for the computer-assisted management of sources by enabling the personal collection, organization, and use of citation information and supporting the management, analysis, and further utilization of the corresponding source material	Chapter "Digital Tools for Written Argumentation"
Referencing	Acknowledging a source in the text and in the bibliography	Chapter "Digital Tools for Written Argumentation"
Reflective Writing	A rhetorically encoded way of thinking about what he or she is in the process of doing (reflection-in-action) and / or what has been done (reflection-on-action). Reflective writing in digital logs and journals is private and therefore not focused on an audience. Audience-based reflective writing requires an additional step in text revision which takes into account the expectations of the audience, e.g. in portfolios the existence of artifacts and the explanation thereof	Chapter "The Electronic Portfolio: Self-Regulation and Reflective Practice"
Revision	Changing an existing text is called "revision." In analogue writing, revision is only partially possible since the text is either permanently fixed (and not changeable) or changeable but not permanently fixed. Digital writing technology solved this problem by ensuring infinite changeability and enduring fixity of text. Inscription and revision are now linked to each other, making it easy for writers to insert and revise text alternatively without any conflict between the two processes	Chapter "Word Processing Software: The Rise of MS Word"
Revision	An insertion that takes place away from the leading edge, a deletion, or a substitution of text	Chapter "Investigating Writing Processes with Keystroke Logging"

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Term	Definition	Referencing Chapter
Right to left writing	Right-to-left (RTL) script systems like Arabic, Hebrew, or Sindhi used to be a serious problem for programmers. During the 1980s and 1990s, only a handful of standard PC word processors could handle RTL scripts and text. Even today, software created in the western world often fails to process non-Roman writing systems effectively	Chapter "Beyond MS Word: Alternatives and Developments"
Roles	Roles of collaborators may be specified by software (e.g., 'read only', 'edit'), or by a human coordinator through agreement among the contributors, or implicitly (for example, by one or more contributors taking on the task of proof-editing a shared document)	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Rubric	A set of evaluative criteria for application during peer review	Chapter "Learning Management Systems (LMSs)"
Screen recording	Technologies that record all activities at the screen like a video and make them available for a subsequent evaluation. The data provided covers everything visible on the screen, such as inscription activities, the use of word processor support functionalities, all windows opened during the observed session, all contacts to internal files, web-based sources, and use of tools other than the word processor. Screen recording is a technology applied most often in settings conducting usability research, along with eye-tracking and think-aloud or stimulated-recall assessments	Chapter "Word Processing Software: The Rise of MS Word"
Screencast	A video made of all activity captured on a screen along with voice narration if desired	Chapter "Digital Note-Taking for Writing"
Sentence completion	Technologies that try to predict how sentences will finish once some words have been provided	Chapter "Word Processing Software: The Rise of MS Word"
Sharable Content Object Reference Model (SCORM)	SCORM was developed by the United States Department of Defense in 2000 to provide a set of guidelines and features for e-learning which could enable transfer of applications across different systems. SCORM, and its successor, Experience Application Programming Interface (xAPI) underlie the operations of most LMSs	Chapter "Teacher Feedback Tools"
Snippet	A piece of prewritten text inserted through a text expander	Chapter "Digital Note-Taking for Writing"

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Term	Definition	Referencing Chapter
Social annotation	A type of learning technology enabling the addition of notes to digital and multimodal texts for the purposes of information sharing, peer interaction, knowledge construction, and collaborative meaning-making	Chapter "Content Management System 3.0: Emerging Digital Writing Workspaces"
Social bookmarking	Storing and sharing (annotated) source material online for future reference; a way to help writers stay up to date by browsing other people's bookmarks to discover additional information	Chapter "Digital Tools for Written Argumentation"
Spell checker	Software, mainly included in grammar checkers, indicating spelling errors	Chapter "Word Processing Software: The Rise of MS Word"
Sticky	A digital note containing either prewritten or customized commentary	Chapter "Learning Management Systems (LMSs)"
Student model	the ITS component that represents the students' cognitive and meta-cognitive states including but not limited to knowledge, affect, behaviour, progress, and skills	Chapter "The Future of Intelligent Tutoring Systems for Writing"
Summarizing	Providing the main idea or argument from a source in one's own words and in a significantly shorter way than the original	Chapter "Digital Tools for Written Argumentation"
Synchronous writing	Synchronous writing involves contributors interacting with a shared document and with each other at the same time. This adds a layer of complexity to writing since it involves managing or making visible not only different writers' schedules, experiences, and disciplinary backgrounds but also their intentions. This can be done by writers annotating parts of the document with their intentions to revise or their reasons for a specific wording	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Synchronous writing tools	Synchronous tools usually make all writing and editing activities of the participants visible to all others and record them to be traced back. Web-based storage of shared documents has now blurred the former clear distinction between synchronous and asynchronous writing	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Tagging	Adding an individually generated label or keyword to a reference entry to classify and remember it	Chapter "Digital Tools for Written Argumentation"

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Term	Definition	Referencing Chapter
Text editor	Refers to a computer programme to enter, edit, and format text visible on screen. In contrast to word processors and desktop-publishing software, text editors have restricted functionalities for formatting and layout depending on the context in which they are used. Originally developed for writing and debugging code around 1960, text editors are also used to author 'plain text' documents (containing no graphical information) and more complex documents tagged with markup languages like Markdown	Chapters "The Beginnings of Word Processing: A Historical Account", "Beyond MS Word: Alternatives and Developments"
Text expander	A tool that inserts prewritten text into a document when a specific command is typed	Chapter "Digital Note-Taking for Writing"
Text obfuscation	Manipulating text to avoid detection by plagiarism detection software	Chapter "Plagiarism Detection and Intertextuality Software"
Text recycling	Using parts of one's own previously published text in a new text without attribution	Chapter "Plagiarism Detection and Intertextuality Software"
Text-formatting program	A program that processes text files containing control characters, commands or tags in a markup language and turns them into formatted documents (with page breaks, pagination, justified paragraphs etc.) suitable for displaying and printing. Invented in the 1960s, text-formatting programs have been largely replaced by PC word processors with WYSIWYG capability. Still in use today is the Roff family of text-formatting programs on Unix systems	Chapter "The Beginnings of Word Processing: A Historical Account"
text-matching software	A sometimes-preferred term for plagiarism detection software	Chapter "Plagiarism Detection and Intertextuality Software"
Time-sharing	The sharing of computing resources provided by a single mainframe or minicomputer for multiple users at the same time. Pioneered in the 1960s, it was the primary model for interactive computing until the advent of microcomputers in the late 1970s	Chapter "The Beginnings of Word Processing: A Historical Account"

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Term	Definition	Referencing Chapter
Track changes	Storage of all changes (revisions/deletions) that are made during the production of a document. It allows multiple users to identify changes made by the author and/or other writers and to reconstruct former versions if required	Chapter "Word Processing Software: The Rise of MS Word"
Tutor model	The ITS component that represents the different instructional strategies and scaffolding available	Chapter "The Future of Intelligent Tutoring Systems for Writing"
Validity	"Overall evaluative judgment of the degrees to which empirical evidence and theoretical rationales support the adequacy and appropriateness of interpretations and actions based in test scores or other modes of assessment" (Messick, 1989, p. 13)	Chapter "Automated Feedback on Writing"
Version control and revision history	Keeping track of versions of the document as a whole and of revisions to specific sections, so changes can be negotiated and undone; especially important for sequential and reciprocal coordination	Chapter "Social Annotation: Promising Technologies and Practices in Writing"
Voice-to-text program	A tool that transcribes spoken text into written text	Chapter "Digital Note-Taking for Writing"
Wikis	Kinds of CMS centred on collaboration and the organic development of knowledge through semantic hyperlinks within simple interfaces that allow both reader and author to add and change content	Chapter "Creativity Software and Idea Mapping Technology"
Word embedding	Models representing words similar in meaning together in a vector space. Such representations help identify meaningful relations and knowledge of the surrounding contexts in which a word is used. And are widely used to improve the accuracy of NLP tasks in state-of-the-art research	Chapter "Analytic Techniques for Automated Analysis of Writing"
Word processing	The activity connected with the inscription and formatting of text in a digital environment, usually done with an editor or word processor	Chapter "Word Processing Software: The Rise of MS Word"

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Term	Definition	Referencing Chapter
Word processor	A computer program designed to make writers create text. Word processors are inscription tools because they allow the user to choose letters and symbols stored digitally and made visible on screen or in print. Word processors can follow different philosophies regarding the connection between script and graphic design. For example, WYSIWYG-based word processors and graphical user interfaces (GUIs) connect the inscription of language with layout and typesetting activities. Markup editors, in contrast, separate the script creation from graphical design activities	Chapter "Word Processing Software: The Rise of MS Word"
Writing platform	Cloud-based writing editors are accessible through a browser by many users. Various functions usually enable the platform's adaptation to particular writing domains, professions, genres, and tasks	Chapter "Beyond MS Word: Alternatives and Developments"
Writing process(es)	Classic writing process theory suggested five stages–prewriting, drafting, revising, editing, and publishing. Advances in writing process theory, post-process approaches, work in Writing Through the Lifespan (WTTL), and other more situated approaches to understanding how writers work have emphasized not only the recursive nature of writing processes but also the plurality of writing processes. That is, different writers write differently, and these differences may vary not only among writers, but also between different contexts (i.e., one writer might go through different writing processes depending on the writing task they are engaged in	Chapter "Reference Management Systems"
What You See Is What You Get (WYSIWYG)	An interface that shows documents created on the computer screen just as they would appear in their finished form (e.g., the page of a text document being rendered with correct font size and shape, paragraph alignment etc.) This is the default mode for all word processors since the early 1990s	Chapters "The Beginnings of Word Processing: A Historical Account", "Beyond MS Word: Alternatives and Developments"
XML (Extensible Markup Language)	A fully customizable system for creating tag sets and markup languages, of which HTML is one example	Chapter "Hypertext, Hyperlinks, and the World Wide Web"

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O. Kruse et al. (eds.), *Digital Writing Technologies in Higher Education*,
https://doi.org/10.1007/978-3-031-36033-6