IEA International Computer and Information Literacy Study 2023

ASSESSMENT FRAMEWORK

Julian Fraillon
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Editors

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IEA ICILS

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The International Association for the Evaluation of Educational Achievement (IEA), with headquarters in Amsterdam, is an independent, international cooperative of national research institutions and governmental research agencies. It conducts large-scale comparative studies of educational achievement and other aspects of education, with the aim of gaining an in-depth understanding of the effects of policies and practices within and across systems of education.

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Foreword

The International Association for the Evaluation of Educational Achievement (IEA) is a nonprofit independent research organization that is committed to investigating various aspects of education systems, measuring strengths, weaknesses, and trends across international contexts. More than 100 education systems across six decades have participated in large-scale comparative studies, and this has been further supported by the collaborative network of scholars, researchers, policy analysts, and technical experts from national education research centers and government research agencies. The reports and data stemming from these initiatives have provided foundational aspects in supporting education research as well as evidence-based policymaking.

Furthermore, IEA has a longstanding interest in the application of information and communication technology (ICT) in education which is investigated through the lens of the International Computer and Information Literacy Study (ICILS). This 2023 cycle marks the third installment of ICILS and its trend data, although IEA has conducted multiple variations of ICT large-scale assessments since 1989. Inquiries into contexts and outcomes of ICT-related education programs, as well as how schools and teachers play a role in supporting students' computer and information literacy achievement, are essential aspects to understand; ICILS also goes further by investigating students' proficiency in using computers to explore, create, communicate, and participate effectively in a digital world, be it at home, in school, the workplace, or the community.

IEA's research in this subject has its roots in earlier studies like the Computers in Education Study (COMPED) conducted in 1989 and 1992, and the Second Information Technology in Education Study (SITES) in 1998–1999 and 2006. ICILS 2013 marked the implementation of this study, in which 21 education systems around the world gathered data in order to assess how grade 8 students were evolving to engage in an increasingly digital world. This led to a collective understanding that more research and trend measurement were crucial to shaping policies that would enhance students' computer and information literacy (CIL) skills. Additionally, it emphasized the growing significance of computational thinking (CT), an area increasingly relevant in twenty-first century education. ICILS 2018 and the 14 education systems that participated furthered this goal by offering countries the opportunity to assess students in CT as well. This innovation challenged students not only to analyze problems and break them down into logical steps, but also to grasp how computers can be employed to solve these problems effectively.

Participation in ICILS 2023 grew rapidly, a reflection of how valuable data is in this rapidly changing field, with 35 education systems joining from around the world. Digital information resources are so rapidly developing that additional questions relating to early impressions of ChatGPT were optionally offered. Although this tool was launched in November 2022, it quickly became an essential part of digital life, and thus it was seen as an essential factor to include in the main survey data collection, despite late additions not being the standard format for IEA studies. This was an elective addition for principals to fill out various questions surrounding ChatGPT, its influence, perception, and use.

The ICILS 2023 assessment framework, documented within this publication, serves as a foundational resource to describe the context, constructs, and design of the assessment, encompassing CIL and CT skills. While based on the framework from the two previous cycles for trend, this framework has been meticulously adapted and refined to address new challenges arising from evolving educational requisites. This transformation underscores the continuous growth and development within ICILS.

The remarkable effort of this assessment framework could not have come to fruition without the dedication of the ICILS team. I offer my sincere gratitude to them for their pivotal roles. Special thanks go to the international study director, Julian Fraillon, and to the lead content and item development specialist, Daniel Duckworth. I would also like to extend my appreciation to colleagues at IEA Amsterdam, the Netherlands, and IEA Hamburg, Germany, for their unceasing support. My thanks further go to the IEA Publications and Editorial Committee for their contributions to the review of the framework. Gratitude also extends to the European Commission's Directorate-General for Education, Youth, Sport and Culture (EAC) and European Education and Culture Executive Agency for EU funding toward Erasmus+ countries in recognition of the contribution from ICILS data toward developing European education policies. Furthermore, the EU provided additional support by covering the costs of Western Balkan participants interested in enrollment.

It's important to acknowledge that ICILS would not be possible without the steadfast commitment of national research coordinators from participating countries. They have played an indispensable role in shaping and implementing this study, ensuring that it reflects the interests of a broader community of researchers, policymakers, and practitioners. With the collaborative efforts of all involved, our work continues to provide high-quality data from large-scale assessments to better understand education systems and provide evidence-based improvements for the future.

Amsterdam, The Netherlands

Dirk Hastedt
Executive Director IEA

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1 Introduction

Julian Fraillon, Sara Dexter and Jeppe Bundsgaard

1.1 Overview

For many people across the world, the effective use of digital technologies is essential to their participation in education, work, leisure, and as citizens. We rely on digital information to make sense of our world, and on digital infrastructure and resources to manage the day-to-day functions to communicate with others, manage money, and participate as citizens in society. These functions require informed, critical, constructive, generative, and responsible uses of technology, as well as the capacity to use technology to solve problems (Cansu & Cansu, 2019; National Assessment Governing Board, 2018; Vuorikari et al., 2022). In education young people both learn to use technology and use technology to learn and, as the use of technology continues to increase in all facets of our lives, the importance for young people to become confident, critical, and productive users of technology only continues to increase. The value placed on peoples' capacity to engage effectively with technology is evident, for example, in the inclusion of measures of youth and adults' information and communications technologies (ICT) skills in indicator 4.4.1 of the United Nations (UN) Sustainable Development Goals (UN, 2017). In addition, under the *Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021–2030)* (European Commission, 2021) the digital skills of grade 8 students will be monitored, using data collected in the International Computer and Information Literacy Study (ICILS).

The International Association for the Evaluation of Educational Achievement (IEA) has been studying the relationship between ICT and educational processes, as well as factors related to the pedagogical use of ICT, since the late-1980s (Pelgrum & Plomp, 2011). IEA's ICILS emerged in response to the increasing value being placed on the use of ICT in modern society and the need for citizens to develop relevant capabilities to participate effectively in a digital world. ICILS also addresses the need for policymakers and education systems to monitor the development of these essential capabilities over time, and to gain a better understanding of the contexts and outcomes of ICT-related education programs in their countries. The first cycle of ICILS in 2013 (ICILS 2013) assessed students' computer and information literacy (CIL) with an emphasis on the use of computers as information seeking, management, and communication tools. The international recognition of the importance of developing students' abilities to recognize and operationalize real-world problems using computational formulations on computers or other digital devices has prompted the development of an ICILS assessment of computational thinking (CT), which was offered to participating education systems as an international option as part of ICILS 2018.

In ICILS, CIL and CT (defined and articulated in detail in Chaps. 2 and 3 respectively), are regarded as outcomes associated with a broader notion of *digital literacy* education within countries. Digital literacy is a contested term, with varying definitions within and across countries, that are influenced by language and culture (Pangrazio et al., 2020) and have continued to evolve with changes in technology and educational priorities (Reddy et al., 2020). In this framework, the term *digital literacy* is used broadly to encompass the curriculum areas across countries that are associated with students' abilities to use digital technologies to investigate, manage information, create content, communicate, collaborate, and solve problems. This use is intended to be consistent with broad conceptualisations of digital literacy or competence, such as the European Commission Digital Competence Framework for Citizens (DigComp) (Vuorikari et al., 2022).

ICILS 2023 continues and extends the work of the previous cycles, through the use of CIL and CT as outcome measures of digital literacy education in schools, and by seeking to measure and explain how the contexts in which CIL and CT are being developed relate to student learning in these areas.

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1.2 Purposes of ICILS

The primary purpose of ICILS 2023 is to assess systematically the capacities of students to use ICT productively for a range of different purposes, in ways that go beyond a basic use of ICT. ICILS 2023 includes authentic computer-based assessments that are administered to students in their eighth year of schooling. These generate data reflecting two dimensions of ICT-related capacities:

- First, ICILS 2023 assesses CIL. This was first measured in ICILS 2013, where it was defined as "an individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society" (Fraillon et al., 2013, p. 17). CIL refers to a student's ability to use computer technologies to collect, manage, produce and exchange digital information.
- Second, ICILS 2023 assesses CT. This was first measured in ICILS 2018 where it was defined as "an individual's ability to recognize aspects of real-world problems which are appropriate for computational formulation and to evaluate and develop algorithmic solutions to those problems so that the solutions could be operationalized with a computer" (Fraillon et al., 2019, p. 28). This is the type of thinking used when programming a computer or developing an application for another type of digital device.

ICILS investigates, in 2023 and across study cycles, variations in CIL and CT among and within countries, and the relationships between those constructs and student attributes (background characteristics and developed attributes) including students use and experiences of computer technologies. ICILS also investigates how CT is related to CIL.

In addition, ICILS 2023 investigates the broader contexts in which students' CIL and CT develop. Within-school contexts are investigated, such as students' access to ICT at school and their experiences of using ICT in their general schoolwork and, specifically with respect to learning about CIL and CT. ICILS 2023 also includes a strengthened focus on teachers' reports of their approaches to teaching with and about technology, as well as the broader approach to leadership for technology use within schools. Out-of school contexts in which students' CIL and CT develop are also investigated, such as the extent of students' use of ICT for a range of purposes, as well as their attitudes toward the use of computer technologies.

ICILS is not restricted to measuring only those contextual aspects that are known or hypothesized to be directly related to students' CIL and CT achievement. ICILS seeks also to inform our understanding of the broader context in which digital literacy learning is taking place within and outside of school. Further contextual information is provided by schools and education systems about the learning environment, policies, resources, expectations, and support available for schools, teachers and students as they relate to the development of students' CIL and CT competencies.

1.3 Purpose of the ICILS Assessment Framework

The ICILS assessment framework articulates the basic structure of the study. It provides a description of the field and the constructs to be measured. It outlines the design and content of the measurement instruments, sets down the rationale for those designs, and describes how measures generated by those instruments relate to the constructs. Above all, the framework links ICILS to other work in the field so that the contents of this assessment framework combine theory and practice in an explication of "both the 'what' and the 'how'" (Jago, 2009, p. 1) of ICILS.

1.4 Background to the Study

The mass production of microcomputers in the late 1970s and early 1980s resulted in computers being smaller and more affordable, and to an increase in the availability of software that could be used by people with less specialist computing knowledge. Over this time, there was a shift in the focus on technical usage and programming, including simplified programming using languages such as *Logo* (McDougall et al., 2014), to the widespread use of applications incorporating information management and communications. Punter et al. (2017) argued that the widespread use of the internet, as well as the ready availability of office applications, changed the nature of computer use. Caeli and Bundsgaard (2019) identified a similar pattern of change across four phases of computer use in education in Denmark. These began in the 1970s and 1980s with exploration of the implications of computing for society in combination with aspects of CT. In the 1990s the emphasis was on the use of computer applications by students and this was followed by a phase in the early 2000s that focused on the pedagogical use of digital resources. The most recent phase has again focused on societal aspects with CT as one of four competence areas. Flury and Geiss (2023) make a distinction between two broad categories of approaches relating to the introduction of computers into classrooms: efforts to use computers to improve teaching and learning within existing subjects; and efforts to teach students about computer technology.

IEA has responded to the interest in and need for research into the use of computers and ICT in school education since the 1980s. This work began with the IEA Computers in Education (Comped) "in which at two points in time, data would be collected regarding the content and outcomes of this innovation in more than 20 educational systems" (Pelgrum & Plomp, 1993, p. 1). Comped included a two-stage data collection, with data collection in stage 1 in 1989 and in stage 2 in 1992 (Pelgrum & Plomp, 1993). Stage 1 aimed to collect information about the status of the use of computers in schools as well as establishing a baseline against which data in stage 2 could be compared. Despite Comped predating the first cycle of ICILS by 24 years, the two studies share remarkably similar designs, with questionnaire data being collected from school principals, "technical" coordinators, teachers and students and both studies including tests of student learning outcomes. Comped included a functional information literacy test (FITT), and optional tests in elementary programming and word processing (Pelgrum et al., 1993) which were measures of student computer use in schools and have been considerably broadened and expanded upon in the ICILS measures of CIL and CT. This evolution within the sphere of IEA studies alone reflects the expansion from computer literacy to broader notions of digital literacy(ies) that characterize the development of computer and ICT use in schools across the past 40 years.

IEA Comped was followed by the IEA Second International Technology in Education Study (SITES) which emerged in the late 1990s in response to perceptions and policy reflections on the evolution from "industrial societies to 'information societies,' in which the dissemination of information was deemed to be of paramount importance" (Pelgrum & Anderson, 2001, p. 2). SITES included three modules. SITES-Module 1 was conducted in 26 countries with data collected between 1997 and 1999. Principals and technology coordinators in schools completed questionnaires and reported on "the extent to which ICT was being used in education and on which education systems had implemented objectives important for education in a knowledge society" (Anderson & Plomp, 2009, p. 7). In late 2000 and early 2001, 28 countries participated in SITES-Module 2. In-depth case studies were reported on to investigate the nature and range of innovative teaching practices with technology, and the contextual factors that underpinned their success. SITES 2006 (initially known as SITES-Module 3) built on the work of SITES-Module 2 by examining the extent and impact of ICT integration in teaching and learning and the factors that contribute to successful integration. The teaching practices identified as most closely associated with innovation in SITES-Module 2 were used as the basis for framing the interpretation of the teaching methods and their level of innovation in SITES 2006. Data in SITES 2006 were collected from school principals, ICT-coordinators, and mathematics and science teachers (Anderson & Plomp, 2009).

The IEA suite of Comped and SITES surveys provided a strong foundation for the development of ICILS. They formally recognized and demonstrated the value of the development of student learning about computer use and with computers. Furthermore they investigated the relationships between innovative, effective teaching with technology. The studies established the conceptual framework for further investigating the role of the school context to support teachers' use of technology in their teaching, both through the provision of support and resourcing for teachers and the removal of obstacles that can inhibit technology integration in teaching.

In the early 2000s the expansion of the internet, characterized by improved connection speeds, stability and, in an increasing number of countries, access, made online data collection an increasingly viable proposition. When describing the work of SITES 2006, for example, Anderson and Plomp (2009) felt it worth reporting that "another feature of this study is that it used, on a large scale, online data collection' (p. 8). The increased viability of online data collection, coincided with recognition of the transition from the industrial society to the information society and knowledge society (Phillips et al., 2017) and a concomitant increased recognition of the value of ICT and information literacy-related competencies school education (Geiss, 2023; GESCI, 2011; Tapper et al., 2007). It became widely accepted that information technologies would provide the tools for creating, collecting, storing, and using knowledge, as well as for communication and collaboration (Kozma, 2003). In the early 2000s, the OECD commissioned a feasibility report into the potential inclusion of ICT literacy in the Programme for International Student Assessment (PISA). The report, published in 2003, concluded that "developing and administering an ICT literacy assessment would be challenging, but successful" (Lennon et al., 2003, p. 12). At a similar time, for example, in Australia, a national sample-based assessment of ICT literacy (NAP-ICTL) was being developed with the first cycle of computer-based data collection taking place in 2005 (see, for example Australian Curriculum, Assessment and Reporting Authority, 2015) and in the United States, the National Assessment of Educational Progress (NAEP) was planning to include Technology and Engineering Literacy (TEL) in the 2014 administration, using computer-based tasks (National Center for Education Statistics, 2014). The NAP-ICTL program and NAEP TEL are examples of the establishment of computer-delivered, scenario-based assessments of digital literacy-related skills that were being developed and implemented around the same time as the first cycle of ICILS was being planned and conducted. These emerged from the combination of technical advancements making such large-scale computer-based data collection possible and increasing interest in the objective assessment and monitoring of digital-literacy related competences in students. ICILS was developed as the first study in international large-scale assessment (ILSA) to collect data and report on these competences.

1.5 The Evolution of CIL and CT in ICILS

Since its inception, ICILS has focused on students' learning about the use of ICT. However, the student learning outcomes measured in ICILS have evolved across the ICILS cycles to remain consistent with shifts in emphasis in digital education in schools. Student CIL, at the core of ICILS 2013, was described according to two strands that framed the skills and knowledge addressed by the instruments (Fraillon et al., 2013, pp. 34–35). Strand 1 focused on the receptive and organizational elements of information processing and management (*understanding computer use* and *accessing, evaluating, and managing digital information*) and strand 2 was concerned with producing and exchanging information (*transforming, creating, and sharing computer-based information*). The ICILS 2013 assessment instrument consisted of four 30-minute modules. Each student completed two of the four modules. A module was a set of questions and tasks contextualized by a real-world scenario and following a linear narrative structure. Each module had a series of small discrete tasks (skill execution and information management) followed by a large task that required the use of several applications to produce an information product that was scored by trained scorers according to specified scoring rubrics. The results of ICILS 2013 indicated that one dimension, CIL, underpinned the responses to the assessment (Gebhardt & Schulz, 2015).

ICILS 2018 sought to continue and improve on the measurement of CIL established in ICILS 2013. Following completion of ICILS 2013, and in consultation with national researchers, the project team "established a revised structure for the CIL construct for ICILS 2018" (Fraillon, 2018, p. 17). This revised structure was primarily intended to better communicate the contents of the CIL construct and to minimize overlap of separate content described across the strands. The restructure did not presuppose a change to the analytic structure of the CIL construct and this was later supported when the results of ICILS 2018 again showed CIL to be a uni-dimensional construct (Ockwell et al., 2020).

Computational thinking was introduced as an option available to countries participating in ICILS 2018. This was a reflection of increasing recognition of the value of CT as supporting people's understanding of how to make use of computers as tools, and in providing a foundational set of skills associated with creating novel computer-based solutions to existing real-world problems. Despite the clear differences between the conceptualization, measurement and reporting of CIL and CT, they have both been developed within ICILS to assess students' capacities to research, understand and offer solutions to real-world problems set within real-world contexts. This reflects the dominant paradigm of contemporary digital competencies (see for example, (Cansu & Cansu, 2019; ISTE, 2018b; Martínez-Bravo et al., 2022; National Assessment Governing Board, 2018; UNESCO Institute for Statistics [UIS], 2021; Vuorikari et al., 2022).

Computational thinking had its origins in the computational science movement of the 1980s and, after a period in the 1990s when ICT literacy and computer application use were prominent, had a resurgence in the 2000s (Caeli & Bundsgaard, 2020; Denning & Tedre, 2021) with a shift in emphasis on CT to be more strongly associated with creativity and problem solving. The national curriculum framework in England, for example, suggests that "[a] high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world" (Department for Education, 2014, p. 230). In ICILS 2018, CT was described according to two strands that addressed the conceptualization of computer-based solutions to problems (strand 1) and the operationalization of the solutions (strand 2) (Fraillon et al., 2019, 2020). Students in countries participating in the ICILS CT option complete two 25-min CT test modules. Similar to the CIL test modules, each CT module include a series of conceptually interrelated tasks that are based on an overarching real-world theme for each module. In the case of CT, the themes have the common property that a computer-based solution is being developed to address a real-world problem.

While the content of the CT construct used in ICILS has remained the same between ICILS 2018 and ICILS 2023 (see Chap. 3 for a complete description of the ICILS CT construct), the structure of the CT test content has been altered in ICILS 2023 to better reflect the integrated process of problem solving that lies at the core of CT. In ICILS 2018, the CT assessment comprised two modules, one module comprised tasks with a strong emphasis on conceptualizing problems and the second module comprised tasks with a strong emphasis on operationalizing solutions. In ICILS 2023, two new modules have been added to the assessment. Each of these modules comprises an integrated combination of tasks associated with both conceptualization and operationalization and include a stronger emphasis on evaluation of solutions as part of the iterative problem solving process. Details of the ICILS test design are provided in Chap. 5.

1.6 Recent Education Policy Developments and Programs Related to CIL and CT

One key purpose of ICILS is to inform policy and program development associated with CIL and CT education. ICILS data and outcomes have been used to consider and review CIL and CT resourcing, curricula, teaching and learning practices and programs within and across countries, and to monitor changes over time (European Commission, 2021). Since ICILS 2018 there have been many developments in education policy concerned with computer and information literacy. In this section, we focus on developments that are particularly relevant to CIL and CT education. We begin with a brief overview of the scope of CIL- and CT-related initiatives across countries and continue with details of developments within selected ICILS countries, based on contributions provided by ICILS national research centers.

1.6.1 Cross-National Developments and Programs

Digital competence frameworks, intended to guide, support and act as points of reference within and across countries have been developed across a number of contexts. The European Commission Digital Competence Framework for Citizens (DigComp) is the pre-eminent supranational digital skills framework across Europe. DigComp has evolved since 2010 (European Commission, n.d.) to provide “a common understanding, across the EU and beyond, of what digital competence is, and therefore provided a basis for framing digital skills policy” (Vuorikari et al., 2022, p. 1). The current version of the framework, DigComp 2.2 outlines five competence areas: Information and data literacy; Communication and collaboration; Digital content creation; Safety; and Problem solving (Vuorikari et al., 2022, p. 7). Each competence area is further explicated through constituent dimensions which are described in terms of their expression through knowledge, skills and attitudes, and across eight proficiency levels. In addition to providing a central point-of-reference for countries to help frame their policies and practices associated with digital literacy, DigComp supports communities of practice in the development and implementation of DigComp (DigComp CoP), and in Digital Skills Certification (Digital Skills Certification CoP) (European Commission, n.d.; All Digital, n.d.). The European Framework for the Digital Competence of Educators (DigCompEdu) was developed to describe the areas of educators’ Digital Competence with specific emphasis on the use of digital technologies for teaching (European Commission and Joint Research Centre et al., 2017). The framework articulates six areas of educators’ professional activities: Professional Engagement; Digital Resources; Teaching and Learning; Assessment; Empowering Learners; and Facilitating Learners’ Digital Competence (European Commission and Joint Research Centre et al., 2017).

The UNESCO ICT Competency Framework for Teachers “consists of 18 competencies organized according to the six aspects of teachers’ professional practice, over three levels of teachers’ pedagogical use of ICT” (UNESCO, 2018, p. 8). The six aspects of professional practice are: Understanding ICT in Education Policy; Curriculum and Assessment; Pedagogy; Application of Digital Skills; Organization and Administration; and Teacher Professional Learning. The framework is a resources to guide teacher training and professional learning policy and program development (UNESCO, 2018). The UNICEF Educator’s Digital Competency Framework (UNICEF, 2022) offers a common frame of reference to support work across Europe and Central Asia to “empower teachers, improve online teaching and boost innovation in education” (UNICEF, 2022, p. 1). The framework was developed to be consistent with DigCompEDU and with the UNESCO ICT Competency Framework for teachers, and describes four main areas of educators’ digital competencies: Knowledge Development; Knowledge Application; Knowledge Sharing; and Knowledge and Communication (UNICEF, 2022, p. 1). DigCompEDU, the UNICEF Educator’s Digital Competency Framework and the UNESCO ICT Competency Framework for Teachers all share the common global aim of supporting the work of teachers to improve the development of digital competencies in learners.

The International Society for Technology in Education (ISTE) Standards “provide the competencies for learning, teaching and leading in the digital age” (ISTE, 2023a) and are used within and outside of the U.S. (ISTE, 2023a). Standards are available for students (competencies described across seven areas) (ISTE, 2023e), educators (competencies described across seven areas) (ISTE, 2023b), education leaders (competencies described across five areas) (ISTE, 2023d) and coaches (competencies described across seven areas) (ISTE, 2023c). The ISTE Standards also include Computational Thinking Competencies for Educators, with the specific goal of helping educators to enable their students to “harness the power of computing to improve their success in their personal, academic or professional lives” (ISTE, 2018, p. 11).

Across Europe, CT is increasingly being included in national curricula. In an initial review of CT in compulsory education across Europe Bocconi et al. (2016) identified 11 countries that had recently implemented reforms to include CT-related concepts in compulsory curriculum with further sets of countries planning to initiate similar reforms or to more strongly integrate CT in existing computer science education. In a subsequent review, conducted six years later, 25 European countries were found to have "already introduced basic computer science concepts to some degree in their statutory curriculum for developing CT skills" (Bocconi et al., 2022, p. 5), with a further four countries actively planning and implementing similar polices. The review's authors further observed the need to "understand better how CT skills contribute to young people's skillsets and competences essential for the digital world we live in" (Bocconi et al., 2022, p. 5). As examples of initiatives in the Latin American region, Pereiro et al. (2022) describe a range of programs including curriculum reforms that associated with CT education in Uruguay, Argentina, and Brazil. In Chinese Taipei, a new learning subject, *Information Technology*, that incorporates CT is now mandatory for all students beginning in grade 7. Similar curriculum reforms have taken place in the past decade across the world, including in Australia, British Colombia (Canada), Japan, the Republic of Korea, and Singapore (Bocconi et al., 2016).

1.6.2 Policy Developments and Programs Within Selected ICILS Participating Countries

Since September 2019, secondary education in Belgium (Flemish) has been moving to have a greater emphasis on the use of digital technologies, starting with grades 7 and 8. This process has included revisions to the curriculum in which learning content associated with CIL and CT has been given higher priority. There are explicit expectations for all students to obtain the necessary knowledge and skills to: (1) use digital media and applications to create, participate, and interact; (2) handle responsibly, critically, and ethically digital media and information; (3) employ appropriate learning activities, strategies, and tools to critically acquire, manage, and process (digital) information taking into account the intended learning outcome and process; and (4) maintain and enhance a healthy lifestyle by distinguishing effects of potential addictive substances and actions of ICT use on themselves and their immediate environment. In addition, students must also learn to understand how digital systems work, by being able to distinguish building blocks of digital systems. They must be able to design and develop algorithmic solutions to solve complex problems. However, in 2023, the renewed curricula for grades 9 to 12 have been revised again after disagreement amongst diverse stakeholders, resulting in a reduced amount and more evaluable formulations of the related attainment targets. This revision implied again a reduced focus on competences related to CIL and especially CT from grade 9 and up. The Belgian (Flemish) attainment targets for all students regarding digital literacy and CT have a transversal character, meaning that they are relevant to different subject areas and therefore not necessarily limited to one specific subject course. This aims to encourage an integrated cross-disciplinary approach to teach these skills in Flemish secondary schools.

In addition to revisions in the curricula, Belgium (Flemish) has introduced a new strategic initiative called "Digisprong" in 2021. This programme, seen as a response to the COVID-19 crisis, seeks to modernize and digitalize education through four key objectives: (1) establishing a future-oriented and secure ICT infrastructure for all schools; (2) implementing a robust and efficient ICT school policy; (3) enhancing the digital competence of teachers and teacher trainers, and providing tailored digital learning resources; and (4) establishing the Digisprong knowledge and advisory center serving the educational field. Every key objective encompasses a range of coordinated actions aimed at achieving top-tier digitalization in education, all with the ultimate goal of equipping tomorrow's adults to thrive in a technology-driven society.

The above advancements in education are in accordance with the objectives set forth in the Belgian (Flemish) Reform Programme (2020), which seeks, among other goals, to enhance digital literacy among citizens, including the integration of targeting digital skills in education (see, for example, Misheva, 2021).

In connection with the *Strategy for the Education Policy of the Czech Republic up to 2030+*, the Ministry of Education, Youth and Sports initiated a revision of curriculum documents in the Czech Republic. In this context, the area of informatics and information and communication technologies are undergoing the most significant change. The changes will affect all levels of school education and have begun with primary and lower secondary levels. From the beginning of 2021, schools could have begun teaching according to the new informatics/computer science curriculum. In a staged introduction, primary schools are required to begin teaching to the new curriculum in 2023 and lower secondary schools to begin no later than in 2024.

Unlike the previous educational content of ICT in basic schools, which emphasized the ability to use computers and information and digital literacy, the "new informatics" focuses primarily on the development of computational thinking and understanding the principles of how digital technologies work. The new informatics is based on an active approach in which students use informatics procedures and concepts such as: algorithms, coding, and modeling. Understanding how digital technologies work also contributes to their effective, safe, and ethical use. The reform also introduces the inclusion of a new key competence—*digital* —and significantly strengthens the instruction time of informatics in primary education.

In primary education, pupils, through games, experiments, discussions, and other activities, form their first ideas about the ways in which data and information can be recorded and discover the IT aspects of the world around them. They gradually develop the ability to describe the problem, analyze it and find a solution. In a suitable programming environment, they verify algorithmic procedures and form the basis for understanding computer concepts. The new informatics curriculum also includes the safe handling of technologies and the acquisition of skills and habits that lead to the prevention of risky behavior. Even at lower secondary level, students create, experiment, test their hypotheses, discover, actively seek, design and verify various solutions, discuss with others and thus deepen and develop an understanding of basic computer science concepts and principles of digital technology. When analyzing a problem, they choose which aspects can be neglected and which are essential for its solution. They learn to create, formally write and systematically assess procedures suitable for automation, and process large and inconsistent data sets. Pupils understand the basic principles of coding, modeling, learn to test prototypes and their gradual improvement as a natural part of design and development in information technology. They consider and verify the impacts of the proposed solutions on individuals, society, and the environment (European Commission, 2023; Fryč et al., 2020).

In 2019, the Danish government launched a three-year pilot project of the subject *technology comprehension* in primary and lower secondary school (K-9). The purpose of the subject was for students to develop understanding of digital technologies, including being able to critically reflect on digital technologies, and design rather than just use technologies. The subject consisted of the four competence areas: Digital Empowerment, Digital Design and Design Processes, Computational Thinking, and Technological Knowledge and Skills (EMU, 2019). The pilot was finalized in 2021, but no decision has yet been made on whether to introduce the subject in K-9. In the meantime, some of the participating schools have continued their experiments with the subject. Some schools have also implemented ICT initiatives on their own as electives (Caeli & Bundsgaard, 2020).

Additionally, the Danish university colleges, that include teacher training programmes, and universities have initiated a collaboration that aims to develop technology comprehension throughout the Danish education system. They state that "technology comprehension is emerging as a new professional subject in the Danish education system"[1] (KP, n.d.) with the purpose to "support that Danish children and young people gain a basic understanding of the effects of technology in society, can critically analyze and actively use technology to create new things and solve complex problems within all subject areas"[1] (KP, n.d.). Their work primarily aims to ensure that technology comprehension is implemented in K-9 and throughout the education system.

Furthermore, the teacher training programme in Copenhagen has launched technology comprehension as a pilot teaching subject from 2022, arguing that "society's need for our teachers to have these types of competences is increasing"[1] (KP, 2021).

The curriculum introduced in 2016 in Finland, defines ICT as a transversal skill that crosses subject areas. CT/programming is included in specific subjects (mathematics and crafts) and the curriculum includes an emphasis on CIL and CT content in the transversal competences *Multiliteracy* and *ICT competence*, which are cross-curricular topics covering all subjects. These concern operating principles and concepts, responsible safe use of ICT, applications in information management, and creative work and interaction and networking (Finnish National Agency for Education, 2016). The curriculum has been introduced gradually since 2016. Consequently, Finnish students in ICILS 2018 can be considered as having followed the previous curriculum whereas those in ICILS 2023 have been following the curriculum introduced in 2016.

A country report on ICT in education in Finland included many other aspects of need in Finland, such as the need for teacher education and the development of digital curriculum content (Koskinen, 2017). Saari and Säntti (2018) pointed to the priority accorded to digitalization through modernizing infrastructure and expanding teacher education, and how the reform conflicts with traditions of devolved authority. Kaarakainen et al. (2018) reported on performance-based testing of students' and teachers' ICT skills, and argued that assessment data are pivotal to improving the computer literacy of students in Finland. Tanhua-Piiroinen et al. (2020) reported of varying progress of digitalization in schools, with positive changes in operational practices, but only modest changes in teachers' and students ICT skills. Unequal access to digital learning opportunities and differing school cultures have contributed to disparities among students' digital skills. Oinas et al. (2023) reported that digital technology in Finnish lower secondary schools is underutilized, with a limited scope of activities primarily centered around information retrieval, editing, and storage, with certain groups of students, such as those receiving intensive support or having an immigrant background, being more active users.

[1] Translation provided by Danish National Center.

To meet the identified needs and challenges, the *New Literacies Development Programme for 2020–2023* was launched to support the implementation of the new curriculum by providing detailed descriptions of three competence areas: digital competence (Finnish National Agency for Education, n.d.-a), media literacy (Finnish National Agency for Education, n.d.-b), and programming skills (Finnish National Agency for Education, n.d.-c; Ministry of Education and Culture, n.d.). Descriptions are provided for the following educational levels: Early childhood education and care, Pre-primary education, grades 1–2, grades 3–6, grades 7–9. Also, pedagogical content, guides, articles, videos, and models have been published to support the use of the framework, and funds have been allocated to several projects for piloting and specifying these competencies, as well as for training teachers in their adoption.

In addition to this programme, there are several other educational initiatives, programmes, and projects that contribute to the overall development of digital literacy-related areas in basic education in Finland. Among these are "Lukuliike," ("Movement for literacy") which supports the development of multiliteracy including aspects relating to CIL (Finnish National Agency for Education, n.d.-d). With respect to CT, there are several programming-themed initiatives, such as the Innokas Network (Innokas Network, n.d.) and Code School Finland (Code School Finland, n.d.), which have become more prominent in the recent years.

The French Ministry of Education is working towards the widespread use of digital technology in its schools. And it has a policy of supporting the development and distribution of digital teaching resources. The importance of digital skills was reaffirmed by the introduction of new courses at high school at the start of the 2019 academic year and by the Ministries of National Education, Youth and Sport and Higher Education, Research and Innovation releasing a reference framework for digital skills. The framework was inspired by the European DigComp Framework and describes the development of digital skills across eight levels, the first five of which are targeted at primary, middle, and high school students (Ministère de l'Education Nationale et de la Jeunesse, n.d.-a). This training in digital skills and their assessment are therefore part of the curriculum. Digital skills are assessed and national certification called PIX awarded at the end of grade 4, grade 8, and the final grade, 11 (Service-Public.fr, n.d.). After a year of consultation with education stakeholders, the French Ministry of Education presented the new Digital Strategy for Education 2023–2027. It is based on a series of measures designed to enhance pupils' digital skills and accelerate the use of digital tools to help pupils succeed (Ministère de l'Education Nationale et de la Jeunesse, n.d.-b).

In Germany, the national strategy "Education in the Digital World" by the Standing Conference of Ministers of Education and Cultural Affairs (KMK, 2016), established the first cross-federal ICT policy regarding teaching and learning in the digital world and was the key catalyst for digital learning reform. It includes plans, goals, and policies across a range of aspects of teaching and learning. With regard to learning, students' competences, potentials of learning in the digital world and new formats of exams are addressed. On the teaching side, the paper includes pedagogical professional attributes, development processes at school level, digital transformation as a task of school principals and school administration, the design of learning processes, teacher competences and teacher training. The supplementary strategy (Kultusministerkonferenz, 2021), which is more responsive to teaching and learning, highlights that ICILS 2023 will first show the effort of the national strategies. Moreover, a national extension of TIMSS 2023 will provide information and help monitoring digital teaching and learning in primary education. In order to implement the goals outlined in the national strategy, Germany has also launched the investment programme "DigitalPakt Schule" (2019–2024) to provide funding support to the federal states and municipalities to support the development of educational infrastructure (Bundesanzeiger, 2019).

In 2023 the Norwegian Ministry of Education and Research in collaboration with the Association of Municipalities launched a new national Strategy for digital competence and infrastructure in kindergartens and schools (Kunnskapsdepartementet, 2023). The main objectives of the strategy for school are that:

- Students develop digital competence in line with the curriculum.
- All staff in schools have suitable professional digital competence.
- All children, young people, and adults have inclusive, safe, and good digital environments in kindergarten and school.
- The digital services and information management in the nursery and school sector are designed with the needs of children, pupils, staff, and parents at the core, and developed as interconnected services.

The strategy applies a whole government approach and highlights the importance of cooperation between levels of administration, different stakeholders, and different service areas.

The updated core curriculum, that applies to primary and secondary education and training in Norway was initiated in 2020. The core curriculum states that digital skills are one of five basic skills along with reading, writing, numeracy, and oral skills (Ministry of Education and Research, 2019). All teachers in all subjects are expected to support students in their work in the five basic skills. Computational thinking is integrated across the core curriculum as well. Programming can be found in core elements, digital skills and competence aims. It is mostly incorporated into learning outcomes for Natural Science and Mathematics subjects.

Alongside the curricula, the Norwegian Directorate for Education and Training has developed a framework and resources for CT (Utdanningsdirektoratet, 2019). Additionally, in 2020 the Directorate implemented several digital competence packages for teachers. Following this initiative, the professional digital competence was incorporated into all Continuing Professional Development (CPD) course studies for teachers as mandatory. The directorate also introduced a CPD course on digitalization to school leaders (Utdanningsdirektoratet, n.d., 2022).

In 2016, the Slovenian Ministry of Education convened an expert working group (RINOS I) to plan for better integration of the core content of computer science and informatics into Slovenian education (RINOS, 2023). The first objective of the RINOS I group was to review the state of computer science and technology (CS&.T) within school education in Slovenia. The scope of the review included analysis of the Slovenian curriculum, student achievement, teacher training, and continuous professional development. The review was to consider both data available within Slovenia and with reference to international comparisons. Outcomes of the review were to inform proposed changes by RINOS I to improve the state of teacher education and training and to propose content to be included in a plan for improvement and change (RINOS, 2023). In 2019, the RINOS II working group was appointed to prepare, implement and monitor an action plan for including basic CS&.T content in Slovenian education. The action plan includes:

- Introducing basic CS&.T content into programmes that include reference to the interaction between technology and society across all levels of schooling.
- Ensuring comprehensive assessment of digital competences across subjects and all levels of schooling.
- Improving the system for training and ongoing professional development for teachers in CS&.T.
- Establishing an open education system that enables stakeholders to contribute to the vision and implementation of CS&.T in teaching and learning.

(RINOS, 2023)

In July 2021 in Slovenia, the *Služba za digitalizacijo izobraževanja* (Digital Education Unit) was established as a body within the ministry of education (Gov.si, 2023). The Digital Education Unit plans, implements, and monitors digitalization tasks across all levels of education. The unit has responsibility for the provision of software, hardware, and internet connectivity in schools as well as providing support to educational institutions in the preparation of digital transformation plans at all levels of education and training. The unit also supports the development of digital pedagogy and knowledge in the use of digital tools in education and training. The work of the Digital Education Unit is framed by the Digital Education Action Plan 2021–2027 (ANDI), approved on 22 April 2022. ANDI covers the following areas:

1. National coordination of digital education
2. Didactics of digital education
3. Amendment to the education and study programmes, and work posts
4. Education and training of education staff, leadership, and other educators, as well as lifelong learning
5. Digital education ecosystem
6. Protocols for education in extraordinary circumstances

(European Commission, 2023; Gov.si, 2023)

In March 2023, the Slovenian government approved *Digitalna Slovenija 2030–Krovna strategija digitalne preobrazbe Slovenije do leta 2030* (the Digital Slovenia 2030 strategy). The strategy aims to support, strengthen, and promote digital transformation across all segments of Slovenian society by 2030. To this end, the strategy includes six priority areas that encompass digital infrastructure, digital competences and inclusion, digital transformation of the economy, digital innovation, digitalization of public services, and cybersecurity. In the area of digital competences and inclusion, the strategy includes the following goals:

1. To ensure digital rights for every citizen
2. To introduce digital competences into the compulsory curriculum of the school system
3. To develop a common training programme for basic digital competences and promote it accordingly

4. To ensure pedagogical digital competences for all educators
5. To improve the digital literacy of the population
6. To increase the number of ICT staff
7. To reduce the gender gap in ICT

(Ministry of Digital Transformation, 2023; Ministry of Education, Science and Sport, 2022)

In Spain, the *Digitization and Digital Competences of the Educational System Plan* (INTEF, 2022) has been introduced under a broad range of initiatives consistent with the Digital Spain 2026 agenda (Ministerio de Asuntos Económicos y Transformación Digital, n.d.). The plan includes four key areas of actions. The aim to develop digital competence is addressed through its inclusion in curricula and has a reference framework for teachers to accredit their CIL level. More than 22,000 Spanish schools are publishing their own Digital Plans as part of this initiative. A range of digitalization initiatives have been implemented to provide broadband internet connectivity to schools and devices to the most disadvantaged students and computers and digital whiteboards to schools. Further initiatives are in place relating to the creation and dissemination of open educational resources and teacher training and technical resources associated with computational thinking-related skills associated with advanced digital methodologies and competences.

In 2019, Chinese Taipei began to implement a literacy-based national curriculum standards for mandatory education, known as the *12-Year Basic Education Curriculum Guidelines*, announced by the Ministry of Education in Chinese Taipei in 2014 (Hao & Hsin-Hsien, 2014; Ministry of Education in Taiwan, 2014). The new guidelines include ICT and media literacy as a core competency, and aim to cultivate students' abilities to utilize information technology effectively for in-depth learning and real-world problem solving. They also intend to develop students' positive attitudes, proper behavior, and responsible use of information technology (NKNU, 2014, 2021).

Computational thinking and computer programming have been incorporated into this new curriculum standard (Tsai et al., 2019, 2021). A new subject, *Information Technology*, beginning in grade 7, is now mandatory for all students. The curriculum for this subject describes learning outcomes in four aspects: computational thinking and problem solving; collaboration and creativity around computing; communication and presentation about computing; and attitudes toward computing. The learning content comprises six dimensions: algorithms; programming; system platforms; data representation, processing, and analysis; applications of information technology; and the relationship between information technology, humans, and society (Ministry of Education in Taiwan, 2018). The new curriculum is designed to, progressively across the different levels of schooling, develop the student skills necessary for their future life and career development in the information age. At the elementary school level, the curriculum focuses on using and applying ICT. The emphasis at the junior high school level is on utilizing CT and information technology to solve problems. By the high school level, the focus shifts to conceptual learning of CT and further integration of its applications.

Concurrently, starting from 2022, a 4-year project entitled *Every Classroom Has Internet Access, Every Student Has a Tablet* was implemented nationwide. The primary goals of this project are to: enhance students' abilities to apply digital technology for self-directed learning; provide learning devices to all elementary and junior high schools; improve bandwidth to support classroom wireless internet access; and minimize the urban-rural digital divide in ICT education. As part of this initiative, digital learning devices were provided to economically disadvantaged students during the COVID-19 pandemic. Further to this, the government has an ongoing programme to provide online digital teaching resources and fosters social groups for teachers, aiming to enhance their innovative teaching skills and motivation (Ministry of Education in Taiwan, 2022).

1.7 Selected Research Publications Using ICILS Data Since 2018

One of the fundamental purposes of ICILS is to provide a repository of representative data relating to CIL and CT education and education outcomes in ICILS countries, with the intent that these data are used as the basis for further research, analysis, and reporting. Since ICILS 2018, research publications using data from both ICILS 2018 and 2013 have been released addressing themes associated with students, teachers, principals and schools within and across countries. The research literature using ICILS data covers outcomes that can be reported with a view to informing digital literacy education policy and practices, as well as explorations of alternative analysis techniques and research methodologies. The following summary of selected research using ICILS data since 2018 is included to provide readers with a sense of the breadth and depth of uses to which the ICILS data have been used by the research community.

A key area of research interest has been the ways in which student achievement in CIL and CT can be explained by the contribution of measured contextual factors. The ICILS 2018 International Report included the outcomes of multilevel modeling that showed similarities and differences in the relationships between contextual factors and student achievement in each of CIL and CT. Students' reported use of test language at home, socioeconomic background, and expected level of education were consistent positive predictors of CIL and CT, as were their frequency of use of ICT, and their experience using computers (Fraillon et al., 2020). In contrast, "[f]emale gender tended to be positively related to CIL but negatively associated to CT scores" (Fraillon et al., 2020, p. 215) and, while student reports on having learned about CIL tasks at school was positively associated with CIL achievement, student reports of having learned about CT-related tasks at school tended to have a a negative association with student CT scores (Fraillon et al., 2020).

Two meta-analyses of the relationships between student ICT literacy and contextual background variables have reported findings broadly consistent with those across both previous cycles of ICILS. Siddiq and Scherer (2019) reported an overall positive effect of female students demonstrating higher ICT literacy scores, with higher effect sizes in primary schooling than in secondary schooling. Overall the effect reported by Siddiq and Scherer (2019) was smaller than those reported in earlier studies based on self-reported ICT literacy only. Data from ICILS come from objective measures of ICT literacy achievement in contrast to self-report measures that were used before, therefore Siddiq and Scherer (2019) suggest the gender gap in ICT literacy may be smaller than it was previously believed to be. It is important to note, however, that different conceptualizations of the relative importance of ICT technical skills in comparison to ICT communication skills influence the instruments used to measure ICT literacy (regardless of whether this is done through self-report or objective testing) and consequently may affect the magnitude of reported gender differences in ICT literacy. Siddiq and Scherer (2019) further suggested that the gender differences in ICT literacy were relatively small in comparison to those reported in other domains. Scherer and Siddiq (2019) reported similarly, from a meta-analysis including performance assessments of ICT literacy, that the association between socioeconomic status (SES) and ICT literacy was positive and significant but "less than for other, more traditional domains such as reading, mathematics and science" (Scherer & Siddiq, 2019, p. 30).

The relationship between SES and digital literacy is often considered in the context of the *digital divide*[2] which was reported in ICILS 2018 as being "clearly apparent in the student achievement results in both CIL and CT" (Fraillon et al., 2020, p. 245). Hatlevik et al. (2018) explored the determinants of students' ICT self-efficacy (regarding the use of general applications), and its relationship to student CIL using path analysis of ICILS 2013 data. Students' reports of the degree to which they believe they have taught themselves to use ICT and their experience with using ICT were the most important variables in explaining variations in their ICT self-efficacy. While SES was the strongest positive predictor of student CIL, it was not a strong predictor of student ICT self-efficacy. Furthermore, while a positive relationship was reported between ICT self-efficacy and CIL, the relationship varied from low to moderate across countries. Hatlevik et al. (2018) interpreted these findings together through the lens of the *digital divide* and concluded that SES appeared to be contributing at the second level of the digital divide (the use of technology in the classroom) rather than the first level (access to technology resources) (see Hohlfeld et al., 2008). They consequently suggested that, in order to "prevent and dismiss the digital divide, schools should take action to help students develop ICT literacy" (Hatlevik et al., 2018. p. 118).

van de Werfhorst et al. (2022) concluded from analysis of ICILS 2018 data that the digital divide was more clearly at the level of differences among students rather than clearly across the readiness of schools to provide digital education. Similar to Hatlevik et al. (2018), they suggested that emphasis should be for schools to focus on improving students digital skills as a way of ameliorating the differences in digital literacy across students. Ercikan et al. (2018) similarly found evidence of a digital divide from ICILS 2013 data and, in addition to reflecting on its impact on teaching and learning, made recommendations regarding the creation and conduct of digital assessments to reduce extraneous impact of the the digital divide on students' test taking experiences and consequently their results. Although the relative impact of factors associated with the digital divide (such as SES, and access to digital resources) varies across countries, based on multilevel modeling of ICILS 2018 data, Aydin (2021) suggested that the substance of these factors is largely similar across countries, including across those with different economic structures and different levels of digital literacy.

Scholars have sought to further investigate the factors associated with student CIL as measured in ICILS. Based on the outcomes of latent class analysis of students' time spent completing ICILS test tasks, Heldt et al. (2020) identified two classes of students (fast and slow). The fast class of students, which was associated with higher CIL achievement, completed the ICILS skills tasks more quickly, but took relatively longer than students in the slow class to complete the large information communication tasks that require planning and editing. This suggests that time on task in ICILS is affected by the ability

[2] In ICILS the *digital divide* is defined to be the varying opportunities and access that people have to digital technologies. "This can extend beyond access to technology to include how technology is used in schools and how students are empowered through technology to participate in their digital world" (Fraillon et al., 2020, p. 244).

of students relative to task difficulty for skill execution tasks (with relatively easier tasks for a student taking less time to complete), and by the level of planning and refinement required for the large information communication tasks, in which students with higher CIL spend more time than students with lower CIL on the processes of engaging with and refining their product-based responses to the tasks. Karpiński et al. (2023) explored potential fatigue and motivation effects on ICILS test-takers, as measured by three proxies: response time per task, relative probability of response correctness across successive tasks, and non-response to questionnaire items. They found that, while all three proxies were significant predictors of student CIL test scores, drop in response time was the strongest predictor. Both Heldt et al. (2020) and Karpiński et al. (2023) reported on, and suggested that there was further work to be done in analyzing the relationships between test-taking behaviors and student sub-groups.

ICILS seeks to describe and support better understandings of the roles teachers play in the development of student CIL and CT, as well as the factors that can support the work of teachers. Among the conclusions from ICILS 2018 about how the work of teachers can be supported, were the observations that "while the provision of ICT infrastructure in schools can impact on the likelihood of teachers using ICT, they should be accompanied with the provision of time for teachers to plan for ICT use and develop ICT skills" (Fraillon et al., 2020, p. 247). It was further reported that teacher perceptions of collaboration regarding the use of ICT, confidence to use ICT in their teaching, and positive beliefs in the value of using ICT in teaching all were positively associated with their likelihood to engage in teaching practices that emphasize CIL- and CT-related competencies (Fraillon et al., 2020). Secondary analyses of ICILS data have further sought to identify areas of influence on teacher practice that may inform policy and program development.

Structural equation modeling (SEM) has been used by a number of researchers to investigate the contribution of a variety of factors to teachers' use of ICT, and their emphasis on CIL and CT in their teaching. Hatlevik and Hatlevik (2018) used ICILS 2018 data to investigate a model to explain Norwegian teachers' likelihood to use ICT in their teaching and reported that "it is not enough to be confident in using ICT yourself... you also need to be confident in how to use it for instructional purposes" (Hatlevik and Hatlevik, 2018, p. 7). They further demonstrated that the relationship between that teachers' perceptions of a lack of facilitation for the use of ICT by school management was not associated with their self-efficacy for the use of ICT in teaching, or the use of ICT in their teaching. This was in contrast to teachers perceived collaboration with colleagues, which was significantly positively associated with both variables (Hatlevik & Hatlevik, 2018). Further to these findings, Hatlevik and Hatlevik (2018b) demonstrated that the degree of emphasis teachers place on the evaluation of digital information in their teaching is positively associated with their use of ICT in their teaching and also mediated by teacher's self efficacy for the use of ICT in their teaching. Konstantinidou and Scherer (2022) applied mulitlevel SEM and regression trees to ICILS 2018 data supplemented by external country data to investigate teacher-, school-, and country-level effects on teachers' emphasis on CIL and CT and their use of ICT in teaching. Consistent with the findings of Hatlevik and Hatlevik (2018) and Hatlevik and Hatlevik (2018b) they also reported that the predictors of teachers' use of technology and emphasis on CIL and CT are mainly at the teacher-level, with teacher motivation, expertise and collaboration playing more important roles in explaining variation in instructional practices than collective school-level factors or country-level factors, although the profile of these contributions varied across countries (Konstantinidou and Scherer, 2022).

Lomos et al. (2023) applied the theoretical lens of the *Four in Balance* model of the implementation of ICT in schools (Kennisnet, 2013; Tondeur et al., 2009) to ICILS 2018 data from Luxembourg. They also concluded that individual teacher attributes (reported as teachers' *vision* with respect to the outcomes of the use of ICT in teaching and teachers' *expertise* regarding the use of ICT in their teaching) were key factors that differentiated teacher use of ICT rather than school-level attributes such as the provision materials or ICT infrastructure (Lomos et al., 2023).

ICILS data have been used to establish profiles of students' computer use (Scherer et al., 2017) and their association with CIL (Bundsgaard & Gerick, 2017). Drossel et al. (2020) sought to address a suggested "research gap" (p. 4) with respect to "school characteristics related to the successful teaching of CIL" (p. 3). They applied latent profile analysis to ICILS 2018 data in order to establish a typology of *organizationally resilient* schools—schools with student averages that are in the lowest third of SES and highest third of CIL achievement within each country (Drossel et al., 2020). They identified three profiles of organizationally resilient schools that vary in particular with respect to teachers' perceptions of the availability of ICT resources in the schools, collaboration, and their use of and attitudes toward the use of ICT in their teaching (Drossel et al., 2020). ICILS 2018 data from European countries were used by Gerick (2018) to establish profiles of schools based on their *visions and strategies, teacher professional development and ICT infrastructure*. Five profiles were established, with varying distributions across countries. There was no clear pattern of association between student CIL and school profile type across the countries (Gerick, 2018).

Tulowitzki et al. (2022) used European ICILS 2018 data together with qualitative data to compare the ICT use of German school principals with those of other European countries, to establish profiles of German school principals according to their

ICT use, and to explore challenges with respect to the use of ICT in their work as perceived by school principals. They identified two profiles of school principals with respect to their ICT use, with 56 percent of German school leaders classified as using *partial digital school management* and 44 percent as using *comprehensive digital school management* (Tulowitzki et al., 2022).

A number of studies have explored aspects of design and analytic methodological issues associated with Large Scale Assessment (LSA) using ICILS data. These have included considerations associated with the application of multilevel modeling (Bokhove, 2022; Yildiz et al., 2022), alternative analysis procedures (Ozbasi & Ilgaz, 2019) including alternative item response theory (IRT) models (Yalçin, 2019) and the use of the outcomes of differential item function (DIF) analysis outcomes as information to support the teaching of CIL (Bundsgaard, 2019).

1.8 Areas of Increased Focus in ICILS 2023

Across each cycle of ICILS, there has been a commitment to innovation with a view to maximizing the relevance of ICILS to stakeholders. ICILS 2013 was the first International Large Scale Assessment (ILSA) to measure and report on students' digital literacy-related competencies (CIL) as the central learning outcome. In addition, the study introduced the thematically based modular assessment of CIL in authentic real-world contexts together with the cross-national application of analytic criteria to assess students' work on digital information products (such as presentations, websites or posters). In the second cycle of ICILS, the optional assessment of CT was introduced, including the technical innovation of using a live block-based coding environment within the assessment. In ICILS 2023, we have expanded the breadth and depth of contextual information to be collected as part of the assessment. Two new focus areas for ICILS 2023 are *teaching practices and teachers' beliefs* and *leadership for ICT*.

1.8.1 Teaching Practices and Teachers' Beliefs

In the first two ICILS cycles, teachers were asked about their use of ICT when engaging in different teaching and learning activities with their students. These items were used to create scales describing the extent of use of ICT for teaching and learning at school, but they were not providing information on which types of teaching and learning practices were prevalent in schools. That information would be relevant, for example, when trying to determine if some teaching and learning practices were associated with higher CIL or CT scores. For this reason, in ICILS 2023, teachers are asked both how often they and their students are engaging in a number of different teaching and learning activities, and to what extent they used ICT in each activity. The purpose of this is to be able to identify teaching practices used within and across countries. Identification of different teaching practices or instructional design models (Reigeluth & Carr-Chellman, 2009) has proven to be a challenge in previous cycles of ICILS. This might be because teachers' classroom activities may reflect more immediate, contextually expedient responses to the classroom context rather than a consistent and coherent underlying theoretically and epistemologically-driven approach. An example of this could be inferred from the high percentages of teachers who in ICILS 2018 reported that their students used ICT both for working individually on learning materials at their own pace, and on extended projects lasting over a week (Fraillon et al., 2020). The first practice would theoretically be part of a direct instructional design model, while the second would be part of a problem or project based model. In the IEA precursor to ICILS, SITES 2006, three "teacher-practice orientations" were identified: Traditionally important, Lifelong learning, and Connectedness, but for some participating education systems the reliability of some of the scales were less than satisfactory (Law et al., 2008, p. 128). In ICILS 2023, two approaches to teaching, *direct instruction* and *inquiry based instruction* (Reigeluth & Carr-Chellman, 2009) underpin the teaching and learning activities that are included in the questionnaire instruments.

Another approach to understanding how teachers teach, is to inquire into their epistemological beliefs about knowledge, learning, and cognition. In theory, teachers' beliefs shape their teaching methods. Research using data from Teaching and Learning International Survey (TALIS) 2013 indicates a somewhat weak correlation between constructivist beliefs and adaptable learning environments that support students' knowledge construction (OECD, 2014). As an international option in ICILS 2023 teachers are asked about their epistemological beliefs. The question includes statements that express different views on the nature of learning and cognition, and on how to characterize knowledge. The statements were developed to represent three distinct types of epistemological beliefs, (1) Embodied cognition, knowledge is built on the physical experience of one's environment and connected to both the associated psychological experience of being in the environment;

(2) Cognitivist, knowledge is identifiable as facts or information which can be acquired by transmission from someone who knows already, and (3) Constuctivist, knowledge is constructed by the individual by relating and situating new experiences into the existing system of knowledge. Where feasible, ICILS 2023 aims to explore the degree to which teachers' expressed epistemological beliefs are reflected in their teaching practices.

1.8.2 Leadership for ICT

In previous ICILS cycles, aspects of the school context were not directly addressed but could be considered as indirect indicators of leadership for ICT. ICILS 2023 includes leadership for ICT as an explicit area of research interest. Selected questions from previous cycles addressing school context for ICT teaching and learning are retained and supplemented by explicit new questions representing key functions of leadership for ICT.

The inclusion of this focus area reflects the growing body of evidence indicating that leadership does play a role in the nature and extent of ICT use in a school, influencing both teachers' conceptions of appropriate ICT use in the classroom and the support they receive for their integration. In ICILS, how leadership exerts influence on ICT use is mapped to the findings of how leaders influence any aspect of a school. The ICILS 2023 leadership context variables are categorized using the same framework utilized in two reviews of approximately 20 years of peer-reviewed literature (Dexter et al., 2016; Dexter & Richardson, 2020). This framework, the Unified Model of Effective Leadership Practices (Hitt & Tucker, 2016), is a synthesis of three previous evidence-based school leadership frameworks (Leithwood, 2012; Murphy et al., 2006; Sebring et al., 2006). Thus, the leadership context variables conceptualize leadership for ICT in terms of previous research on school leaders' practices. As a result, the emphasis in ICILS is also on *leadership*—the process of exerting influence in a particular direction and the marshaling of means to achieve that end. While the head leaders of the school, the principals, are asked many of the questions, the questions are not focused on whether persons in those roles complete that work, but they do ascertain their estimation regarding the understandings, processes, and resources that are present in their schools. To gain insight from the individuals most able to report on certain aspects or outcomes of leadership for ICT, the ICT coordinators and teachers are also asked some questions.

While in ICILS 2018, framed as part of the school/classroom context, there were questions that asked about the expectations of teachers to integrate ICT and the provision of resources to support this, in 2023 new questions are added to create a more complete portrayal of the vision, professional capability building, and supportive organizational features at the school for ICT use.

1.9 Research Questions

The core student achievement measure of ICILS is CIL and CT is available as an optional additional measure. As a consequence, two sets of ICILS research questions are presented relating to these two outcome measures, and the contexts in which CIL and CT are developed.

1.9.1 CIL

RQ CIL 1 What variations exist in students' CIL within and across countries?

RQ CIL 2 How is CIL education implemented across countries, and what aspects of schools and countries are related to students' CIL?

Following are some of the aspects of schools and education systems that could potentially be related to students' CIL:

(a) General approaches and priorities accorded to computer and information literacy education at system and school level
(b) School coordination and collaboration regarding the use of ICT in teaching
(c) School and teaching practices regarding the use of technologies in students' CIL
(d) Teacher proficiency in, attitudes towards, and experience with using computers
(e) ICT resources in schools

(f) Teacher professional development
(g) School leadership for technology

RQ CIL 3 How has CIL changed since ICILS 2013?

RQ CIL 4 What aspects of students' personal and social backgrounds (such as gender, and socioeconomic background) are related to students' CIL?

RQ CIL 5 What are the relationships between students' levels of access to, familiarity with, and self-reported proficiency in using computers and their CIL?

1.9.2 CT

The proposed research questions relating to CT closely reflect those proposed for CIL. Analyses will include data from those countries participating in the international option assessing students' CT achievement.

RQ CT 1 What variations exist in students' CT within and across countries?

RQ CT 2 How is CT education implemented across countries, and what aspects of schools and countries are related to students' CT

RQ CT 3 How has CT changed since ICILS 2018?

RQ CT 4 What aspects of students' personal and social backgrounds (such as gender, and socioeconomic background) are related to students' CT?

RQ CT 5 What are the relationships between students' levels of access to, familiarity with, and self-reported proficiency in using computers and their CT?

RQ CT 6 What is the association between students' CIL and CT, and how has this changed since 2018?

1.10 Target Population and Instruments

1.10.1 Target Population and Sampling

The ICILS target student population comprises students in their eighth year of schooling. In most education systems, this is grade 8, provided that the average age of students in this grade is 13.5 years or above. In education systems where the average age in grade 8 is below 13.5 years old, the adjacent upper grade (9) is defined as the ICILS target population. Schools with students enrolled in the target grade will be selected randomly proportional to size (PPS). Within each sampled school, one intact class of the target grade is selected randomly.

The target population for the ICILS teacher survey is defined as all teachers teaching regular school subjects at the target grade. Within each school, eligible teachers are those teachers who teach target grade students during the testing period and have been employed at school from the beginning of the school year. In schools with more than 20 eligible teachers, 15 eligible teachers are randomly selected to participate.[3] In schools with 20 or fewer eligible teachers, all eligible teachers are selected to participate.

School-level data are provided by the principal and ICT coordinator from each sampled school. In addition, national centers will provide information about the national contexts for CIL and CT learning by drawing on relevant expertise in each country.

1.10.2 Instruments

The following instruments form part of ICILS.

An *international computer-based student test* consisting of:

[3] Some countries selected more than 15 teachers per school in order to meet the minimum sample size.

- questions and tasks set in authentic contexts designed to measure students' CIL[4]
- questions and tasks set in authentic contexts designed to measure CT[5]

A *student questionnaire* consisting of a computer-based set of items measuring student background, access to, experience and use of, and familiarity with ICT at home and at school (including their experiences of using ICT in their lessons). The questionnaire also includes questions designed to gauge students' attitudes toward using ICT.

A *teacher questionnaire* administered to selected teachers teaching any subject in the target grade. It gathers information about teacher background, their use of ICT and their experiences of professional learning associated with ICT. The questionnaire includes items that ask teachers to rate their confidence in using computers in their teaching, to indicate the frequency with which they engage in specified teaching activities and the degree to which they use ICT and which ICT tools they use, to indicate the degree to which they emphasize aspects of CIL and CT in their teaching, and to express their attitudes toward using computers in teaching and learning.

A *school principal questionnaire*, administered to the principals of sampled schools and designed to capture school characteristics, school policies, and approaches regarding the application of ICT in teaching and learning, and aspects of the management of ICT at school and vision and implementation of leadership for technology use in the school.

An *ICT coordinator questionnaire* administered to ICT coordinators of sampled schools designed to capture information on resources and support for ICT and the use of ICT in teaching and learning at schools.

A *national contexts survey* completed by ICILS national research centers drawing on relevant expertise in each country. The survey will gather information on the structure of the education system, the status of CIL-related education in the national curriculum and policies, initiatives and resourcing associated with ICT, and CIL-related education. The online questionnaire also includes questions related to extent in which CT learning is incorporated into the national educational policies (for instance, questions on the extent in which CT processes such as writing or evaluating code, programs or macros are included in the curriculum). The data obtained from this survey should provide a description of the contexts for CIL- and CT-related education in each country and assist with the interpretation of results from the student, school, and teacher questionnaires.

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[4] This is the core test instrument completed by students in all participating countries.

[5] This test instrument is completed only by students in countries participating in the international option of assessing CT.

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2 Computer and Information Literacy Framework

Julian Fraillon and Daniel Duckworth

2.1 Background

Computer and information literacy (CIL) is the core student achievement outcome measured and reported on in the International Computer and Information Literacy Study (ICILS). It was first defined and described for use in ICILS 2013 (Fraillon et al., 2013) and is reviewed at the beginning of each new ICILS cycle, with reference to developments in CIL-related research, policies and curriculums, and with respect to its operationalization in previous ICILS cycles (Fraillon et al., 2019). In managing the ongoing challenge of measuring student achievement over time in an area of dynamic change, ICILS seeks to identify and emphasize the connections between the competencies described in the CIL construct and those that emerge as young people engage with new software platforms and information contexts (Fraillon et al., 2013).

In this chapter we begin by outlining key influences on the establishment and ongoing review of the CIL construct and test instrument, before describing in detail how the CIL construct was established, and explicate its constituent definitions and content.

In the late 1970s and early 1980s, when personal computers were being introduced into schools, the concept of *computer literacy* was narrowly defined, emphasizing an individual's ability to use computers and related applications for occupational purposes (see, for example, Binkley et al., 2011; Haigh, 1985). This perspective was expanded during the 1990s, with the development of a broader range of software applications that could be used within schools and, most significantly, with the development of the internet as an information and communication resource (Flury & Geiss, 2023). In this evolving landscape, terms such as "digital competence," "digital literacy," "digital skills," and "e-skills" were, and are still frequently used interchangeably, adding a layer of complexity to the discourse (Lemke, 2003; Van Laar et al., 2017; Martínez-Bravo et al., 2022).

To understand the relationship between Information and Communication Technologies (ICT) and student literacy, the Organisation for Economic Co-operation and Development (OECD) commissioned a feasibility study in 2001 to explore the potential for integrating an assessment of ICT literacy into the Programme for International Student Assessment (PISA). The resulting framework, published in 2002, proposed a more comprehensive definition of ICT literacy, extending beyond mere technological proficiency to include components representing skills and knowledge for information access, management, integration, evaluation, and creation (Educational Testing Service, 2002). During these formative stages of conceptualizations of ICT literacy, a distinction emerged between the operational aspects of hardware and software, which were the focus of computer literacy, and the broader competencies of information literacy and communication, which were emphasized in ICT literacy (Binkley et al., 2011).

Subsequent developments in the field have continued to integrate technological proficiency with facets of information literacy and communication (Catts & Lau, 2008). ICILS 2013 introduced the term "Computer and Information Literacy" (CIL) (Fraillon et al., 2013, 2014) to underscore the significance of internet-based information search and evaluation within the broader competency of utilizing contemporary technology. CIL combined the traditional conceptualizations of computer literacy, which focused on hardware and software operation, with those of information literacy and communication, which were rapidly evolving to encompass the internet as both a repository of digital information and a platform facilitating digital communication (Catts & Lau, 2008; Markauskaite, 2006; Erstad, 2010).

In 2010 the European DigComp project set out to identify key components of digital competence, develop descriptors of those components, and establish a framework for the field (Ferrari 2012). Initially, seven competence areas were specified: information management; collaboration; communication and sharing; creation of content and knowledge; ethics and responsibility; evaluation and problem solving; and technical operations. The DigComp framework was further developed and refined in 2013 with DigComp 1.0 describing five competence areas: information; communication; content creation; safety; and problem solving (Ferrari, 2013). These areas were further revised as part of DigComp 2.0 in 2016, resulting in

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the following competence areas: information and data literacy; communication and collaboration; digital content creation; safety; and problem solving (Vuorikari et al., 2016). In 2017, DigComp 2.1 was released to provide additional information about the five competence areas described in DigComp 2.0 and included the introduction of eight proficiency levels which outline the progression in the acquisition of each competence by "expanding the initial three proficiency levels to a more fine-grained eight level description as well as providing examples of use for these eight levels" (Carretero et al., 2017, p. 6). The proficiency levels are based on the complexity of tasks, autonomy and guidance needed, and the cognitive domain. The most recent update released in 2022, DigComp 2.2, involved close collaboration with stakeholders and addresses new and emerging topics in the digital world. It was released with a focus on "[E]xamples of the knowledge, skills, and attitudes applicable to each competence" (Vuorikari et al., 2022, p. 4). For each of the 21 competencies, 10–15 statements are given to illustrate timely examples that highlight contemporary themes such as "misinformation and disinformation; Artificial Intelligence (AI); remote working, data-related skills and datafication of digital services; emerging technologies such as virtual reality, social robotics, Internet of things, green ICT skills" (Vuorikari et al., 2022, p. 72). Importantly, DigComp 2.2 also includes a fully accessible version of the framework, reflecting the growing priority of creating accessible digital resources and a demonstration of applying theory to practice.

The evolution of the DigComp framework reflects the dynamic nature of digital competence and the need to adapt to the rapidly changing digital landscape. The updates in each version were driven by the goal of creating a common understanding using agreed vocabulary, addressing contemporary themes, and tailoring interventions to fit specific needs. The collaborative approach, involving stakeholders, experts, and the wider user-base, helps the framework remain relevant and responsive to the challenges arising from digitization in various aspects of modern lives.

In the context of the United States, the landscape of digital literacy and technological competence in education has been shaped by several key initiatives and frameworks. Initially, the International Society for Technology in Education (ISTE) laid the groundwork by establishing the National Educational Technology Standards, aimed at providing a structured approach to technology integration in educational settings (ISTE, 2007). These standards were renamed as the ISTE Standards in 2017, evolving from a national guideline into an international framework. The updated standards not only cater to both students and educators but also extend beyond the geographical boundaries of the United States, thereby gaining a broader scope of global applicability (ISTE, 2018).

Adjacent and complementary to the work of ISTE, the US National Education Technology Plan places considerable emphasis on the cultivation of 21st-century competencies. These include "critical thinking, complex problem solving, collaboration, multimedia communication, and adding multimedia communication into the teaching of traditional academic subjects" (US Department of Education, Office of Educational Technology, 2017, p. 10). This plan serves as a strategic roadmap for educational institutions, guiding them in the incorporation of these competencies into their curricula.

Further contributing to the discourse is the Technology and Engineering Literacy (TEL) assessment, which is part of the National Assessment of Educational Progress (NAEP) in the United States. The TEL assessment includes ICT literacy as a major area, encompassing knowledge and capabilities associated with "computers and software learning tools, networking systems and protocols, hand-held digital devices, digital cameras and camcorders, and other technologies, including those not yet developed, for accessing, managing, creating, and communicating information" (National Center for Education Statistics, 2018, p. 53). Furthermore, it delineates five sub-areas of ICT literacy: construction and exchange of ideas and solutions; information research; investigation of problems; acknowledgment of ideas and information; and selection and use of digital tools. Notably, these sub-areas resonate with the 21st-century competencies outlined in the US National Education Technology Plan, offering educational stakeholders with a nuanced and integrated framework.

Collectively, these initiatives and frameworks–ranging from the ISTE Standards and the US National Education Technology Plan to the TEL assessment–represent a multi-faceted approach to the development and assessment of digital literacy in the United States. They not only provide structured guidelines but also reflect the evolving nature of digital literacy, accommodating both national and international contexts as well as emerging technological trends.

Assessments of ICT literacy as a curriculum and learning outcome have included traditional multiple-choice items, text responses items, and skills and performance assessments. Siddiq et al. (2016) noted that many of the assessments focus on lower secondary-school students, and that most of them are computer-based and measure aspects such as searching, retrieving, and evaluating information, as well as technical skills. They also noted that many of these assessments include performance assessments in which students are required to perform tasks on a computer, with those tasks being embedded in a narrative. ICILS 2013 and 2018, involving grade 8 students, is one example of this approach to the assessment of ICT literacy-related outcomes (Fraillon et al., 2014). Other examples of studies using this type of assessment strategy include the national assessments of ICT literacy that have been conducted every three years among grade 6 and grade 10 students in Australia since 2005 (Australian Curriculum, Assessment and Reporting Authority, 2007, 2010, 2015, 2018, 2023), the national evaluations of ICT literacy in Chile (Claro et al., 2012), the NAEP TEL assessment of grade 8 students in the United States (NAGB, 2013; National Center for Education Statistics, 2018) (for a detailed comparison of NAEP TEL and ICILS assessment frameworks see Wang and Murphy (2020)), and the ICT literacy assessment of middle school students in the Republic of Korea (Kim et al., 2011). Aesaert et al. (2014) also used similar performance measures to assess the ICT competence of primary school students in the Netherlands. In France *PIX* (Direction of Legal and Administrative Information (Prime Minister), 2023), a digital platform designed to evaluate and certify digital competencies, is recognized throughout Europe, and is based on the Reference Framework for Digital Competencies (CRCN), which is aligned with DigComp.

In ICILS, the measure of CIL needs to meet the potentially contradictory needs of measuring change in student achievement over time, and maintaining relevance given the ongoing changes in software applications and digital learning environments. In ICILS we monitor the development of CIL-related learning, learning environments, initiatives, frameworks and assessments at both the international and national levels and reviewing the CIL construct accordingly as part of each study cycle. Furthermore, the core information-literacy and communicative aspects of ICILS (as described and defined in the following sections of this chapter) are conceptualized such that they can be demonstrated across a range of software and internet application environments, with the expectation that new ones will be introduced into ICILS in order for the study to remain contemporary and relevant. The ICILS assessment of CIL which is rooted in *real-world* contexts and expressions of CIL in contemporary and relevant digital information and communication contexts for students. Details of the ICILS student assessment instrument are provided in Chap. 5.

2.2 Establishing the Parameters of CIL

The ICILS CIL framework was initially developed for ICILS 2013 "to investigate the competencies associated with computer and information literacies as the enabling components of digital competence and 21st century skills" (Fraillon et al., 2013, p. 16). At the time, it was noted that there was a variety of terms relating to CIL in the research literature (see, for example Virkus, 2003) and that the development of context-specific constructs related to CIL had led to a "proliferation of frequently overlapping and confusing definitions" (Fraillon et al., 2013, p. 15). Since the development of ICILS 2013, the range of concepts associated with students' use of digital technologies has further increased. For example, Siddiq et al. (2016, p. 15) listed nine different names for "concepts for describing what and how students acquire, use, adapt to and learn with technology," ranging from "internet skills" through to "21st century skills"; (Siddiq et al., 2016, p. 60), these include the ICILS 2013 conceptualization of CIL. The expanding variety of competencies associated with the use of digital technologies is partly influenced by the diversity of local contexts, including local curriculum needs. As countries develop their own approaches to CIL-related education, they focus both on teaching students how to use digital technologies and on leveraging these technologies to enhance learning across various subjects and domains. The ICILS 2013 framework acknowledged the analogy between CIL and reading literacy, highlighting their dual role as both a means and an end in education. It elaborated on how technology served as a tool for both discipline-specific and cross-disciplinary learning, leading to two distinct approaches to assessing computer-based achievement. When the CIL construct was first defined and described for use in ICILS 2013, it was necessary to locate CIL within the existing broad suite of constructs related to digital literacy and to clearly articulate the scope of the CIL construct. The CIL construct also embraced information literacy (for a discussion of this in contrast to media literacy see Fraillon et al., 2013, p. 16), which emphasizes the processes of information management including the evaluation of the veracity of information (Catts & Lau, 2008; Christ & Potter, 1998; Livingstone et al., 2008; Ofcom, 2006; Peters, 2004). While information literacy can be expressed within or outside of the digital environment, the aspects of information literacy that are conceptualized and measured in ICILS are defined according to their application to digital information sources, with particular consideration given to the characteristics of internet-based information.

Following is a summary of the key decisions made by the research team in this process with some reflection on their ongoing relevance for ICILS 2018 and ICILS 2023.

The CIL construct was formulated during a period when there was a tension in the research literature between: (i) beliefs in the need to develop new constructs to describe and measure the new skills being demonstrated with changes in technology; and (ii) beliefs that the description and measurement of new skills should be assimilated into those of existing constructs. This tension was described by Voogt and Roblin (2012) in their comparative analysis of international frameworks for 21st century skills as an "ongoing controversy on whether these terms are actually used to designate new competences, or rather to give greater emphasis to a specific set of long known competences that are considered as especially relevant to the knowledge society" (Voogt & Roblin, 2012, pp. 301–302). One of the conceptual challenges for ICILS 2013 was to decide whether the construct of CIL should address a new set of competencies or emphasize its connection to existing ones. The research team, in consultation with external experts, eventually opted for the second approach (Fraillon et al., 2013, pp. 15–16). The chosen approach for ICILS aligns with the broader aim of assessing ICT literacy-related competencies, which have been progressively seen as a broad set of transferable, cross-curricular skills. This approach has been maintained in ICILS, which has reported in both 2013 and 2018 that, while approaches varied among and within countries, CIL-related content was included within specific ICT-related subjects and was also regarded as a cross-curricular responsibility (Fraillon et al., 2014, 2020). More recently, the OECD Future of Education and Skills 2030 policy analyses of curricula also reported a pattern across countries for ICT/digital literacy to be embedded within learning areas (OECD, 2020). The ICILS conceptualization of CIL reflects the paradigm of CIL-related skills being integrated within and operating across learning areas (Fraillon et al., 2013). Furthermore, the ICILS conceptualization of CIL required consideration of two fundamental parameters specific to ICILS, which guided the framework and approach:

- ICILS targets school-aged children (in their eighth year of schooling)
- The assessment is completed using computers and focuses on computer use.

The second of these parameters necessitated the establishment of a working definition of *computer* for ICILS. In the final decades of the 20th century, the predominant concept of the computer associated with school-aged children was either as a desktop or laptop computer (but not a smartphone or tablet). These devices could be used for a range of educational purposes, including but not limited to: program development, use of productivity tools (such as word processing or spreadsheet tools), tuition applications, art and design tools, data collection, the conduct of simulations, and searching for information (such as from an encyclopedia). As the internet evolved, many learning and information resources became internet delivered rather than residing on personal devices or local networks, and electronic communication was added to the suite of activities associated with computer use in schools. In the early part of the 21st century, the concept of the computer in education has broadened, largely due to the proliferation of portable digital technologies, in particular tablet devices and smartphones, which can access the internet and run applications.

The use of tablet devices has become increasingly prevalent in schools since ICILS 2013. With each new ICILS cycle we consider the suitability of tablet devices for use in ICILS. For ICILS, the concept of the computer was developed with reference to the primary use of the device in the context of education rather than with reference to the size and portability of the device. However, in doing this, it was acknowledged that the properties of a device do impact on the purposes for which it can best be used. Haßler et al. (2016), following an extensive literature review of reported use of tablet devices in school, suggested that:

> Unsurprisingly, certain technologies are more appropriate for particular tasks than others and this is also true when considering uses for tablets: for example, keyboards, larger screens and specialized software (perhaps only available for certain operating systems) may be needed to support specialized tasks such as extensive writing, mathematical constructions and computer programming. (Haßler et al., 2016, p. 148)

The ICILS test of CIL contains tasks that require students to act as both information consumers and producers. While tablet devices are well suited for information consumption, information production tasks performed on tablet devices are best conducted with sufficiently large screens to manage layout. Screen size can be considered in terms of both the physical size of the screen and the available space on the screen. For tablet devices, the latter is maximized by the use of an external keyboard, which consequently excludes the need for an on-screen keyboard from displaying and greatly reducing the visible screen space. For ICILS 2023, the concept of the *computer* was operationally defined as any device able to run the assessment software with a minimum screen size of 29 cm and an external keyboard and mouse. This included conventional desktop computers, portable computers, and tablet devices with an external keyboard and mouse. The CIL construct for ICILS 2023 was consequently conceptualized with reference to this concept of computer rather than the broader device contexts implicit (although not always measured in practice) in constructs relating to digital literacy, ICT literacy, and digital competence (Australian Curriculum, Assessment and Reporting Authority, 2023; Carretero et al., 2017; Janssen and Stoyanov, 2012; Pangrazio, 2016). In essence, when considering the environment in which CIL can be expressed in ICILS, the manifestation of a *computer* is deemed to require a sufficiently large screen and external keyboard and mouse so that all participating students can be considered to have an equivalent experience of using a computer to manage a broad range of information consumption and production tasks.

At the time ICILS 2013 was in its planning and development stage, the concept of 21st century skills was emerging as an umbrella term to account for skills that are broadly regarded as necessary for successful participation in life, work, and education in the 21st century. Definitions and conceptualizations of 21st century skills in the research literature are varied, but largely influenced by six prominent frameworks (Chalkiadaki, 2018). Some scholars have attempted to identify the common elements of the broad suite of 21st century skills. For example, Van Laar et al. (2017) listed core 21st century digital skills as: technical; information management; communication; collaboration; creativity; critical thinking; and problem solving. They further listed contextual 21st century digital skills as: ethical awareness; cultural awareness; flexibility; self-direction; and lifelong learning. Chalkiadaki (2018) classified 21st century skills into four sets: personal skills; interpersonal and social skills; knowledge and information management skills; and digital literacy (p. 6). What is common across the different conceptualizations of 21st century skills is that they comprise a broad range of skills that typically include a sub-set of skills consistent with CIL as defined in ICILS, but also extending well beyond the reach of what can be assessed in a study such as ICILS. CIL can be regarded as fitting under the broader umbrella of 21st century skills. ICILS was established to investigate the competencies associated with computer and information literacies as enabling components of a broader digital competence, which sits firmly within the suite of 21st century skills. The ICILS research team developed the CIL construct independently of specific curriculum goals; the construct focused on what Lampe et al. (2010) characterized as technology-mediated educational priorities for middle-school students (p. 62). These include finding and synthesizing relevant resources, connecting to people and networks, and knowing how to present and express oneself online in general and through online systems in particular.

With each new cycle of ICILS we need to consider the nature of students' interactions with, and learning with and about newly developing application interfaces, functions and functional types of application (such as the the use of social media platforms, collaborative work-spaces, and the shift from the use of locally installed to web-apps). As part of this process are decisions about how much the introduction of new digital environments necessitates the development of new skills that represent a new *category* of learning in students, in comparison with how much the digital environments initiate an adaptation of existing skills that represent existing *categories* of learning.

2.3 Defining CIL

ICILS defined CIL for use in ICILS 2013 with reference to definitions and constructs associated with information literacy and computer literacy. Information literacy constructs developed first through the fields of librarianship and psychology (Bawden, 2001; Church, 1999; Homann, 2003; Marcum, 2002) and are acknowledged as having the following processes in common: identifying information needs, searching for and locating information, and evaluating the quality of information (Catts and Lau, 2008; Livingstone et al., 2008; UNESCO, 2003). Information literacy constructs evolved to include the ways in which the collected information can be transformed and used to communicate ideas (Catts & Lau, 2008; Peters, 2004). Computer literacy constructs in education typically focus not on the logical reasoning of programming (or the syntax of programming languages) but rather on declarative and procedural knowledge about computer use, familiarity with computers, and, in some cases, attitudes toward computers (Richter et al., 2000; Wilkinson, 2006). As the use of digital technologies expanded for them to become the world's primary information sources, information literacy constructs adopted and then largely subsumed computer literacy constructs (see, for example, Cartelli, 2009).

Some scholars have emphasized the potential for information literacy and ICT skills to develop independently of each other. Catts and Lau (2008) observed that "people can be information literate in the absence of ICT," (p. 7) and Rowlands et al. (2008) commented that "the information literacy of young people, has not improved with the widening access to technology: in fact, their apparent facility with computers disguises some worrying problems" (p. 295). The CIL skills measured and reported on in ICILS, however, address computer literacy skills in the context of information literacy as applied to digital information sources. They reflect a combination of skills that, given the pervasiveness of digital information, continue to have a high profile in contemporary frameworks. For example, as described earlier in this chapter, the DigComp framework defines digital competence in terms of five competences (established in DigComp 2.0 and maintained in DigComp 2.1 and 2.2): information and data literacy; communication and collaboration; digital content creation; safety; and problem solving (Vuorikari et al., 2016). The US NAEP TEL framework also described ICT proficiency in terms of five, albeit different, subareas: construction and exchange of ideas and solutions; information research; investigation of problems; acknowledgment of ideas and information; and selection and use of digital tools.

The definition of CIL established for ICILS 2013 was derived with reference to pre-existing definitions of ICT and digital literacy that illustrated the convergence between information literacy and computer literacy skills in practical real-world applications.

These definitions were:

- Digital literacy is "... the ability to use digital technology, communications tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society" (Lemke, 2003, p. 22).
- Technological literacy is "Knowledge about what technology is, how it works, what purposes it can serve, and how it can be used efficiently and effectively to achieve specific goals" (Lemke, 2002, p. 15).
- Information literacy is "The ability to evaluate information across a range of media; recognize when information is needed; locate, synthesize, and use information effectively; and accomplish these functions using technology, communication networks, and electronic resources" (Lemke, 2002, p. 15).
- "ICT literacy is using digital technology, communications tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society" (Educational Testing Service, 2002, p. 2).
- "ICT literacy is the ability of individuals to use ICT appropriately to access, manage and evaluate information, develop new understandings, and communicate with others in order to participate effectively in society" (Australian Curriculum, Assessment and Reporting Authority, 2007, p. 14).

Common to these definitions is the assumption that individuals have the technical skills needed to use the technologies. The definitions also list very similar sets of information literacy and communication processes. Each also maintains that individuals need to acquire these forms of literacy in order to participate and function effectively in society. Binkley et al. (2011) postulated six categories under which ICT literacy knowledge, skills, attitudes, values, and ethics can be classified: access and evaluate information and communication technology; analyze media; create media products; use and manage information; apply technology effectively; and apply and employ technology with honesty and integrity.

The definition of CIL established in ICILS 2013 and maintained as the definition in ICILS 2018 and ICILS 2023 is:

> Computer and information literacy refers to an individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society.

This definition relies on, and brings together, technical competence (computer literacy) and intellectual capacity (conventional literacies including information literacy) to achieve a highly context-dependent communicative purpose that presupposes and transcends its constituent elements. This view of CIL is congruent with the Audunson and Nordlie (2003) conceptual model of information literacy and, when considering the digital and ICT literacy definitions cited above, is most closely aligned with the construct evident in the Educational Testing Service (2002) definition.

2.4 Revising the Structure of the CIL Construct

According to the ICILS 2013 assessment framework (Fraillon et al., 2013), CIL was described as comprising two strands each of which was specified in terms of a number of aspects.

Strand 1 collecting and managing information comprised three aspects:

- Aspect 1.1: Knowing about and understanding computer use
- Aspect 1.2: Accessing and evaluating information
- Aspect 1.3: Managing information.

Strand 2 producing and exchanging information comprised four aspects:

- Aspect 2.1: Transforming information
- Aspect 2.2: Creating information
- Aspect 2.3: Sharing information
- Aspect 2.4: Using information safely and securely.

The structure described above did not presuppose an analytic structure although, at the time of its development, the ICILS research team anticipated the possibility that Strands 1 and 2 might lead to separate measurement dimensions. Analyses of the ICILS 2013 main survey data included an investigation of the dimensionality (for details regarding the analytic approach see Gebhardt & Schulz, 2015) but the very high latent correlations between the two strands led to the decision to report CIL achievement as a single dimension.

Following ICILS 2013, the project team together with ICILS 2013 national researchers evaluated the CIL construct with reference to its use throughout the full life-cycle of study (Fraillon et al., 2019). While the content of the construct was deemed to be appropriate, they identified potential improvements that could be made to the structure of the CIL construct. Firstly, positioning *knowing about and understanding computer use* (aspect 1.1) within Strand 1 (the receptive strand) and *using information safely and securely* (aspect 2.4) within Strand 2 (the productive strand) was problematic because it undermined the stated acknowledgment that each of these aspects was applicable across both the receptive and productive strands. At the time the CIL construct was specified, this problem was acknowledged with the caveat that the aspects were included in the strands in which they were deemed to have the greatest applicability. However, on reflection, the ICILS research team decided that it would be better to remove any implication that either aspect was more closely associated with receptive or productive skills. Furthermore, in a time of increasing opportunity for young people to become content creators, it became apparent that aspect 2.3 (*sharing information*) should be afforded greater prominence in the structure of the CIL construct. In response to these concerns, and in consultation with ICILS national researchers, the project team established a revised structure for the CIL construct for ICILS 2018 (Fraillon et al., 2019). It is important to note that the restructuring of the CIL construct was undertaken to better communicate the contents and emphases of the construct and to minimize overlap across the aspects of the construct. The change in structure neither means a change in ICILS assessment content nor presupposes a change to the analytic structure of the CIL construct. A similar process of evaluation of the structure of the described CIL construct was conducted following completion of ICILS 2018 and in preparation for or ICILS 2023. No further changes were suggested and, therefore the structure of the described CIL construct used in ICILS 2023 is the same as that used in ICILS 2018.

2.5 Structure of the ICILS 2023 CIL Construct

The CIL construct includes the following elements:

- Strand: This refers to the overarching conceptual category for framing the skills and knowledge addressed by the CIL instruments.
- Aspect: This refers to the specific content category within a strand.

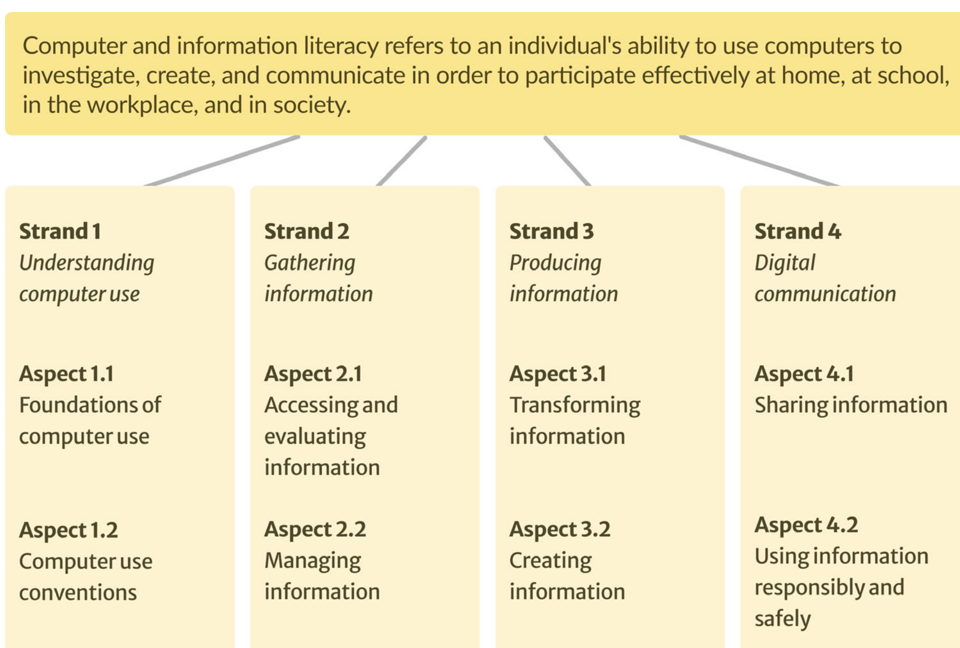

Fig. 2.1 ICILS 2023 CIL construct

The construct comprises four strands, each with two aspects (summarized in Fig. 2.1 and described in detail in Sect. 2.6). The aspects encompass the set of knowledge, skills, and understandings held in common by the range of definitions of ICT literacy and digital competency discussed previously.

2.6 Strands and Aspects of CIL

2.6.1 Strand 1: Understanding Computer Use

Understanding computer use refers to the fundamental technical knowledge and skills that underpin the operational use of computers as tools for working with information. This includes a person's knowledge and understanding of the generic characteristics and functions of computers. Early constructs of ICT and digital literacies typically focused on the receptive and productive elements of information literacy and de-emphasized generic computing technical knowledge and skills (see, for example, Educational Testing Service, 2002). However, as described earlier in this chapter, it soon was acknowledged that fundamental knowledge and skills when using technology could be blended with information literacy in conceptualizations of ICT literacy (Catts & Lau, 2008), and ICILS 2013 included understanding computer use as an aspect of CIL to reflect the evolution of the domain (Fraillon et al., 2013). The role of basic technological skill in digital literacy continues to be important. The DigComp 2.2 framework includes skills associated with solving technical problems and identifying needs and technological responses as part of the problem solving competence area (Vuorikari et al., 2022). The 2018 US NAEP TEL framework included ICT as a major area of assessment "understanding technological principles" as a practice. Understanding technological principles "focuses on students' knowledge and understanding of technology and their capability to think and reason with that knowledge" (National Center for Education Statistics, 2018, p. 69) and the constituent understanding and reasoning is deemed to be applicable across all three major areas of TEL.

Understanding computer use comprises two aspects:

- Foundations of computer use
- Computer use conventions.

Aspect 1.1: Foundations of Computer Use

Foundations of computer use includes the knowledge and understanding of the principles underlying the function of computers, rather than the technical detail of exactly how they work. This knowledge and understanding underpins effective and efficient computer use, including troubleshooting basic technical problems. At a declarative level, students should know, for example, that computers use processors and memory to run programs; or that operating systems, word processors, games, and viruses are examples of programs. Students should be able to demonstrate knowledge that computers can be connected and so can "communicate" with one another through networks, and that these can be local or global. They should understand that the internet is a form of computer network that is run through computers, and that websites, blogs, wikis, and all forms of computer software are designed to meet specific purposes. They should further be aware that information (such as files) can be stored across a range of locations including locally on a device, on removable media (such as USB flash drives, SD cards and portable hard disk drives), and on local or remote networks (such as in cloud storage), and be aware that the various storage locations have specific user benefits, risks, and security procedures.

Following are examples that provide evidence of a student's knowledge and understanding of the foundations of computer use:

- Understanding that computers require physical memory, and that this is finite but may be expanded
- Suggesting basic strategies to improve the performance of a computer that is running slowly
- Explaining why the content of a completed web-based form might be lost if a user navigates away from the page and then returns to the page
- Describing the consequences of working offline on a shared file in comparison to working online
- Identifying components of a computer network that might be malfunctioning if a network connection has been lost.

Aspect 1.2: Computer Use Conventions

Computer use conventions include the knowledge and use of software interface conventions that help users make sense of and operate software. This knowledge supports the efficient use of applications, including the use of devices or applications that are unfamiliar to the user. Accordingly, at the procedural level, a student may know how to execute basic, generic file and software functions, such as opening and saving files in given locations, resizing images, copying and pasting text, entering text in a chat interface, and utilizing accessibility functions (e.g., text to voice), or modifying settings such as display resolution or font size scaling. The procedural knowledge included in aspect 1.2 is thus limited to generic basic commands that are common across digital devices, operating systems and software applications.

Following are examples that provide evidence of a students's ability to apply computer use conventions:

- Editing an image using a graphical user interface with conventional controls typical of graphics editing software
- Clicking on a hyperlink to navigate to a web-page
- Navigating between two or more browser tabs to access multiple web-pages
- Saving an existing file to a new location with a new name
- Opening a file of a specified type
- Selecting one or more contacts to send a message to.

2.6.2 Strand 2: Gathering Information

Gathering information embraces the receptive and organizational elements of information processing and management. This strand comprises two aspects:

- Accessing and evaluating information
- Managing information.

Aspect 2.1: Accessing and Evaluating Information
Accessing and evaluating information refers to the combined investigative processes that enable a person to find, retrieve, and make judgments about the relevance, integrity, and usefulness of computer-based information. The extensive reach and wide accessibility of the internet in many countries, make it a primary communication medium for diverse actors (including individuals and groups) who use it in ways specific to their needs and objectives. Consequently, a vast array of competing information is available to individual end-users. At the point of accessing information, a user may know very little about how the information was created, including the quality assurance processes undertaken in the creation of the information. This information is not only increasing in volume but is also evolving with advances in technologies such as the capacity of AI to generate digital content. One consequent challenge is for information seekers to filter information to identify what is relevant, credible and ultimately useful.

Further to this, the increasing intuitiveness of computer-based information search and retrieval programs,[1] and the presentation of "curated" content by information platforms places an additional demand on users to consider the processes that are leading to the presentation of content to them, and to use this to evaluate the breadth and adequacy of their access to information.

While accessing and evaluating information are rooted in conventional literacies, the multimodal and evolving nature of computer-based information requires different processes that stand apart from those related only to traditional literacies. Accessing and evaluating computer-based information involves a unique amalgamation of skills (i.e., those typically associated with digital and media literacies) that differ from, and are broader than, the range of skills employed with conventional literacies.

The following examples illustrate tasks that provide evidence of an individual's ability to access and evaluate computer-based information:

- Selecting information from within a website or file list that is relevant to a particular topic
- Describing and explaining the functions and parameters of different computer-based information search programs
- Suggesting strategies for searching for information and/or adjusting the parameters of searches to better target information
- Recognizing and explaining characteristics of computer-based information (such as hyperbole and unsubstantiated claims) that detract from its credibility
- Analyzing the bias in social media influencers' product reviews by considering factors such as financial incentives for positive reviews

[1] This includes search engines that tailor search results to individual searchers using their personal data, algorithmically curated news feeds in social media, and large language models that synthesize new information in response to a user's query.

- Suggesting and implementing strategies to verify information, such as cross-checking with multiple sources.

Aspect 2.2: Managing Information
Managing information involves understanding and applying techniques and tools to handle, organize, store, and protect computer-based information. It plays a central role in today's digital age, where information is a valuable asset to be managed with care and expertise. Information to be *managed* can take various forms, such as files that can be saved, accessed, and modified using specific applications, or data that can be systematically organized within these files. File management involves handling files that can be stored and opened with various applications for later use. These files may contain different types of content, including text documents, spreadsheets, or multimedia. Within files, data can be organized in structured formats like tables or tabular data grids. Metadata properties might also be used to describe the document's content, references, version, or other pertinent attributes.

The process of managing information includes the ability to adopt and adapt different classification and organization schemes. These schemes enable users to arrange and store information systematically, ensuring that it can be accessed, used, or reused efficiently. Managing information also involves selecting and utilizing various file storage locations, such as local drives, remote network locations, or cloud-based services. These choices must be evaluated in terms of the trade-offs that support user access and collaboration across different platforms and devices. For example, local file storage can be accessed quickly and reliably without internet access, while cloud storage provides redundancy in the event of accidental or malicious local data loss.

Following are examples that provide evidence of an individual's ability to manage information:

- Creating a file and folder structure according to given parameters
- Sorting or filtering information on an internet database
- Explaining how the application of metadata tags can enhance searchability and categorization of digital content
- Recognizing the most relevant data type (i.e., text string or numerical) for a given purpose within a simple database.

2.6.3 Strand 3: Producing Information

This strand, which focuses on using computers as productive tools for thinking and creating, has two aspects:

- Transforming information
- Creating information

Aspect 3.1: Transforming Information
Transforming information refers to a person's ability to use computers to modify and present information in a way that enhances its clarity and communicative efficacy for specific audiences and purposes. The process of transforming information is more than merely changing the appearance of the content of information. Guided by an understanding of the audience and purpose of a communication, this process involves thoughtful selection and integration of the formatting, graphical, and multimedia capabilities of software applications to augment the communicative impact of information that might otherwise be presented as plain text or data. Computers offer a wide array of formatting tools that can be used to enhance the flow and visual appeal of information. These include adjusting fonts and colors to signal the purpose of text elements (such as headings, lists or labels) in order to guide viewers' attention and support their comprehension of the content. By integrating images, icons, diagrams, charts, and animations, content creators can use visual information to supplement or even replace text.

Following are examples that provide evidence of an individual's ability to transform information:

- Formatting the titles in a document or presentation to enhance the flow of and readability of information
- Using, modifying, or creating images to supplement or replace text in a document (such as with a flow chart, diagram, or iconography)
- Creating visual representations of tabular data (such as temperature or velocity) to illustrate change over time
- Creating a short animated sequence of images to illustrate a sequence of events.

Aspect 3.2: Creating Information

Creating information refers to a person's ability to use computers to design and generate information products tailored to specified purposes and audiences. These original products may involve the creation of entirely new content or may expand upon existing content to generate new understandings.

Typically, the quality of information created relates to how the content is structured (whether or not the flow of ideas is logical and easy to understand) and the way in which layout and design features (such as images and formatting) are used together to support the viewer's understanding of the emergent information product. Even though information design and layout design are executed together in creation of an information product, they are typically conceptualized and assessed as discrete elements of creating information.

Following are examples that provide evidence of an individual's ability to create information:

- Defining a descriptive title for document, presentation or animation
- Organizing facts and figures under relevant sub-headings in some research notes
- Integrating text, data, and graphics from multiple sources to make recommendations in a report
- Using a simple graphics program to design a birthday card
- Designing and writing a presentation that explains the key elements of an historical event

2.6.4 Strand 4: Digital Communication

Digital communication encompasses the competencies associated with information sharing through various online platforms, such as instant messaging, social media, and other public or private community forums together with the social, legal, and ethical responsibilities that entail sharing information with others. This strand also includes the implementation of strategies and mechanisms to protect against the misuse of communication tools and personal information by others.

This strand has two aspects:

- Sharing information
- Using information safely and securely

Aspect 4.1: Sharing Information

Sharing information refers to a person's knowledge and understanding of how computers are used and can be used, as well as his or her ability to use computers to exchange information with others. This includes knowledge and understanding of the conventions established by a range of computer-based communication platforms such as, email, instant messaging, blogs, wikis, media sharing platforms, and social media networks. Given the rapidly changing nature of this area, aspect 4.1 focuses on the knowledge and understanding of technical and social conventions associated with sharing information and, at the higher end of the achievement spectrum, the social impact of sharing information through computer-based communication media.

Following are examples that provide evidence of an individual's ability to share information:

- Recognizing some key differences between computer-based communication media
- Using software to disseminate information (such as attaching a file to an email or adding content to a social media network)
- Evaluating the appropriateness of information for a specified audience
- Explaining why a communication platform is best suited for a particular communicative purpose
- Limiting the visibility of content added to a social media network to a set of known contacts.

Aspect 4.2: Using Information Responsibly and Safely

Using information responsibly and safely refers to a person's understanding of the legal and ethical issues of computer-based communication from the perspectives of both a content creator and an information consumer. Many internet-based communication platforms facilitate and encourage users to create and share information with others, including those outside their own network of personal contacts. With this facility comes the risk of contributing to the spread of misinformation and the misuse of one's own information by others, particularly when dealing with personal information. As both consumers and creators of content, individuals bear a significant responsibility to exercise respectful discretion and to critically evaluate information when sharing it with others. Using information responsibly and safely hence includes risk identification and prevention, as well as the parameters of appropriate conduct, including awareness and prevention of cyberbullying, identity theft, and online scams. It furthermore encompasses the responsibility of users to maintain a certain level of information security and identity protection by keeping virus software up to date, using contemporary authentication methods to prevent unauthorized access to devices and online accounts, and withholding private information from unknown contacts and publishers.

The following examples reflect content and contexts related to using information responsibly and safely:

- Fake news dissemination
- Identity theft
- Unauthorized access and impersonation
- Identity concealment
- Phishing
- Online scams
- Malicious software distribution
- Automatic collection of internet usage data
- Publicly shared social media posts
- Provision and use of personal information
- Disclosure of affiliations
- Attribution and copyright.

Following are examples that provide evidence of an individual's ability to use information safely and securely:

- Explaining why people engage with fake news
- Identifying the characteristics that influence the strength of passwords
- Explaining the consequence(s) of making personal information publicly available
- Describing protocols for appropriate behavior in group communications
- Suggesting ways to protect private information
- Suggesting ways to verify a person's online identity
- Identifying various forms of paid advertising on website
- Explaining the techniques used in a phishing email scam.

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3 Computational Thinking Framework

Daniel Duckworth and Julian Fraillon

3.1 Background

The International Computer and Information Literacy Study (ICILS) 2013 was established to address the growing consensus on the importance of computer and information literacy (CIL)-related skills for effective participation in the 21st century. At the same time as ICILS was being developed and implemented, there was a renewed focus among researchers, educators, and policymakers on the significance of computational thinking (CT) in education (Voogt et al., 2015; Weintrop et al., 2021). The decision to include CT as an international option in ICILS 2018 was influenced by the growing emphasis on computer science and CT in educational curricula, as well as international efforts to broaden student access to these domains (Bocconi et al., 2022; Caeli & Bundsgaard, 2020; Peyton Jones, 2011; Yadav et al., 2018). Similar to CIL, CT is measured and reported using an internationally comparable achievement scale. In ICILS 2018, a unidimensional CT scale was established with "exploration of the potential of sub-dimensions of CT to be reported... planned for future cycles of ICILS" (Fraillon et al., 2020, 92). The ICILS 2023 is the first cross-national study to measure trends in CT, and offers the first opportunity to further investigate the dimensional structure of the CT construct.

In this chapter we describe the key influences that have shaped the field of CT and discuss the establishment and ongoing review of the ICILS CT construct. We then explain the development of the ICILS CT construct and provide detail of its constituent definitions and content.

Early conceptualizations of *computer literacy* in education typically focused not on the logical reasoning of programming (or the syntax of programming languages) but rather on declarative and procedural knowledge about computer use, familiarity with computers (including their uses), and, in some cases, attitudes toward computers (Richter et al., 2000; Wilkinson, 2006).

In the early stages of computer integration into educational settings, the focus was on teaching foundational computing principles. During this period, the relationship between "programming" and problem-solving was increasingly recognized as important for educational development (Papert, 1980). A notable development in the 1980s was the introduction of the text-based programming language, *Logo*. In *Logo*, typed commands controlled a cursor or a robotic "turtle" on the screen, facilitating line graphics. Many educational methodologies rooted in constructionism and cognitive development often employed *Logo* as a foundational tool (Maddux & Johnson, 1997; McDougall et al., 2014; Tatnall & Davey, 2014). However, by the mid 1990s *Logo* had "acquired the character of a cannonical curriculum topic" (Kilpatrick and Davis, 1993, 208) and it arguably lost status as a transformative pedagogical tool (Agalianos et al., 2001; Cansu & Cansu, 2019).

The advent of block-based coding platforms, such as *Scratch*, *Blockly Games*, *Code.Org*, *AppInventor*, *mBlock*, *Alice*, *KoduGameLab*, *Snap!*, and *Tynker* has allowed users to construct programs by dragging and dropping graphical blocks that symbolize computational concepts (e.g., variables, logical expressions) and code structures. Block-based coding environments are regarded as valuable tools in the teaching of CT competencies, in particular for novice or beginning programmers (Fidai et al., 2020; Fadhillah et al., 2023; Xu et al., 2016). In a content analysis of practice-based research, Kiliç (2022) found that programming and robotics are very commonly used approaches in the teaching of CT, with the use of block-based coding tools being "generally preferred" (Kiliç, 2022, 296). Within the context of assessing learning in this area, block-based coding is especially relevant because it codifies the algorithmic logic that underpins CT, while eliminating the need for syntactic knowledge and the potential for keyboard errors, as no manual code typing is required.

The inclusion of CT in ICILS has provided an opportunity to separately define and measure the functional aspects of digital literacy that support the use of digital devices when managing digital information (measured using the CIL assessment), from the problem solving and algorithmic thinking features of computer literacy that are core to CT. By defining CT and operationalizing its measurement in an international large scale assessment, ICILS implicitly aimed to contribute to a reduction

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of some of the inevitable definitional confusion that existed across the various efforts to reestablish the role of CT in school education (Denning, 2017; Grover, 2017; Grover & Pea, 2013; Lodi & Martini, 2021; Selby & Woollard, 2013; Voogt et al., 2015).

3.2 Establishing the Parameters of CT

While CT has been recognized "since the beginning of the computing field in the 1940s" (Denning, 2017, 34), many researchers refer to the work of Papert (1980, 1991) in the late 20th century as a touchstone for CT research. Papert's conceptualization of CT is embedded in his constructionist educational philosophy. In contrast to focusing only on technical proficiencies, Papert also emphasizes the social and affective dimensions of CT. By *social dimensions*, Papert refers to the cooperative and communicative aspects that emerge when students engage in computational projects, often necessitating teamwork, sharing of resources, and communal problem-solving. The *affective dimensions* imply the emotional investment and motivation that students experience when actively involved in the construction of computational artifacts.[1] Papert believed that these social and affective aspects enrich the learning experience, making CT an interdisciplinary tool applicable across various educational contexts. Wing's 2006 article on CT has been regarded by many researchers as the catalyst, or at least as a common point of reference, for the re-emergence of interest in CT (see, for example, Barr & Stephenson, 2011; Bower et al., 2014; Grover & Pea, 2013; Shute et al., 2017; Voogt et al., 2015). In this article, Wing characterized CT as "a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" (Wing, 2006, 33).

Wing (2006) regarded CT as a concept that embraces problem solving and system design, and is based on the principles and technical competencies associated with computer science. This concept includes the ways of thinking when programming a computer as part of computer literacy (Grover & Pea, 2013; Lye & Koh, 2014). For Wing, CT is the foundation for understanding the algorithmic fabric of the world and is supported by the "computational concepts we use to approach and solve problems, manage our daily lives, and communicate and interact with other people" (Wing, 2006, 35). Computational thinking can be seen as "applying tools and techniques from computer science to understand and reason about both natural and artificial systems and processes" (The Royal Society, 2012, 29).

Shute et al. (2017) argued that CT is required to solve problems algorithmically (with or without the assistance of computers) by applying solutions that are reusable in different contexts. They elaborated that CT is "a way of thinking and acting, which can be exhibited through the use of particular skills, which then can become the basis for performance-based assessments of CT skills" (Shute et al., 2017, 142). They suggested that CT involves six facets: decomposition, abstraction, algorithms, debugging, iteration, and generalization. Note that such conceptualizations of CT do not necessarily involve developing or implementing a formal computer program (Barr et al., 2011), since algorithmic instructions can be carried out by a human or a computer (Shute et al., 2017, 12). Consequently, assessments of CT can be conducted on a computer or without the use of technology depending on the parameters of the assessment including, but not limited to, its purpose and the age and CT experience of the test-takers (Weintrop et al., 2021). ICILS makes use of computer-based delivery to capture data that reflect the steps involved with students' use of CT to solve problems. These steps can include any of the aspects of planning, solution generation and evaluation that include but also extend beyond developing or assembling instructions (often including blocks of code) that are necessary to accomplish a task (Brennan & Resnick, 2013; Fraillon, 2018).

At the time when CT was reemerging as an area of interest in curriculum and assessment, there was a broad range of perspectives on CT and that could be characterized in the divergent conceptualizations advocated by Wing and Papert (Lodi and Martini, 2021). Wing's perspective highlighted the technical competencies and the role of CT as a lens for understanding the world, while Papert's perspective emphasized the broader social and affective aspects of cross-disciplinary learning through CT.

The National Academies Press (NAP) reported on a 2009 workshop on the nature of CT that cited the following perspectives on CT (National Research Council, 2010, 11–12):

- CT is "closely related to, if not the same as...procedural thinking...that includes developing, testing, and debugging procedures"
- CT is about "expanding human mental capacities through abstract tools that help manage complexity and allow for automation of tasks"

[1] Computational artifacts refer to tangible byproducts or outcomes generated through computational processes or CT. For example, a text prompt for a large language model like ChatGPT serves as a specialized input designed to elicit a specific output, encapsulating the abstraction and algorithmic thought involved in its creation.

- CT is primarily about “processes” and “is a subset of computer science”
- CT is “the use of computation-related symbol systems (semiotic systems) to articulate explicit knowledge and to objectify tacit knowledge, to manifest such knowledge in concrete computational forms”
- CT is about “rigorous analyses and procedures for accomplishing a defined task”
- CT “is a bridge between science and engineering-a meta-science about studying ways or methods of thinking that are applicable to different disciplines”
- CT is “‘what humans do as they approach the world [that is, their framing, paradigm, philosophy, or language], considering processes, manipulating digital representations (and [meta] models),’ and hence all humans engage in computational thinking to some extent already in their daily lives”
- CT “plays a role in the manipulation of software in support of problem solving”
- “What makes computational thinking especially relevant is that computers can execute our ‘computational thoughts’”.

The range of different perspectives listed above exemplifies some of the tensions that have existed in conceptualizations of CT. These tensions are associated with identifying where CT should be located on a spectrum of capabilities that, at one end, are characterized by algorithmic procedural thinking associated with computer programming and, at the other end, are described by a broader suite of problem solving capabilities and dispositions (see, for example, Barr et al., 2011; Barr & Stephenson, 2011; Cansu & Cansu, 2019; Voogt et al., 2015). In reflecting on attempts to define CT, Voogt described the tension between “thinking of the ‘core’ qualities of CT versus certain more ‘peripheral’ qualities” (Voogt et al., 2015, 718).

For ICILS, the definition and explication of CT, as for CIL, were established in the context of the ICILS assessment parameters. In this case the assessment of CT must be:

- Applicable to students in their eighth year of schooling
- Applicable across a broad range of country and curriculum contexts
- Complementary to the ICILS assessment of CIL
- Minimally overlapping with assessment content in other curriculum areas (such as in mathematics or science).

With these parameters in mind, the conceptualization of CT in ICILS combines the competencies associated with (a) framing solutions to real-world problems in a way that these solutions could be executed by computers; and then (b) implementing and testing solutions using the procedural algorithmic reasoning that underpins programming.

3.3 Defining CT

Computational thinking was defined for use in ICILS 2018 with reference to existing conceptualizations and definitions of CT at the time. In a review of CT literature, Selby and Woollard (2013) identified three consistently shared constituent components of CT: (a) a *thought process* (a way of thinking about computing); (b) *abstraction* (describing the common underlying properties and functionality of a set of entities); and (c) *decomposition* (breaking a complex problem into well-defined parts). More recently, based on a review of existing CT constructs, Cansu and Cansu (2019) suggested five essential concepts of CT: *abstraction*, *problem decomposition*, *algorithmic thinking*, *automation*, and *generalization*. The International Society for Technology in Education (ISTE) Standards list five core components of CT: *decomposition, gathering and analyzing data, abstraction, algorithm design,* and *how computing impacts people and society* (ISTE, 2018). These are examples of the differences in the number and nature of attributes listed across descriptions of CT. These differences are, however, primarily influenced by the degree of specificity with which the way of thinking about computing (Selby & Woollard, 2013) is defined (whether this includes, for example, algorithmic thinking, or algorithm design) and the emphasis and specificity provided for the application of CT to solve real-world problems (whether this includes, for example, generalization, gathering and analyzing data and the interaction between humans and computers). These differences are primarily ones of emphasis and breadth. In contrast Voogt et al. (2015) adopted a broader conceptual approach by suggesting that many definitions of CT focus on the “skills, habits and dispositions needed to solve complex problems with the help of computing” (p.720).

Following is a selection of definitions and descriptions of CT that were used to inform the development of the definition of CT established for use in ICILS.

1. “Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (Wing, 2006, as cited by Grover and Pea 2013, p. 39).
2. “We consider computational thinking to be thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms” (Aho, 2012, 832).
3. “It [computational thinking] is a cognitive or thought process that reflects:
   - the ability to think in abstractions,
   - the ability to think in terms of decomposition,
   - the ability to think algorithmically,
   - the ability to think in terms of evaluations, and
   - the ability to think in generalizations” (Selby & Woollard, 2013, 5).
4. “Computational thinking describes the processes and approaches we draw on when thinking about how a computer can help us to solve complex problems and create systems” (Education Services Australia, 2018).
5. “Computational thinking is the process of recognizing aspects of computation in the world that surrounds us, and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes” (The Royal Society, 2012, 29).
6. “Computational thinking is a problem-solving process that includes:
   - Formulating problems in a way that enables us to use a computer and other tools to help solve them
   - Logically organizing and analyzing data
   - Representing data through abstractions, such as models and simulations
   - Automating solutions through algorithmic thinking (a series of ordered steps)
   - Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
   - Generalizing and transferring this problem-solving process to a wide variety of problems” (Barr et al., 2011, 21).
7. “Computational thinking is a term often used to describe the ability to think with the computer-as-tool” (Berland & Wilensky, 2015, 630).

More recently, Denning and Tedre (2021) proposed the definition: “Computational thinking is the mental skills and practices for *designing* computations that get computers to do jobs for us, and for *explaining* and *interpreting* the world in terms of information processes” (p.365).

In all these definitions, CT is viewed as a problem-solving approach where problems are framed in a manner suitable for algorithmic and step-by-step solutions that can be executed by a computer. These characteristics are consistent with the ICILS conceptualization of CT as focusing on problem solving with computer-based solutions. While it can reasonably be argued that the core of this conceptualization of CT may be applied to other learning domains, the ICILS test of CT does not include measurement of cross-domain applications of CT. Based on the outcomes of the review of CT literature published since ICILS 2018 and the consultation with ICILS researchers the definition of CT established in 2018 for ICILS has remained unchanged.

The definition of CT established within the context of ICILS is:

> Computational thinking refers to an individual’s ability to recognize aspects of real-world problems which are appropriate for computational formulation and to evaluate and develop algorithmic solutions to those problems so that the solutions could be operationalized with a computer.

3.4 Structure of the ICILS 2023 CT Construct

The CT construct includes the following elements:

- Strand: This refers to the overarching conceptual category for framing the skills and knowledge addressed by the CT instruments.
- Aspect: This refers to the specific content category within a strand.

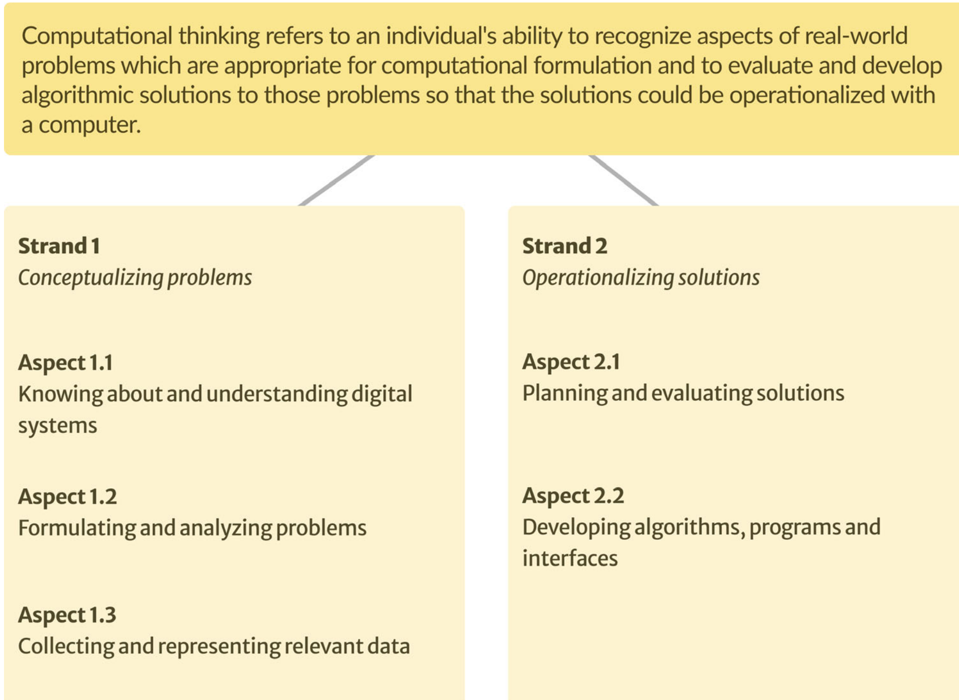

Fig. 3.1 ICILS 2023 CT construct

The CT construct comprises two strands. One strand contains three aspects and the other comprises two aspects (summarized in Fig. 3.1 and described in detail in Sect. 3.5). The aspects encompass the set of knowledge, skills, and understandings held in common across the range of definitions of CT as discussed previously.

The structure shown above does not presuppose a sub-dimensional structure of the CT construct. The primary purpose of describing CT using this structure is to organize the CT content in a way that allows readers to clearly see the different related aspects of CT and to support the auditing of the CT instruments against the full breadth of content in the CT construct. In ICILS 2018 CT was reported as a single measurement dimension (Fraillon et al., 2020) and, although we anticipate that ICILS 2023 will again report CT as a single dimension, the dimensional structure of the CT data will be examined as part of ICILS 2023 to explore the potential for reporting any sub-dimensions of CT.

3.5 Strands and Aspects of CT

3.5.1 Strand 1: Conceptualizing Problems

Conceptualizing problems acknowledges that before solutions can be developed, problems must first be understood and framed in a way that allows algorithmic or systems thinking to assist in the process of developing solutions. This strand comprises three aspects:

- Knowing about and understanding digital systems
- Formulating and analyzing problems
- Collecting and representing relevant data.

Aspect 1.1: Knowing About and Understanding Digital Systems

Knowing about and understanding digital systems refers to a person's ability to identify and describe the properties of systems by observing the interaction of the components within a system.

Systems thinking is used when individuals conceptualize the use of computers to solve real-world problems, which is fundamental to CT.

At a declarative level a person can describe rules and constraints that govern a sequence of actions and events, or they may provide a prediction for why a procedure is not working correctly by observing the conditions of the error. For example, if a student was required to design a game, they would need to specify: the initial state of the game, the winning condition of the game, the parameters of the permissible actions, and sequence of actions within the game.

At a procedural level, a person can monitor a system in operation, make use of tools that help to describe a system (such as tree diagrams or flow charts), and observe and describe outcomes of processes operating within a system. These procedural skills are based on a conceptual understanding of fundamental operations such as iteration, looping, conditional branching, and the outcomes of varying the sequence in which they are executed (control flow). An understanding of these operations can enhance a person's understanding of both the digital world and the physical world; and it can therefore assist in solving problems. With reference to the above example of a student designing a game, at the procedural level the student might initiate and adjudicate the game play. The student would need to monitor the players' actions and the consequent outcomes according to the specified rules and conditions of the game. In conducting this oversight, the student may identify problems within the game, such as unresolvable or ambiguous scenarios (e.g., a stalemate in chess). Conceptually, the student would then have the capacity to adjust the game parameters to resolve these problems.

It is not always necessary that the game be created as a computer application, as *digital systems thinking* can also be applied to non-digital systems. In the context of ICILS, *digital systems thinking* can be applied to describe the actions of a physical system (such as filling a glass with water from a tap) in such a way that these actions could later be controlled by a computer program.

Following are examples that provide evidence of an individual's ability to know about and understand digital systems:

- Exploring a system to describe rules about its behavior
- Operating a system to produce relevant data for analysis
- Identifying opportunities for efficiency and automation
- Explaining why simulations help to solve problems.

Aspect 1.2: Formulating and Analyzing Problems

Formulating problems entails the decomposition of a problem into smaller manageable parts and specifying and systematizing the characteristics of the task so that a computational solution can be developed (possibly with the aid of a computer or other digital device). Analyzing problems consists of making connections between the properties of, and solutions to, previously experienced and new problems to establish a conceptual framework to underpin the process of breaking down a large problem into a set of smaller, more manageable parts.

Following are examples that provide evidence of an individual's ability to formulate and analyze problems:

- Breaking down a complex task into smaller, more manageable parts
- Creating a self-contained sub-task that could potentially be applied repeatedly
- Exploring the connection between the whole and its individual constituent parts.

Aspect 1.3: Collecting and Representing Relevant Data

In order to make effective judgments about problem solving within systems it is necessary to collect and make sense of data from the systems. The process of collecting and representing data effectively is underpinned by knowledge and understanding of the characteristics of the data and of the mechanisms available to collect, organize, and represent these data for analysis. This could involve creating or using a simulation of a complex system to produce data that may show patterns or characteristics of behavior that are otherwise not clear when viewed from an abstract system level.

Following are examples that provide evidence of an individual's ability to collect and represent data:

- Identifying an abstracted representation of map directions
- Using a route simulation tool to store data
- Displaying data to help draw conclusions and inform planning
- Using a simulation tool to collect data and evaluate outcomes.

3.5.2 Strand 2: Operationalizing Solutions

Operationalizing solutions comprises the processes associated with creating, implementing and evaluating computer-based system responses to real-world problems. It includes the iterative processes of planning for, implementing, testing, and evaluating algorithmic solutions (as the potential bases for programming). The strand includes an understanding of the needs of users and their likely interaction with the system under development. The strand comprises two aspects:

- Planning and evaluating solutions
- Developing algorithms, programs and interfaces.

Aspect 2.1: Planning and Evaluating Solutions
Planning solutions refers to the process of establishing the parameters of a system, including the development of functional specifications or requirements relating to the needs of users and desired outcomes and with a view to designing and implementing the key features of a solution. Evaluating solutions refers to the ability to make critical judgments about the quality of computational artifacts (such as algorithms, code, programs, user interface designs, or systems) against criteria based on a given model of standards and efficiency. These two processes are combined in a single aspect because they are iteratively connected to the process of developing algorithms and programs. While the process of developing algorithms may begin with planning and end with evaluation, throughout the process there is an ongoing iterative cycle of planning, implementation, evaluation, and revision (with resolution being a final end-point). Typically, there is a broad array of potential solutions to any given problem and, consequently, it is important to be able to plan and evaluate solutions from a range of perspectives, and to understand the advantages, disadvantages, and effects of alternative solutions.

Following are examples that provide evidence of an individual's ability to plan and evaluate computational solutions:

- Identifying the starting point for an algorithmic solution to a problem by reflecting on solutions to similar problems
- Designing components of a solution taking into account the limitations of the system and the needs of users
- Testing a solution method against a known outcome and adjusting it as necessary
- Comparing the relative advantages and disadvantages of a solution against alternative solutions
- Locating a faulty step in an algorithm
- Describing solutions and explaining why they are the best solution among many
- Implementing and managing strategies to test the efficacy of a solution (such as user testing).

Aspect 2.2: Developing Algorithms, Programs and Interfaces
This aspect focuses on the logical reasoning that underpins the development of algorithms (and code) to solve problems. It can involve developing or implementing an algorithm (systematically describing the steps or rules required to accomplish a task) and also automating the algorithm, typically using computer code in a way that can be implemented without the need for students to learn the syntax or features of a specific coding language. Creating an interface relates to the intersection between users and the system. This may relate to development of the user interface elements in an application including implementation of specifications for dynamic interfaces that respond to user input.

Following are examples that provide evidence of an individual's ability to develop algorithms, programs, and interfaces include the following:

- Modifying an existing algorithm for a new purpose
- Adapting visual directions into instructions for a computer
- Creating visual representations of instructions for a computer
- Creating a simple algorithm
- Using a new statement in a simple algorithm
- Creating an algorithm that combines simple command statements with a repeat or conditional statement
- Correcting a specified step in an algorithm.

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4 Contextual Framework

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4.1 Overview

This chapter describes the contextual information collected during the International Computer and Information Literacy Study (ICILS) 2023 in order to aid understanding of variation in the primary outcome achievement measures of the study: students' computer and information literacy (CIL) and computational thinking (CT). Throughout this chapter, the abbreviation CIL/CT has been used where each of CIL and CT may be considered as an outcome measure potentially influenced by a given set of contextual information. We provide a classification of contextual factors that accords with the multilevel structure inherent in the process of student CIL/CT learning, and consider the relationship of these factors to the learning process (antecedents or processes). We also list the different kinds of variables that will be collected via the different ICILS 2023 contextual instruments and briefly outline prior findings from educational research in order to explain why these variables are included in ICILS 2023.

4.2 Classification of Contextual Factors

When studying student outcomes related to CIL/CT, it is important to set these in the context of the different factors influencing them. Students acquire competencies in this area through a variety of activities and experiences at the different levels of their education and through different processes in school and out of school. It is also likely that students' out-of-school experiences of using ICT influence their learning approaches in school (Ainley et al., 2009; Biagi and Loi, 2013; Bundsgaard and Gerick, 2017). Contextual variables can also be classified according to their measurement characteristics, namely, factual (e.g., age), attitudinal (e.g., enjoyment of computer use), and behavioral (e.g., frequency of computer use).

Different conceptual frameworks for analyzing educational outcomes frequently point out the multilevel structure inherent in the processes that influence student learning (see, for example, Fraillon et al., 2020b; Gerick et al., 2017; Hatlevik et al., 2015; Schulz et al., 2016; Vanderlinde et al., 2014). The learning of individual students is set in the overlapping contexts of school learning and out-of-school learning, both of which are embedded in the context of the wider community that comprises local, national, supranational, and international contexts. As for the two previous cycles of ICILS, the contextual framework of ICILS distinguishes the following levels:

- *Wider community:* This level describes the wider context in which CIL/CT learning takes place. It comprises local community contexts (e.g., remoteness and access to internet facilities), as well as characteristics of the education system and country. Furthermore, it encompasses the global context, a factor widely enhanced by access to the internet.
- *Schools and classrooms:* This context encompasses all school-related factors. Given the cross-curricular nature of CIL/CT learning, it is not useful to distinguish between classroom level and school level.
- *Home environment:* This context relates to the student's background characteristics, especially in terms of the learning processes associated with family, home, and other immediate out-of-school contexts.
- *The individual:* This context includes the characteristics of the student, the processes of learning, and the student's level of CIL/CT.

The status of contextual factors within the learning process is also important. Factors can be classified either as antecedents or processes:

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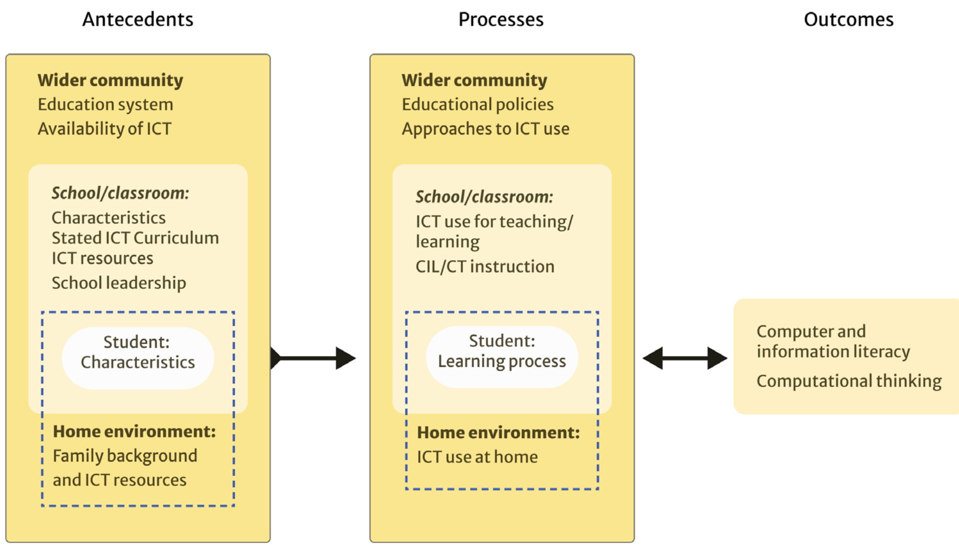

Fig. 4.1 Contexts for ICILS 2023 CIL/CT learning outcomes.
Notes: The double arrow between process-related factors and outcomes emphasizes the possibility of a reciprocal association between learning processes and learning outcomes. The single arrow between antecedents and processes indicates the assumption within the ICILS contextual framework of a unidirectional influence between these types of contextual factors

- Antecedents are exogenous factors that condition the ways in which CIL/CT learning takes place. They are contextual factors that are not directly influenced by learning-process variables or outcomes. It is important to recognize that antecedent variables are level specific and may be influenced by antecedents and processes found at higher levels, for example, the availability of ICT resources in schools/classrooms (a school/classroom antecedent) is likely to be influenced by ICT education policies at the level of the education system (a wider community antecedent).
- Processes are those factors that directly influence CIL/CT learning. They are constrained by antecedent factors and factors found at higher levels. This category contains variables such as opportunities for CIL/CT learning during class, teacher attitudes toward using ICT for study tasks, and students' use of computers at home.

Both antecedents and processes need to be taken into account when explaining variation in CIL/CT learning outcomes. Whereas antecedent factors shape and constrain the development of CIL/CT, process factors can be influenced by the level of (existing) CIL/CT learning. For example, the level and scope of classroom exercises using ICT generally depend on the existing CIL/CT-related proficiency of the students.

When classifying antecedent and process-related contextual factors according to their relationship with CIL/CT outcomes located at the different levels, each type of factor at each level is accompanied by examples of variables that have the potential to influence learning processes and outcomes (Fig. 4.1). It is important to note that there is a reciprocal association between learning processes and learning outcomes while there is a unidirectional influence between antecedents and processes. Reference to this general conceptual framework enables potential contextual factors to be located on a two-by-four grid, where antecedents and processes constitute the columns and the four levels the rows (Table 4.1) shows examples of the contextual variables collected by the ICILS 2023 instruments). Data on contextual factors pertaining to the level of the individual student and his or her home context are collected in the student questionnaire. Data on contextual factors associated with the school/classroom level are collected using the student, teacher, school principal, and ICT coordinator questionnaires. Contextual data at the level of the wider community is collected using the national contexts survey, the principal and ICT coordinator questionnaires and other available sources (e.g., published statistics).

Table 4.1 Mapping of variables to contextual framework (examples)

Level of …	Antecedents	Processes
Wider community	**NCS, PQ, ICQ and other sources:** Structure of education Availability of ICT	**NCS, PQ, ICQ and other sources:** Role of ICT in curriculum Approaches to ICT use
School/classroom	**PrQ, ICQ, & TQ:** School characteristics ICT resources School leadership	**PrQ, ICQ, TQ and StQ:** ICT use in teaching and learning CIL/CT instruction
Student	**StQ:** Gender Age	**StQ:** ICT activities Use of ICT CIL/CT
Home environment	**StQ:** Parent socioeconomic status ICT resources	**StQ:** Learning about ICT at home

Notes: NCS = national contexts survey; PrQ = principal questionnaire; ICQ = ICT coordinator questionnaire; TQ = teacher questionnaire; StQ = student questionnaire

4.3 Contextual Levels and Variables

4.3.1 The Wider Community Context

Levels within the wider community context all have the potential to affect student learning at school or at home. Conceptually, this context has several levels:

- *Local communities*, where remoteness and lack of stable and fast internet connections may affect conditions for ICT use
- *Regional and national contexts*, where communication infrastructure, educational structures, curricula, and general economic/social factors may be of importance
- *Supranational or even international contexts*, where a long-term perspective brings in, for example, factors such as the general advance of ICT on a worldwide scale.

The most important factors potentially explaining variation in CIL/CT are located at the national level (or subnational level in those instances of sub-regions participating in the study). Across previous cycles of ICILS there was evidence of broad differences across countries in terms of access to digital technology (Fraillon et al., 2020b, 2014).

Information relating to the contexts of education systems will primarily be sourced from the ICILS 2023 national contexts survey, and supplemented by information from external databases and other published sources. Typically, these published sources provide information about antecedent country-context variables, while the national contexts survey will deliver data on antecedent and process variables at the education-system level.

More specifically, the national contexts survey is designed to collect systemic data on the following:

- Structure and makeup of the education system (with specific focus on the target grade)
- Educational policy and practice in CIL/CT education (including curriculum approaches to CIL and CT)
- Policies and practices for developing the CIL/CT expertise of teachers
- Current policies and reforms relating to the implementation of digital technology in schools (including approaches to the assessment of CIL/CT and the provision of ICT resources in schools).

Antecedent Variables at the Level of the Wider Community

Previous cycles of ICILS have shown relatively strong associations between the general socioeconomic development of countries and student learning outcomes (Fraillon et al., 2014, 2020b). ICILS 2023 will again select national (and where appropriate possible subnational) indicators related to general human development status as regularly reported by the United Nations Development Programme. Examples of these indicators are gross domestic product per person, access to education, and health statistics.

Given ICILS' focus on students' CIL/CT, it is important to take into account the general availability of and infrastructure for ICT. To this end, ICILS 2023 will collect, with the aim of describing the general ICT-related resources at the national level, information relating to variables such as the proportion of the population with access to the internet. Relevant data can be sourced from international agencies such as the International Telecommunications Union (ITU) that routinely collect and publish high quality data associated with aspects of digital development.

Data from a range of international surveys, including previous cycles of ICILS, show that the provision of ICT resources in schools varies widely across countries (see, for example, Anderson and Ainley, 2010; Fraillon et al., 2014, 2020b; OECD, 2020). In order to obtain information related to the general policies regarding the ICT resourcing of schools, the ICILS 2023 national contexts survey will collect data about the organization and and characteristics of the education systems in each country. System-level variables related to this aspect include length of schooling, age-grade profiles, and structure of school education (e.g., study programs, public/private management), as well as the degree of autonomy of educational providers. In addition, the survey will collect information about approaches to the provision of school-based ICT infrastructure, as well as policy provisions and expectations regarding the teaching, learning and assessment of CIL and CT.

These system-level data will be complemented by school-level information from the ICT coordinator questionnaire, which will collect information about the access to hardware and software resources to support teaching and learning within schools.

Process-Related Variables

The process-related variables on CIL/CT-related education policy that will be collected by the ICILS 2023 national contexts survey include:

- The definition of and the priority that each country gives to CIL education in its educational policy and provision
- Reforms implemented in the past 5 years in the use of ICT in education
- The emphasis on ICT use and CIL/CT learning in the curriculum
- Support by education authorities for teacher professional development in CIL/CT education
- The influence of different institutions or groups on decisions relating to those goals and aims.

The initial ICILS 2013 contextual framework references policies and practices developed as outcomes of earlier large-scale surveys of ICT in education. These studies include IEA's Second Information Technology in Education Study (SITES) (Plomp et al., 2009), the European Commission's Indicators of ICT in Primary and Secondary Education (Pelgrum and Doornekamp, 2009), and the International Experiences with Technology in Education survey, which covered policies and experiences in 21 countries (Bakia et al., 2011). ICILS 2023 builds on this foundation of data relating to students' learning contexts and learning processes and on the outcomes of the previous two cycles of ICILS.

The information from these studies shows that countries take different approaches to the implementation of CIL/CT education in their curricula. Some education systems include it as a subject within the curriculum, whereas others include it by integrating it into other subjects. The explicitness with which countries describe their CIL/CT curricula and the learning outcomes they want from them also vary across education systems. Some have very explicit curricula regarding CIL education and its expected learning outcomes; others describe CIL/CT education as an "implicit" curriculum that weaves through the curriculum documents for other learning areas.

In order to build on what is already known, the national contexts survey will gather data on the inclusion of CIL/CT education (as a separate subject, integrated into different subjects, or as a cross-curricular approach) in the formal curriculum at different stages of schooling and in different study programs. It will also capture the nomenclature for CIL/CT-related curriculum subjects and whether they are compulsory or optional in each program of study. There will also be specific questions regarding the curriculum emphasis on CIL/CT education.

Another important process-related variable at the system level is the development of teacher expertise in ICT-related teaching and learning (Fernández-Batanero et al., 2022; Law et al., 2008; Scherer and Siddiq, 2015). Teacher education programs often provide aspiring teachers with opportunities to develop ICT-related competencies. To aid assessment of the variety of different approaches to teacher education in the field, the national contexts survey gathers (where applicable) data on ICT-related requirements for becoming a teacher. The survey also collects information on the extent to which ICT-related education is a requirement of preservice or initial teacher education and teacher registration, and on the on expectations for teachers' ongoing learning about developments in CIL/CT education including the provision of in-service or continuing professional development for the use of ICT in education.

Education systems continue to undertake reforms involving the expansion in the use of digital technology in education. Results from previous cycles of ICILS have illustrated the considerable variation in such reforms across countries (Fraillon et al., 2013, 2020a). The ICILS 2023 national contexts survey will again collect qualitative information from participating countries about the plans or policies are in place to support the use of ICT in education, including initiatives relating to the use of ICT in education and any major recent (within the past 5 years) changes to the approach and use of ICT in education.

During the COVID-19 pandemic, as direct contact between teachers and students was limited, distance learning became more frequent. In many countries ICT played an important role in mitigating the negative effects of disrupted schooling

(Meinck et al., 2022; Pokhrel and Chhetri, 2021; Schleicher, 2020). The participating education systems will have the opportunity to describe the extent of ICT use in teaching and learning and its approaches during the COVID-19 pandemic.

4.3.2 School/Classroom Context

Any study of students' acquisition of CIL/CT must acknowledge the key role that school and classroom contexts play in that acquisition. Use of ICT is increasingly becoming standard practice in education and is therefore an important part of preparing young people for participation in modern society. Factors associated with the school and classroom context will be collected through the teacher, school principal, and ICT coordinator questionnaires. In addition, the student questionnaire includes some questions gauging student perceptions about classroom practices related to ICT. Even though ICILS 2023 will not attempt to investigate the relationship between ICT use in schools or classrooms and achievement in academic learning areas such as language, mathematics, or science, it is of interest to note the evidence of a positive impact of ICT use on classroom achievement in a meta-analysis conducted by Lei et al. (2021).

Antecedent Variables at the School/Classroom Level

In line with the need to consider basic school characteristics in the analysis of variations in CIL/CT, the school principal questionnaire will collect information on student enrollment, teachers, the range of grades, and the location of each participating school. It will also collect data on school management (public or private).

When considering *leadership for ICT* the vision for ICT is often mentioned as a necessary antecedent to effective ICT integration by teachers (Anderson and Dexter, 2005; Al Sharija, 2012; Dexter, 2011; Yee, 2000). While school leaders are in a particularly influential role regarding forming a vision for ICT and sharing it with teachers (Davidson and Olson, 2003; Yuen et al., 2003), the vision and resulting shared goals are ideally created with the school community and revisited for guidance and decision making, and updated, on an ongoing basis (Vanderlinde et al., 2010). In ICILS 2023, principals were asked about the distribution of leadership for specific ICT related aspects. Further, principals, ICT coordinators and teachers were all asked a number of new questions to identify specific aspects of their school's vision to use ICT for teaching and learning. Creating expectations for performance related to the vision, and collecting data about progress are also important aspects of achieving a vision (Vanderlinde et al., 2010; Yee, 2000). New questions asked of the ICT coordinators and principals capture those aspects. When compared to previous cycles, ICILS 2023 will allow a more complete understanding of the how school-level vision serves as an antecedent for teachers' uses of ICT.

The research is definitive about the need to provide teachers with opportunities to learn to use ICT to support teaching and learning, and findings often indicate these opportunities are either ill-timed, too general, or not provided at all (Dexter et al., 2016). Previously in ICILS principals were asked about teachers' participation in professional learning about ICT. To better reflect the a large body of research on the importance of considering ICT integration through the lens of teaching needs and pedagogy and beliefs (Zhao et al., 2002; Zhao and Frank, 2003) questions added to the 2023 instruments provide detail about school approaches to developing teachers' professional capacity to teach with and about ICT. These include the use of individualized professional learning plans for teachers and opportunities for teachers to engage in activities that contribute to communities of practice within schools.

Leaders' contribution to creating a supportive organization for learning has an increased focus in ICILS 2023, through a number of new questions principals answer regarding teachers' culture for collaboration on ICT. As a result of the increasing recognition that teachers integrate ICT according to their personal beliefs about teaching and learning as well as having different levels of readiness (Ertmer et al., 2015; Tondeur et al., 2009), the collaboration culture of a school is seen to contribute to teachers' learning to integrate ICT in their teaching, supporting them to use a broader variety of approaches and activities when teaching with ICT, and to better target these approaches and activities to meet specific teaching and learning needs. For ICILS 2023, a number of new questions have been added to the principal and ICT coordinator questionnaires to collect data about who contributes to the leadership of ICT. Distributed leadership is a "leader-plus" perspective of leadership in schools that focuses less on specific roles and more so on the interactions among members of a school that move its work forward (Spillane et al., 2004; Spillane, 2006). These added questions ask about the different people who provide support across a variety of leadership functions that contribute to the successful uses of ICT in schools.

SITES 2006 findings suggested that ICT use by science and mathematics teachers is influenced by the school principal's views about its value, as well as the ICT-related support teachers have at hand (Law et al., 2008). Findings also indicated that ICT-related teaching and learning can be constrained or facilitated by the school's stated curriculum and its policies with regard to ICT. The ICILS school principal questionnaire will therefore collect data on the following factors:

- The extent to which the school has policies and procedures relating to ICT use
- The extent to which the school prioritizes ICT acquisition and resourcing
- Perception of the importance ascribed to ICT learning outcomes in teaching at the school
- School-level expectations for teachers' knowledge of and skills in using ICT
- The extent to which teachers participate in ICT-related professional development.

School-level factors related to ICT resourcing and priorities are known to influence both the way in which teachers use ICT for teaching and learning, and students' ICT-related learning (Fraillon et al., 2014, 2020b; Gerick et al., 2017; Konstantinidou and Scherer, 2022). The ICILS questionnaire for each school's ICT coordinator includes questions on the availability of school-owned computing devices at school, their location within the school, how many students have access to them, and the number of years the school has been using ICT. The instrument will also collect data on the support the school provides for ICT use in teaching and learning in terms of personnel and technology or software resources. It additionally includes a question measuring the coordinator's perceptions of the adequacy of the ICT on hand for learning and teaching at school. Analysis of this type of information will support investigation of the role of digital resourcing in schools as an antecedent for CIL/CT learning as well as its relationship to the approaches to teaching with ICT within schools.

The background and experiences of teaching staff potentially influence the acquisition of students' CIL/CT. Teachers' sense of self-efficacy in the use of basic ICT has been reported as linked to greater use of ICT in the classroom (Hatlevik, 2016; Hatlevik and Hatlevik, 2018; Law et al., 2008). In ICILS 2013, teacher ICT self-efficacy was the teacher-level variable that showed the strongest association with teachers' reported emphasis on developing students CIL, and "teachers who were confident about their own ICT capability were more likely than their less-confident colleagues to place a greater degree of emphasis on developing their students' ICT-related skills" (Fraillon et al., 2014, p. 217). Furthermore, ICILS 2013 and 2018 reported that older teachers typically expressed lower confidence than younger teachers in their ability to use ICT in their teaching practice (Fraillon et al., 2014, 2020b). The ICILS 2023 teacher questionnaire will therefore collect information on the background of teaching staff (such as age, gender, subject taught at school) and on their ICT experience (number of years using ICT for teaching purposes, general use of computers at different locations, participation in ICT-related professional development activities, and perceived self-confidence in using ICT for different tasks).

Teachers will also be asked to give their views on the positive and negative consequences of using ICT for teaching and learning, and to identify any factors that they think impede the use of ICT for teaching and learning at their school. Results from ICILS 2013 and 2018 indicated that teachers across participating countries tended to recognize positive benefits from using ICT in teaching (Fraillon et al., 2014, 2020b).

Process-Related Variables at the School/Classroom Level

The use of ICT in school education has been seen as having the potential to influence teaching and learning processes by enabling wider access to a range of resources, allowing greater power to analyze and transform information, and providing enhanced capacities to present information in different forms. Based on student reports from ICILS 2018, school-related use of ICT most often involved internet searching and document production. In addition, teachers' use of ICT for student activities and teaching practices was limited and varies across the different types of activities/practices as well as across countries (Fraillon et al., 2020b).

The ICILS 2023 teacher questionnaire accordingly asks teachers to consider one of their classes (specified in the questionnaire) and to report on the frequency of specific teaching activities, the use of ICT in these activities, and proportion of lessons in which specific ICT-based activities take place. Related to that, an optional question inquires about their epistemological beliefs (their beliefs about how knowledge is created). Furthermore, the teacher questionnaire asks to identify (where applicable) the types of ICT applications used in that class, and the emphasis placed on developing ICT-based student capabilities and skills. A consistent finding reported across both previous ICILS cycles was the positive association between teachers' perceptions of working in a school environment with a collaborative teaching approach and teacher self-efficacy and use of ICT for classroom purposes (Fraillon et al., 2014, 2020b; Hatlevik and Hatlevik, 2018), the questionnaire also asks teachers about their perceptions of whether and how ICT is used as part of collaborative teaching and learning at their school.

Actual student use of ICT in the learning process is another important factor. The student questionnaire also asks students to report on how often they use computers at school, their use of computers for different school-related purposes, and the frequency with which they use ICT in their learning of different subjects. Furthermore, ICILS 2023 asks students about the frequency with which they use different ICT tools (such as multimedia, word processing, or presentation software) in the classroom.

To assess how much students perceive they have learned about ICT use, ICILS 2023 contains a question that is similar to one used in ICILS 2013 and 2018. This question measures the extent to which students think they have learned at school about different ICT-related tasks (such as providing internet sources or looking for different types of digital information on the internet). In response to the ever-increasing need to educate students about online safety and security issues (European Commission, 2022; Ranguelov, 2010; UNESCO, 2014), ICILS 2023 also contains items on whether students believe they have learned at school about the importance of tasks related to security and privacy when using digital devices (such as checking the origin of emails before opening them, or managing privacy settings on internet accounts). To complement this information, ICILS 2023 also asks about learning these tasks outside of school. In addition, the student questionnaire includes a new question about perceived learning of specific topics on responsible ICT use at school.

Students and teacher questionnaires include a set of questions to collect data on the degree to which instruction relating to the skills that underpin CT takes place in classrooms. These questions address process-related context factors that may influence the development of CT skills.

4.3.3 Home Context

Antecedent Variables Related to the Home Environment

The influence of student home background on students' acquisition of knowledge has been shown in many studies, and there is evidence that home background is associated with the learning of ICT skills (Fraillon et al., 2020b, 2014; Nasah et al., 2010; National Assessment of Educational Progress, 2016). Influences that have been shown to be associated include parental socioeconomic status, language used at home, ethnicity, and whether or not the student and/or his or her parents have an immigrant background.

A large body of literature shows the influence of students' socioeconomic background on student achievement in a variety of learning areas (see, for example, National Assessment of Educational Progress, 2016; Saha, 1997; Sirin, 2005; Scherer and Siddiq, 2019; Woessmann, 2004). ICILS 2018 results showed that, in participating countries, socioeconomic background consistently explained considerable variation in students' CIL and CT (Fraillon et al., 2020b). To assess the socioeconomic status of the students' parents, ICILS 2023 will include questions on the highest educational levels of parents, their occupations, and the number of books at home. This procedure is the same as was used successfully in ICILS 2013 and 2018.

In the questionnaire, the highest educational levels achieved by the student's mother and father are defined in accordance with the International Standard Classification of Education (ISCED) (UNESCO, 2011). The occupation of each parent will be recorded through open-ended questions, with occupations classified according to the International Standard Classification of Occupations (ISCO) framework (ILO, 2012) and then scored using the International Socioeconomic Index (SEI) of occupational status (Ganzeboom et al., 1992). Home literacy resources are measured through a question asking students to report the approximate numbers of books at home.

There is evidence from many countries of considerable disparities in students' access to digital resources in homes, and researchers and commentators claim that these disparities affect the opportunities that students have to develop the capabilities required for living in modern societies (Warschauer and Matuchniak, 2010). ICILS 2013 provided evidence for these claims in many participating countries, however, in some highly developed countries only small effects were observed (Fraillon et al., 2014). And the results of ICILS 2018 showed that availability of computers at home was a positive predictor of CIL and CT in most countries but the relationship weakened after controlling for personal and social background (Fraillon et al., 2020b). The student questionnaire gathers information about the digital resources in students' homes to use these data to examine the relationship between resource levels and CIL/CT. In order to take into account changes in technology and use of digital devices, the set of items for measuring digital home resources include computers, tablet devices and smartphones.

Many studies, including ICILS 2013 and 2018, have found that the cultural and language background of students can be associated with their educational performance (see, for example, Fraillon et al., 2014, 2020b; Schulz et al., 2017). To measure these aspects of student background, the ICILS student questionnaire includes questions about students' and parents' country of birth, as well as about the language which is spoken most frequently at home.

Process-Related Variables Related to the Home Environment

Home environment factors that potentially influence the learning process include the use of ICT in the home context and learning through interaction with family members. The student questionnaire therefore includes questions about how often they use ICT outside of school (including at home), their perceptions about how much they learned about ICT use outside of school (including at home), and how often they do activities using digital devices at the same time as doing schoolwork (known as academic-media multitasking (see, for example van der Schuur et al., 2020).

4.3.4 Individual Context

Antecedent Variables at the Individual Level

Antecedent variables at the level of the individual student consist of basic background characteristics that may influence students' CIL-related knowledge and skills. Relevant factors in this category are age, gender, and educational aspirations.

Students' knowledge and skills in different learning areas increase with age (see, for example, Kawaguchi, 2011; Mavilidi et al., 2022; Peña, 2017) and a similar relationship is assumed for the development of CIL and CT with age. However, cross-national data from grade-based surveys tend to find negative associations between age and achievement within a given grade-level within some countries (see, for example, Schulz et al., 2017, p. 63). Findings from ICILS 2013 and 2018 (Fraillon et al., 2014, 2020b) showed a similar negative association which could be due to retention and progression policies where older students in the same grade (grade 8 for ICILS) are also those with lower achievement.

Studies on educational achievement in numerous learning areas have found considerable differences between gender groups. This is why gender differences in CIL/CT are of interest as well. In particular, cross-national research on reading literacy has shown larger gender differences in favor of females (OECD, 2016; Mullis et al., 2023, 2017). Cross-national results from ICILS 2013 and 2018 also indicated that female students tended to have higher levels of CIL than their male counterparts (Fraillon et al., 2014, 2020b). With regard to CT skills, however, male students tended to have higher achievement across all participating countries (Fraillon et al., 2020b).

Individual aspirations with regard to education provide an indication of students' belief in their capacity to succeed in education and should be taken into account during any analysis of variation in students' CIL and CT. In ICILS 2018, expected university education was a consistent positive predictor of both CIL and CT achievement (Fraillon et al., 2020b). The ICILS 2023 student questionnaire includes the same question as in the previous cycle to gauge students' expected highest level of educational qualification.

Process-Related Variables at the Individual Level

Process-related variables at the individual level in this context include attitudinal (e.g. attitudes towards the value of ICT, or ICT self-efficacy), as well as behavioral factors (e.g. use of ICT within and outside of school) that are hypothesized to contribute to the process of student learning. An individual's self-beliefs regarding their own ability with respect to a certain learning area are often viewed as central to the process of learning, and are likely to have a reciprocal association with knowledge and skills (see for example, Schöber et al., 2018; Talsma et al., 2018). Furthermore, it is also important to include student perceptions about responsible and appropriate use of ICT, which can also be seen as intended learning outcomes from teaching CIL and CT. Behavioral variables also relate to using ICT for different purposes and needs, especially in terms of the potential that frequent and varied use of these tools has for facilitating student learning.

The student questionnaire includes items designed to measure the extent to which students express confidence in doing a range of ICT-related tasks. According to Bandura (1993), students' confidence in their ability to carry out specific tasks in an area (self-efficacy) is strongly associated with their performance, as well as perseverance, emotions, and later study or career choices. Moos and Azevedo (2009) concluded from their review of research on computer self-efficacy that this variable plays an integral role in learning in computer-based learning environments. The two authors examined factors related to computer self-efficacy and the relationships between computer self-efficacy, learning outcomes, and learning processes. They found a number of positive associations between behavioral and psychological factors, and computer self-efficacy. A particular finding was that students who experience behavioral modeling also report significantly higher computer self-efficacy than do students who experience more traditional instruction methods. Sample assessments in the United States and Australia have similarly reported positive associations between student ICT-related self-efficacy and technological and ICT-literacy achievement (Australian Curriculum, Assessment and Reporting Authority, 2018; National Center for Education Statistics, 2018).

In ICILS 2013 and 2018, two dimensions of self-efficacy were identified, one related to student confidence in undertaking basic ICT tasks (such as searching and finding a file on a computer) and another one reflecting confidence in more advanced tasks (such as creating a database, computer program or macro) (Schulz and Friedman, 2015; Fraillon et al., 2020a). While self-efficacy related to basic tasks tended to be positively correlated with CIL, confidence in undertaking advanced tasks was not consistently associated with students' CIL (Fraillon et al., 2020b, 2014). The ICILS 2023 includes a modified set of items measuring both student confidence in basic and more advanced ICT tasks that will be analyzed with regard to CIL/CT achievement.

Applying ICT for different purposes on a regular basis has considerable potential to increase knowledge and skills in this area (see, for example, Australian Curriculum, Assessment and Reporting Authority, 2015; Fletcher et al., 2012; National Assessment of Educational Progress, 2016). ICILS 2013 and 2018 showed frequent use of ICT for a wide range of activities

(Fraillon et al., 2014, 2020b). The ICILS 2023 student questionnaire consequently includes questions (modified from the previous cycle) about the frequency of using different ICT applications, using the internet for social communication, and using ICT for recreational (leisure) activities.

Data from other studies suggest a positive association between attitudes toward using ICT and academic achievement (Petko et al., 2016). In ICILS 2023, the student questionnaire includes a series of questions on students' perceptions of the impact on ICT on society and whether they intend to use ICT in the future for work and study purposes.

To gauge the educational context for the acquisition of CT skills, the ICILS 2023 student questionnaire asks students whether they study a CT-related subject (e.g., computing, computer science, information technology, informatics, or similar) in their current school year.

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5 ICILS Instruments

Daniel Duckworth and Julian Fraillon

5.1 The ICILS Tests of CIL and CT

5.1.1 Background

During the International Computer and Information Literacy Study (ICILS) assessment of computer and information literacy (CIL), students engage with a broad range of tasks. These include multiple-choice questions, short text responses, skills-based activities, and tasks focused on information literacy and communication. These tasks are executed within specialized productivity applications, such as document editors, design software, and web browsers specifically developed for the assessment. It is important to emphasize that the web content accessed during the ICILS is exclusively developed for the test, serving as the sole source of web-based material accessible to students. Students in countries participating in the optional assessment of computational thinking (CT) complete a range of tasks that include multiple-choice questions, short text responses, visual representations of concepts (such as flow charts and tree diagrams), and block-based coding and debugging tasks.

A cornerstone of ICILS is its commitment to offering students an assessment experience that reflects authentic uses of ICT. This is achieved by establishing the test content in authentic narratives that students may reasonably experience and by including the types of software applications students are likely to encounter in real-world settings. To facilitate this, the test instrument design process incorporates a comprehensive design system and a user interface component library. These tools enable the creation of interactive interfaces and specialized productivity and block-based coding applications that form the test's stimulus material. ICILS adopts a dynamic approach to addressing the changes in application and interface design across the cycles. In ICILS we leave open the possibility to adapt, as appropriate, the presentation of the assessment content to align with contemporary user interface conventions. The inaugural ICILS cycle in 2013 specified a minimum screen size of 29 cm and a display resolution[1] of 1024 px by 768 px. This resolution was the most universally compatible at that time (StatCounter Global Stats, 2023) and the specification was retained for the 2018 cycle to ensure equitable access for all students, including those without access to devices with higher resolutions. However, increases in standard screen resolutions, and the shift towards using wider screen ratios over the 10 years since ICILS began, necessitated a change in the ICILS screen design. For ICILS 2023, the minimum display resolution was updated to 1280 px by 800 px (see Fig. 5.1 for a comparison of resolutions). This change not only aligns with the trend toward wider display screens but also accommodates the global increase in devices with larger display resolutions. Importantly, it provides a more versatile canvas for the development of test content that accurately reflects the evolving design norms of real-world software applications. All new test materials developed for ICILS 2023 were developed to fit this new resolution. The on-screen layout of materials from previous ICILS cycles (trend materials) was updated, task by task, to make use of the larger available screen resolution in ICILS 2023, while also ensuring the layouts maintained relative parity with the trend materials.

In summary, ICILS embraces a fluid approach to test instrument design, continuously evolving to maintain currency and consequently to provide an authentic and meaningful assessment of students' CIL and CT skills that reflects their real-world digital experiences.

[1] Display resolution is the number of distinct pixels in each of width and height that can be displayed by the computer screen.

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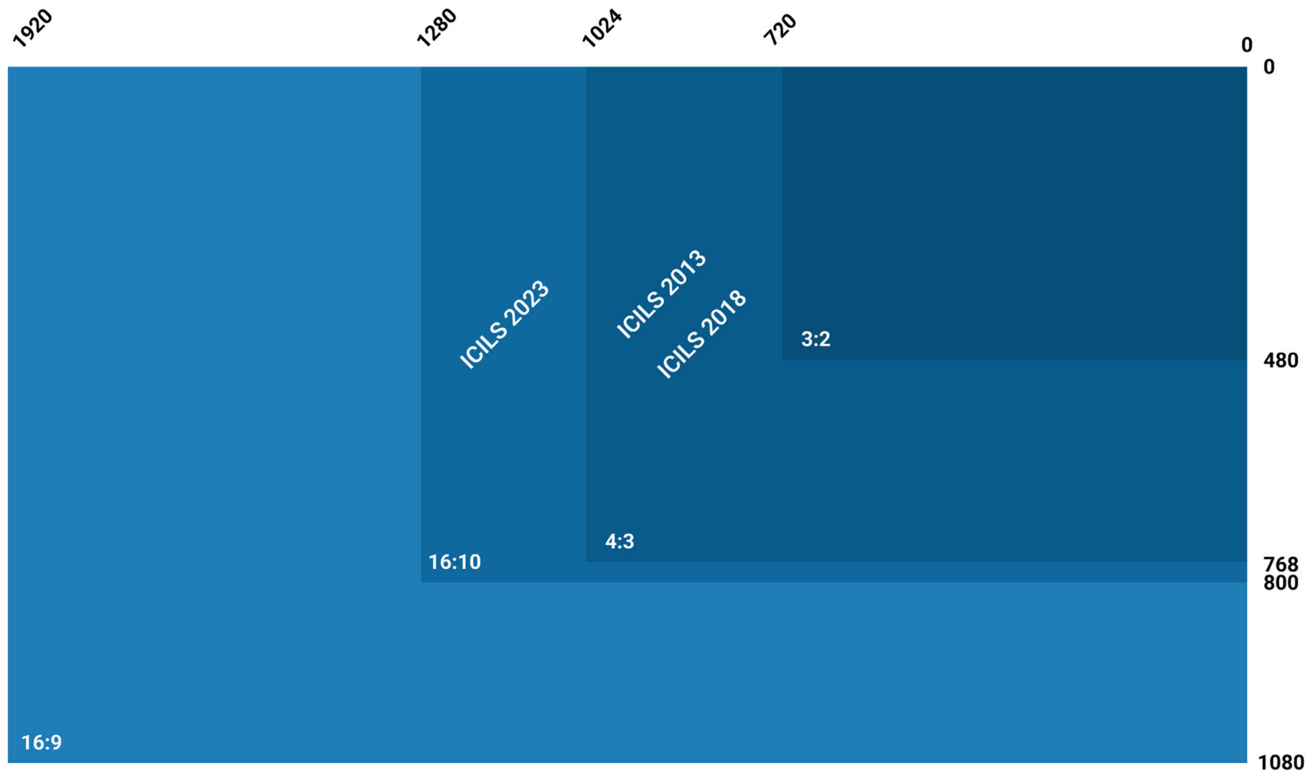

Fig. 5.1 Common computer display resolutions

5.1.2 Test Instrument Overview

Students need to be able to both navigate the mechanics of the test and complete tasks presented to them. In order to support these two purposes, the test environment comprises two functional spaces: the test interface and the stimulus section (Fig. 5.2).

5.1.3 Test Interface

The test interface serves a number of purposes. Firstly, it provides students with information about their progression through the assessment, including the total number of tasks to be completed, the number of tasks that have been completed, the number of tasks yet to be completed, and the remaining time allocated to complete the tasks. The instruction section is located at the bottom of the test interface. This section either presents specific questions to be answered—in which case the designated answer space is also incorporated—or instructions relating to the execution of one or more tasks within the stimulus section. The test interface includes navigation controls that allow students to move between tasks, and an information button that allows students to access general test-taking information and task-specific information, such as scoring criteria or detailed task instructions. The test interface also includes a stimulus section (Fig. 5.2). The stimulus section can house interactive and non-interactive content. It may feature static elements, such as graphical representations of a website's login interface, or dynamic elements such as document editors and web browsers. While the visual style of the test interface been modernized over each successive cycle of ICILS, the core structural and functional attributes have remained consistent across the cycles. For example, the positioning and functionality of navigational elements and task progression indicators have been retained but their visual appearance has been updated to align with contemporary interface design conventions (Fig. 5.3).

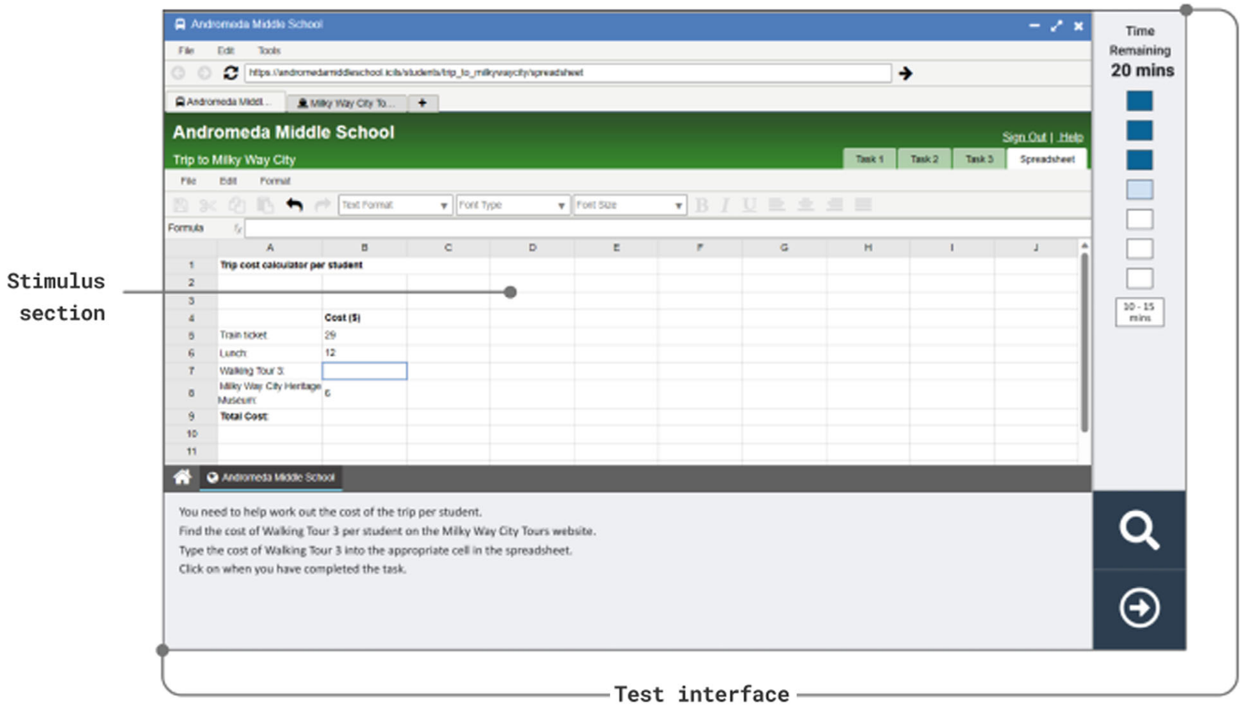

Fig. 5.2 Test environment comprised of two functional spaces

5.1.4 Test Instrument Design

The test of CIL is core to ICILS and is completed by all students. All students also complete the ICILS student questionnaire. The test of CT, administered after the student questionnaire, is an *international option* that countries can choose to administer. The CT option is completed by students in countries participating in the CT international option only.

The CIL instrument comprises a total of seven CIL test modules, three newly developed for ICILS 2023 and four retained from previous ICILS cycles to support the reporting of CIL achievement trends across the ICILS cycles. The three new modules were designed to reflect contemporary software applications and contexts. Data collected from all seven modules in ICILS 2023 are used to report CIL test results on the ICILS CIL achievement scale, originally established in ICILS 2013.

Each student completes a randomly assigned pair of CIL test modules out of the seven available modules in a fully balanced rotational design. This test design allows for the CIL test instrument (comprising all seven modules) to assess content covering the full range of the CIL construct, but for each student to complete a manageable amount of assessment content.

For the ICILS 2018 CT test, two 25-min test modules were developed and used to establish the ICILS CT achievement scale. These modules were used for reporting the CT test results in the ICILS 2018 international report (Fraillon et al., 2020b). In the ICILS 2023 cycle, two additional CT modules have been introduced. In countries participating in the CT international option, students complete two out of the four available CT modules. As with the CIL assessment, the CT modules are allocated to students using a fully balanced rotated design.

Across all booklets, each CIL module was presented an equal number of times in each of the first and second position in the CIL test instrument. Each CIL module was paired an equal number of times with each other CIL module. Each CT module was presented an equal number of times in each of the first and second position in the CT test instrument. Each CT module was paired an equal number of times with each other CT module. While each of the CIL and CT test instruments were fully balanced, the CIL and CT instruments were not full balanced with each other. Across the booklets, each CIL module was not presented an equal number of times with each CT module. It was not essential to the test design for the two different test instruments to be fully balanced with each other, and the ICILS 2023 test design was selected to keep the number of test

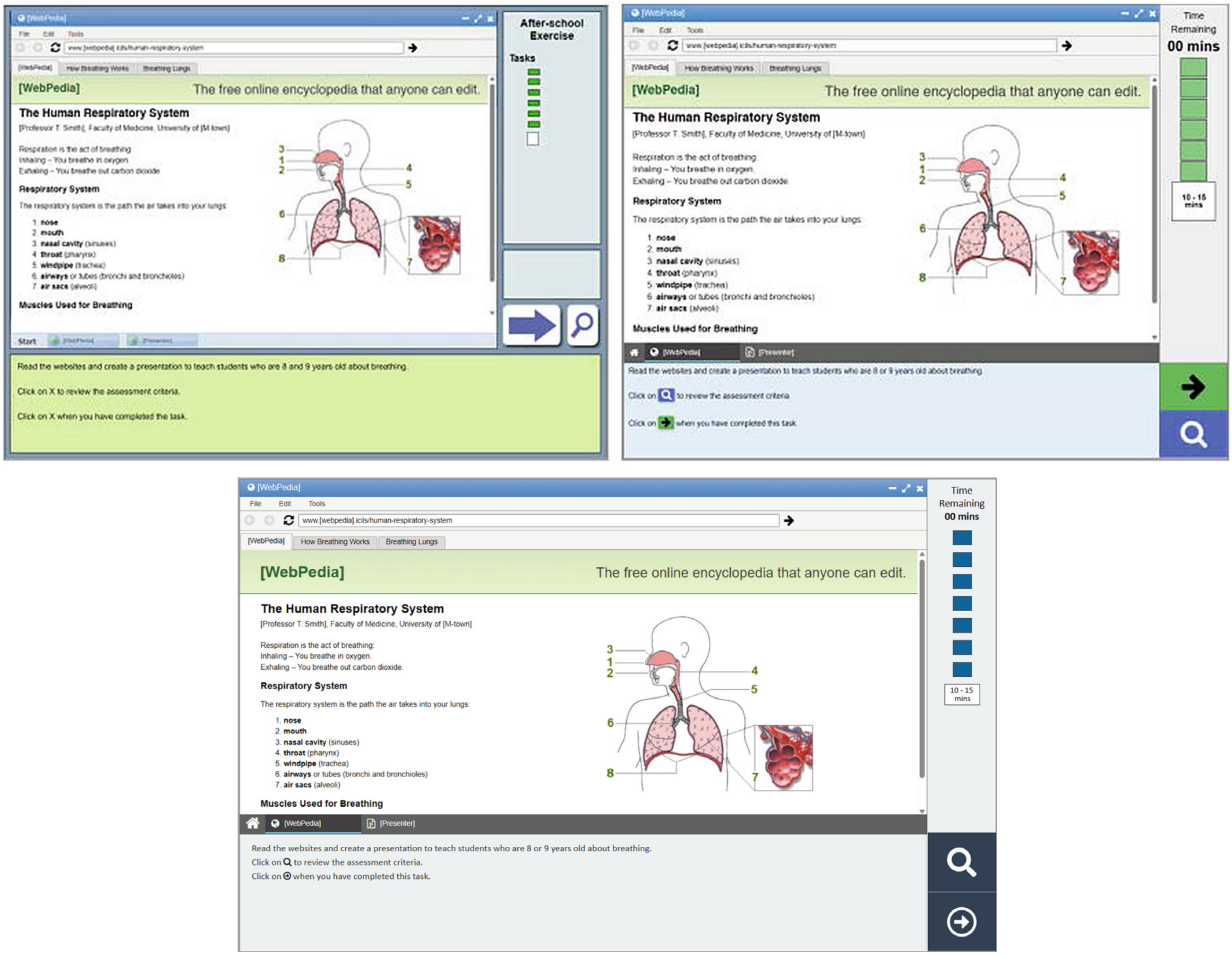

Fig. 5.3 The ICILS test interface design from ICILS 2013, 2018, and 2023

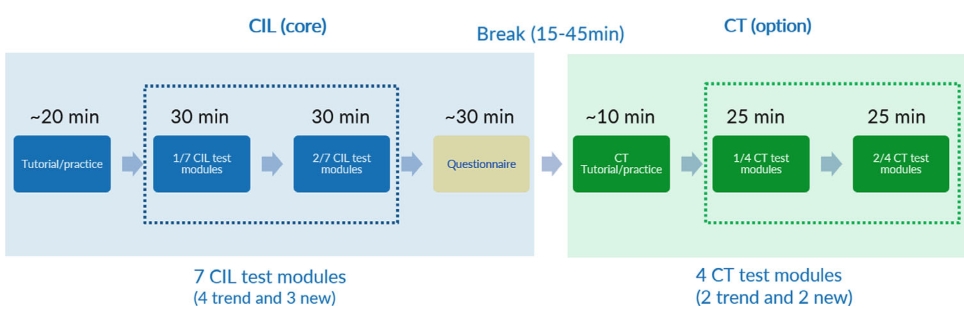

Fig. 5.4 ICILS 2023 test session outline

booklets to a manageable amount.[2] Full details of the ICILS 2023 test design will be provided in the ICILS 2023 Technical Report to be published following completion of ICILS 2023. The sequence of modules in an ICILS test session is shown in Fig. 5.4.

[2] In ICILS 2023 there were 84 test booklets in countries completing both CIL and CT, and 42 test booklets in countries completing CIL only. A fully balanced design combining CIL and CT would have required a total of 504 test booklets.

5.1.5 CIL Test Modules

A CIL test module is a sequence of tasks contextualized by a real-world theme and driven by a plausible narrative. The modules typically begin with a sequence of five to eight small tasks, each of which is designed to take students less than one minute to complete. Within each module, these small tasks collectively contribute to the foundational contextual knowledge that underpins work on a singular, a more extensive large task. The large tasks typically take 10–15 min to complete and involve authoring an information product (such as a presentation, poster, written report or social media post) that makes use of information and resources managed by students in the small lead-up tasks. The parameters of large tasks are specified for students in terms of the software tools and format to be used, the communicative purpose, and the target audience of the information product. Students view a *demo video* to familiarize them with the software application and information resources they will use in the task, and students are provided with information about the criteria that will be used to assess their work for each large task. Students can view and re-view the criteria at any time when they are completing the large task.

The module themes are devised to be engaging and relevant to students, and the tasks are developed with a view to preventing prior content knowledge relating to a module theme from advantaging subgroups of students. This is achieved in four main ways: (1) by providing students with all requisite contextual information within the tasks themselves, thereby eliminating the need for external knowledge; (2) by ensuring that any specialized information, such as scientific terminology, is presented at a complexity level commensurate with upper-primary or elementary school understanding; (3) by preventing students from returning to previous tasks within a module to prevent the utilization of information from subsequent tasks for answering earlier ones (see Fraillon, 2018 for a detailed explanation of these design features); and (4) by ensuring that the scoring criteria applied to the tasks allow credit only for the use of relevant information that is available to all students.

While the themes of the CIL modules are situated within a school environment, they are not confined to traditional academic subjects. Modules may encompass themes related to school subject-based social or environmental issues, but can also extend to scenarios such as planning a class excursion or establishing an online interest club with a community and social emphasis rather than academic one.

5.1.6 CT Test Modules

The CT construct comprises two strands: *conceptualizing problems* and *operationalizing solutions* (see Chap. 3 for an elaboration of the construct). In ICILS 2018, each CT test module focused on assessing competencies associated with one strand. The data collected from the two CT modules in ICILS 2018 supported the reporting of CT as a single measurement dimension (Fraillon et al., 2020b; Ockwell et al., 2020, 92). For ICILS 2023, the new modules have been designed to include tasks from both strands so that the modules reflect the processes of understanding and conceptualizing problems, and executing and evaluating computer-based solutions to those problems.

The ICILS 2018 CT module focusing on *conceptualizing problems* related to planning aspects of a program to operate an automated bus. It included tasks that involved visual representations, such as path diagrams, flow charts, and decision trees, which facilitated the planning of computer programs for automated solutions. It also included tasks facilitating the use of simulations to collect data and draw conclusions, reflecting real-world applications.

The ICILS 2018 CT module focusing on *operationalizing solutions*, required students to work in a block-based coding environment, where they were tasked with creating, testing, and debugging code that controlled the actions of a drone used in farming. The interface included a visual display of the coded actions of the drone. The tasks were designed to incrementally escalate in complexity, corresponding to the range of code functions available, the number of actions the drone was required to perform, and the intricacies of the sequences of those actions. Students were permitted to return to previous tasks within this module. This decision was made because, unlike within other ICILS test modules, the block-based coding tasks did not follow a sequence where information provided in later tasks could potentially reveal the answer to earlier tasks. Consequently the test interface for this module included the facility for students to "flag" tasks that they might wish to return to, and a navigation feature that allowed them to navigate freely between tasks they had already viewed.

For the ICILS 2023 cycle, new modules were developed that naturally complement the types of tasks found in the *Automated bus* and *Farm drone* modules. These new modules introduced unique contexts and problem-solving scenarios. One module is dedicated to game development, focusing on the evaluation and systematic testing of the underlying code. The other is centered around data collection from digital device sensors, aiming to store, explore, and represent these data for smartphone application usage.

The decision in ICILS 2023 to design tasks that integrate both strands of the CT construct was taken so that the modules could better represent a process of design and implementation. Each task in the new CT modules has a clear conceptual link to the preceding tasks. The continuity of the narrative helps to ground the overall problem context in the real-world. Consequently, for some tasks the initial state of a task is the solution to a problem in a previous task, as is the case in the CIL modules. Consequently, for the two new CT modules (as was already established for the *Automated bus* module), students must complete each task in sequence and cannot return to previous tasks.

The CT modules initially developed for ICILS 2018 were retained for use in ICILS 2023 cycle. These two modules will be released at the conclusion of the ICILS 2023 data collection. The content of tasks from both modules serves to illustrate the range of CT task types, as outlined in Sect. 5.1.8.

5.1.7 Types of Assessment Task: CIL

The computer-based assessment of CIL contains three types of task that are integrated into a single testing environment. This section contains details of each of these tasks with an illustrative example from a released module. Some of the example tasks are from the module *Band competition* (ICILS 2013, 2018) where the student's central task was to design a web page representing a band featured in a school band competition. Other example tasks are taken from the modules *Breathing* (2013, 2018, 2023) and *School trip* (2013, 2018, 2023).

Task Type 1: Information-Based Response Tasks

Information-based response tasks employ a digital interface to deliver questions that emulate traditional pencil-and-paper methods but in a more enriched format. The stimulus material presented to students typically depicts a computer-based problem or information source. The response formats for these tasks may be multiple choice, constructed-response, or drag-and-drop. In these tasks, the computer-based environment is used to capture evidence of students' knowledge and understanding of CIL independently of students using anything beyond the most basic skills required to record a response.

As illustration of an information-based response task format, example task 1 (Fig. 5.5) requires students to examine four organizational-structure diagrams for a website (visual sitemaps) and select the structure that best suits a given set of six pages of content. This task relates to aspect 2.2 of the CIL construct (managing information).

The dynamic computer-based environment in example task 1 enables students to view each of the four website structures in turn (see Fig. 5.6). The stimulus could also be presented in a static form (i.e., showing all four diagrams together) in a pencil-and-paper test. The simplest multiple-choice tasks in ICILS could also be presented in an equivalent form on paper.

However, example task 1 provides an additional functionality that allows students to drag and drop the web page content labels into each organizational-structure template. This helps visualize the different information structures to support their choice of the best structure for pages in the website. The dynamic stimulus used in this task extends beyond what could be easily available in a pencil-and-paper format. The task then enables students to provide their answer through a conventional multiple-choice format (shown in the lower section of the test interface), with one correct option that is automatically scored. While the drag-and-drop functionality in example task 1 only serves as an aid for the student to determine the correct response, in other CIL tasks this functionality serves as the response format, recording the placement of the labeled shapes as the data to be scored.[3] The CIL assessment uses the drag-and-drop response format whenever students are required to classify information into groups or to match objects or concepts according to their characteristics. Example task 2 (Fig. 5.7) requires students to analyze a non-interactive promotional website and respond using text input field in the lower section of the test interface. The stimulus material in example task 2 (Fig. 5.7) from *Breathing* depicts a promotional website selling a health supplement formulated from oregano. The task is presented to students as the outcome of an internet search that was the subject of the previous task.

[3] All ICILS tasks are scored based on the final state of the student responses (as saved when they click "Next"). In ICILS 2023, we plan to collect process data, that includes a time-stamped record of students' actions when completing the tasks. These data may used in secondary analysis, or contribute in future cycles of ICILS to the analysis of students' approaches to completing tasks and potentially also in the scoring of selected tasks.

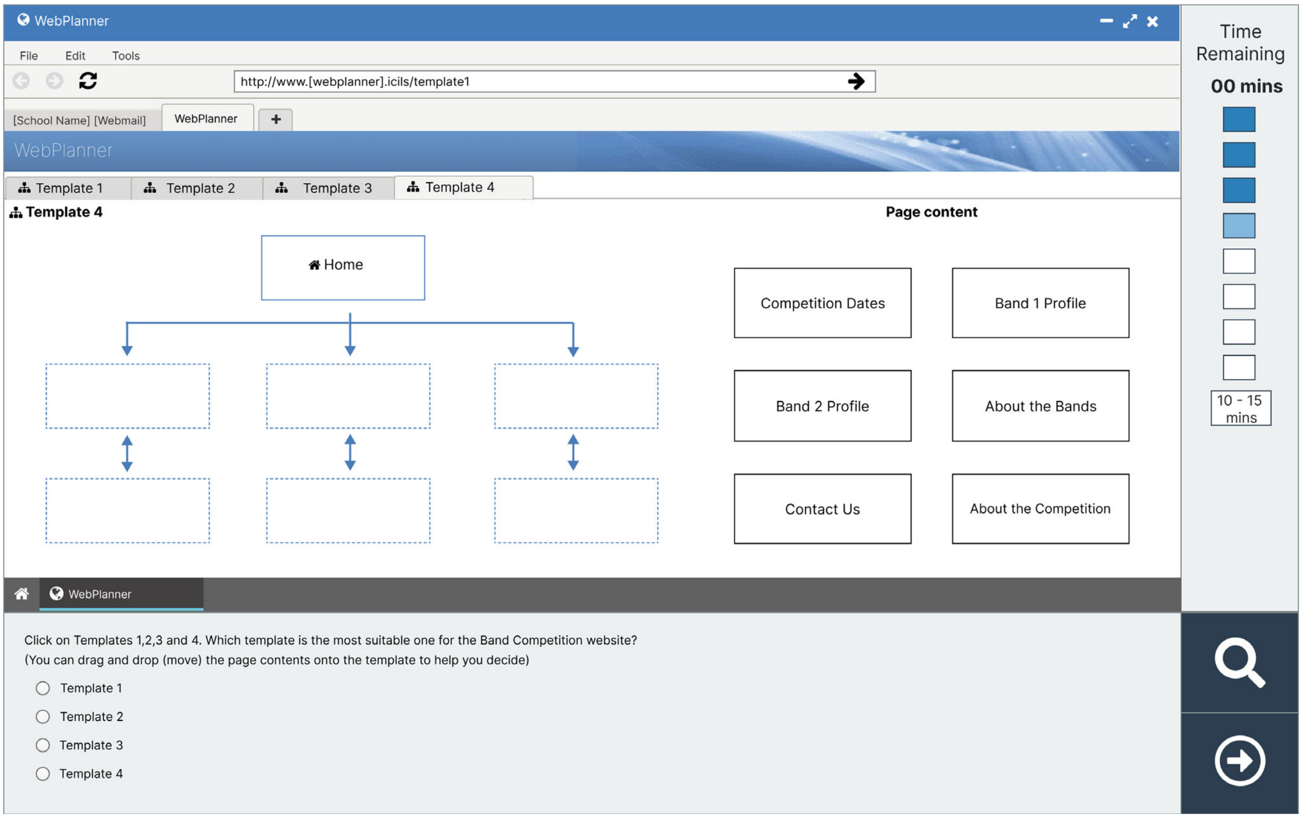

Fig. 5.5 Example task 1 (multiple-choice question from *Band competition* presented in the ICILS 2023 test interface)

The website was contrived to include content that can be used as evidence that the information on the website may be unreliable.

Students must indicate whether they think the information presented on the website is reliable by evaluating the characteristics of content of the website and explaining their answer. Their responses are recorded as text and scored by trained scorers within each participating country, according to a pre-defined scoring guide. Students are awarded full credit if their explanation refers to any of four possible observations about the content of the website. These are: (1) the presence of only a single anonymous testimonial, (2) the lack of independent research about the efficacy of the product, (3) the lack cited sources or supporting evidence, or (4) the potential for exaggerated claims resulting from commercial bias.

Example task 2 relates to aspect 2.1 of the CIL construct (accessing and evaluating information).

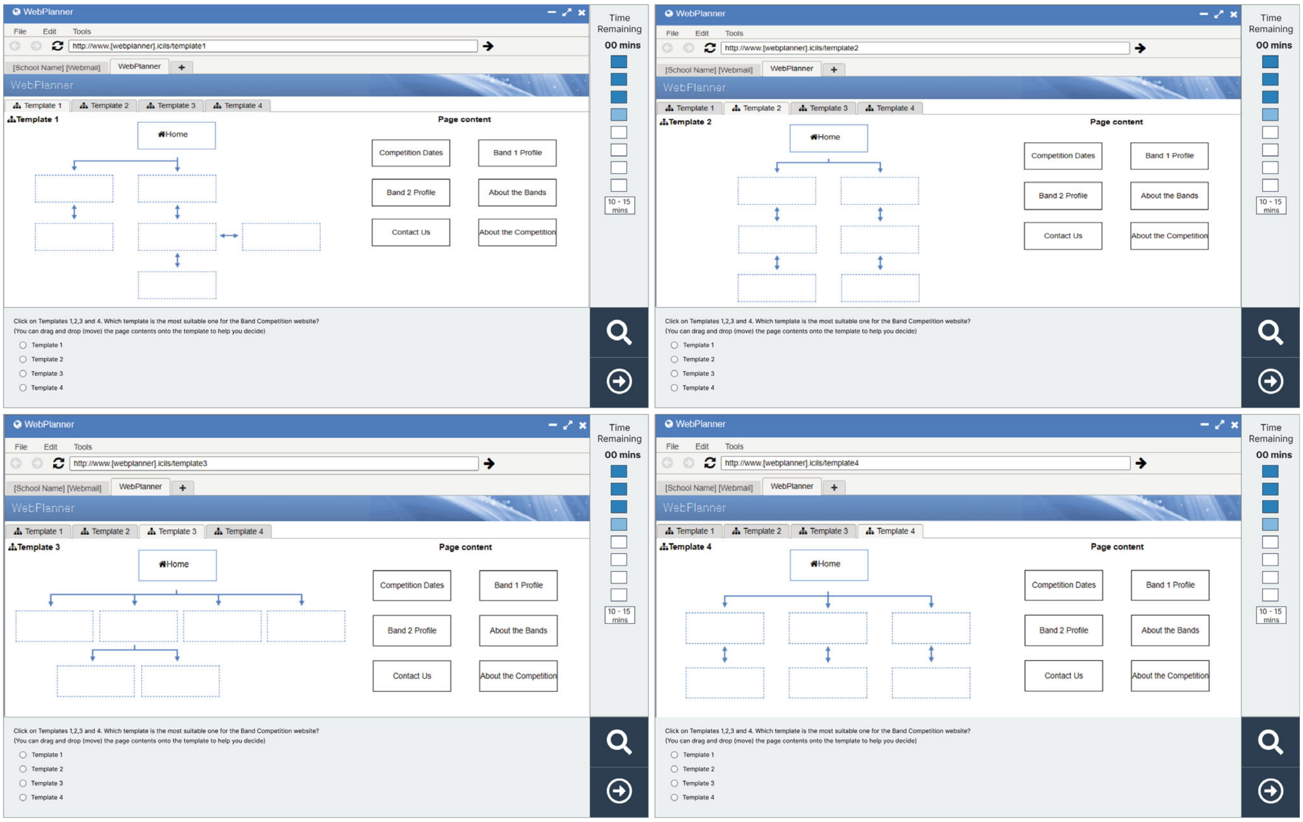

Fig. 5.6 Example task 1 (four website templates)

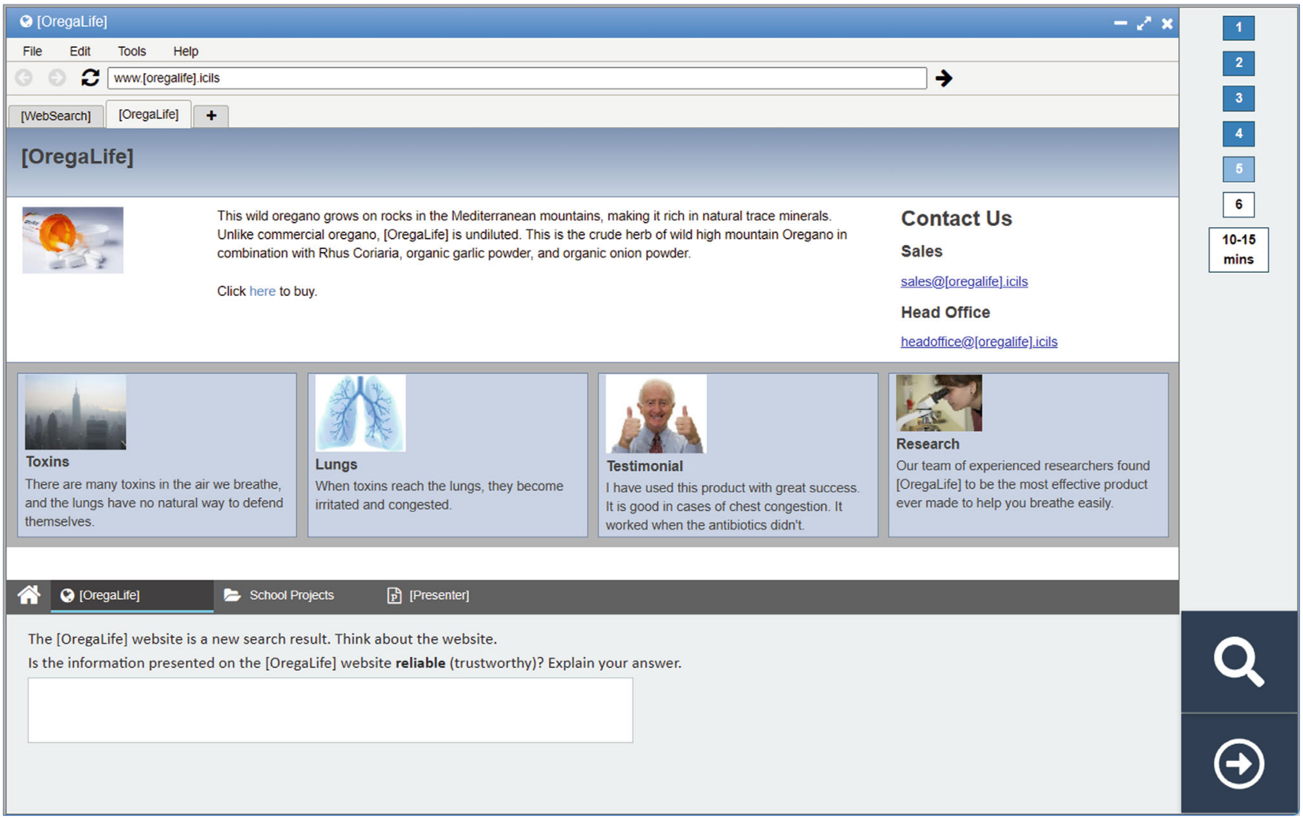

Fig. 5.7 Example task 2 (open-response task from *Breathing*)

Task Type 2: Skills Tasks

Skills tasks require students to interact with functional simulations of generic software or universal applications to accomplish a task. Such tasks can either be single-action tasks (such as copying, pasting, or selecting a browser tab), or they may involve a sequence of steps (such as saving a document under a new file name, or navigating through a menu structure). These tasks are designed to incorporate all standard methods of task completion (such as using keyboard shortcuts or menu items). The testing software records the response data, which are then scored automatically. Some skills tasks rely solely on the knowledge of the user interface conventions presented in a scenario, while others necessitate students to employ information processing skills to execute the correct commands.

The CIL student test comprises both linear and nonlinear skills tasks. A linear skills task can be as simple as executing a single command (such as opening a file from the desktop), or it may require more than one step to complete the task. All standard methods of executing a command (such as using the mouse to open menus, or keyboard shortcuts) are scored equivalently. Linear skills tasks necessitating the execution of more than one command can only be completed correctly if the commands are executed in a predefined sequence, but they do allow for combinations of methods. For example, if students are tasked with copying and pasting an image, they would first need to select the image, and then execute the copy action followed by the paste action. The copy action could be executed using a keyboard shortcut and the paste action could be executed using a menu item.

Example task 3 (Fig. 5.8) shows a multi-step linear skills task. The task requires students to save a file using a specified filename. Initially, students need to select the “File” option from the toolbar, which opens the “File” menu. Following this, they must choose the “Save as” option, which displays the “Save as” dialog box. For full credit, students must replace the existing file name with the specified filename (with or without the “.prs” file extension), and then click on the “Save” button. Partial credit is given if the file name is different from the one specified and not the default name shown in the “Save as” dialog. The scoring is completed by the ICILS assessment system. The specified file name is translated into the language of testing in each country, and the scoring is completed by comparing the name entered by the student to the translated name in the language of testing. This task aligns with aspect 1.2 of the CIL construct (computer use conventions). Example task 4 (Fig. 5.9) from *School trip* shows a nonlinear skills task. In this task, students are presented with a spreadsheet outlining the itemized costs of a school excursion and can access the website containing the necessary information to complete the task. The task requires students to retrieve the per-student cost for the walking tour component of the excursion from the website, and input this value into the appropriate cell in the spreadsheet. Students can visit any of the available tabs within the website often as they choose to, and can enter any text into any cell. They must both locate the correct information on the website, and interpret the structure and content of the spreadsheet to determine the correct cell for the entry. The task’s automatic scoring is based on two criteria: the location of the cell and the value entered into the cell. Full credit is awarded for entering the correct value in the correct cell. Partial credit is awarded to students who enter the correct value in an incorrect cell or an incorrect value in the correct cell. This task serves as an example of a nonlinear skills task necessitating information-processing skills, and is aligned with aspect 2.2 of the CIL construct (managing information).

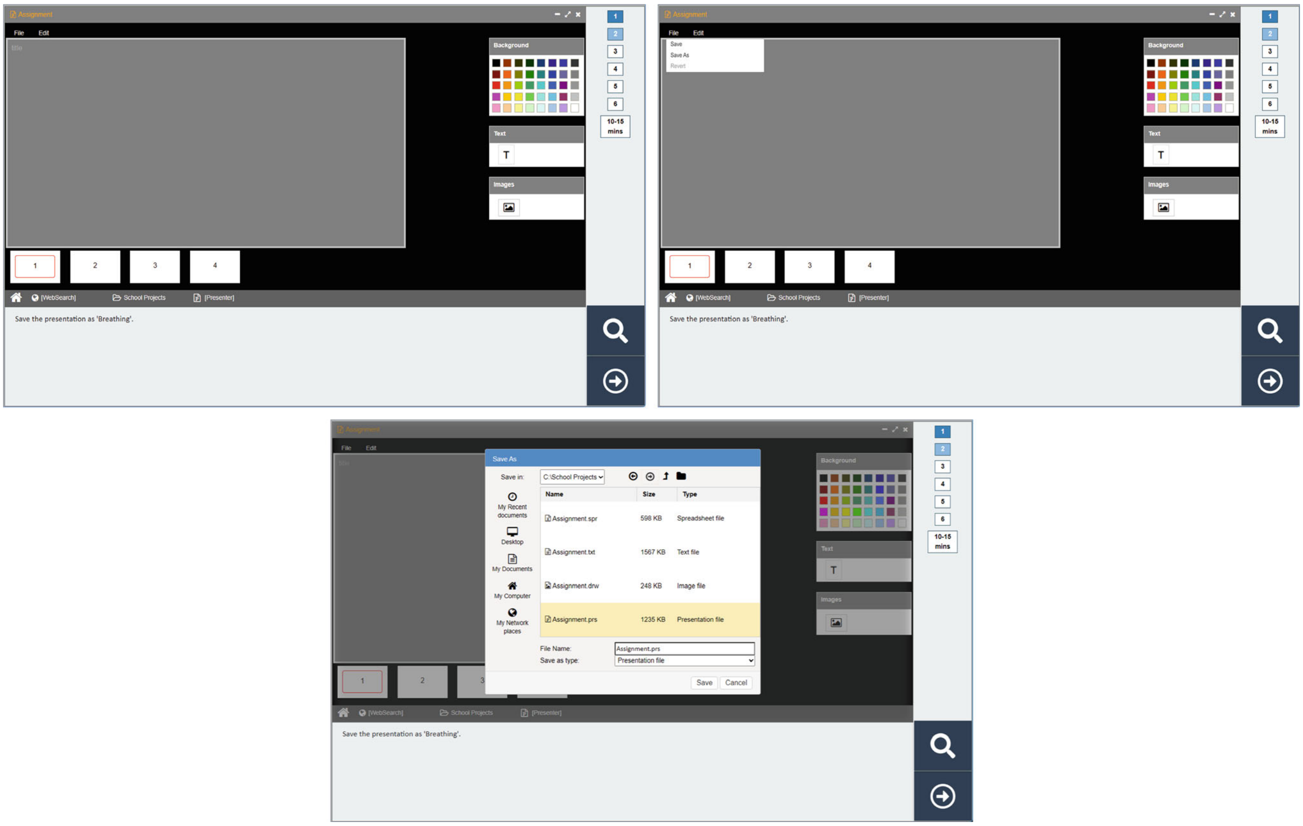

Fig. 5.8 Example task 3 (three step linear skills task from *Breathing*)

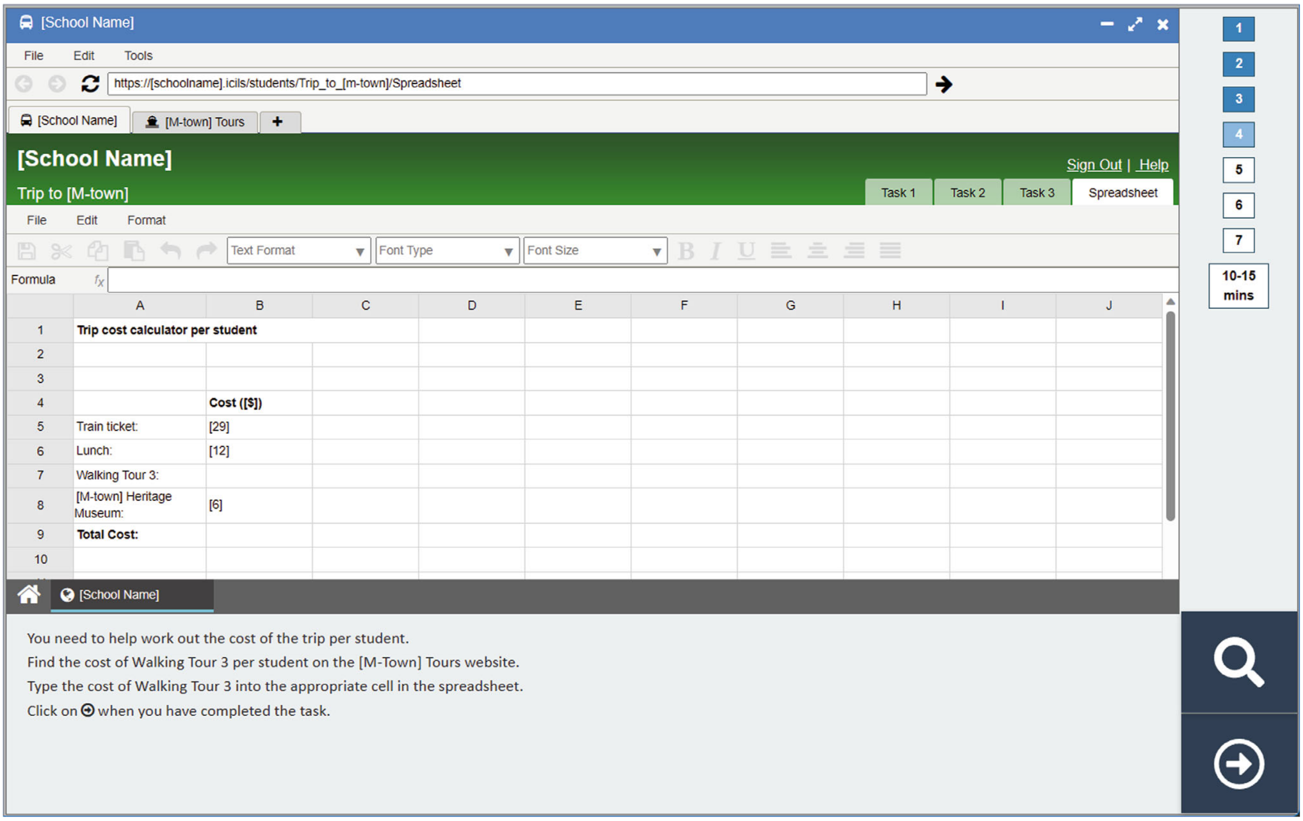

Fig. 5.9 Example task 4 (Nonlinear skills task from *School trip*)

Task Type 3: Authoring Tasks

Authoring tasks require students to alter and create information products using authentic computer software applications. These applications, purpose-built for ICILS, comply with software application conventions, such as the use of recognizable icons associated with typical functions, or common user interface feedback responses to given commands. These tasks may require students to use multiple applications (such as email applications, web pages, spreadsheets, and word processing or multimedia software) in parallel, as is typically required when using computer software to perform complex tasks. The content of each student's work is automatically saved and can be loaded and viewed for subsequent assessment by scorers according to a prescribed set of task specific criteria.

Example task 5 (Fig. 5.10) from the *Band competition* module illustrates a simple authoring task. In this task, students are required to use a basic image manipulation tool to adjust aspects of an image intended to be used as the logo for a website promoting a school's band competition. Students must rotate the image 180°, increase the brightness (by any amount), and crop the border surrounding the image without cropping the figures that are the subject of the image. The task was automatically scored. The application includes an "undo" button that allows students to correct errors; they can use the undo function as often as is required without penalty. This task aligns with aspect 3.1 of the CIL construct (transforming information).

The task is categorized as a simple authoring task rather than a complex one, because it needs only the information given in the instructions and a single software application (the image manipulation tool) to be completed by students. Its simplicity is also due to the relatively narrow range of "correct" ways in which students can manipulate the image to match the specifications.

Example task 6 (Fig. 5.11) from *Breathing* is a complex authoring task. It requires students to use information from two website sources to create a slideshow presentation to describe the process of breathing. One source offers scientific information about the respiratory system, including an annotated diagram of human lungs. The other outlines the three steps of breathing: inhalation, gas exchange, and exhalation. The stimulus is nonlinear, fully interactive, and intuitive. Students can switch between the presentation application and web browser, and between browser tabs to access the two websites. They can add text boxes to the slides and paste text copied from the websites into these boxes, and from a gallery, they can also add images

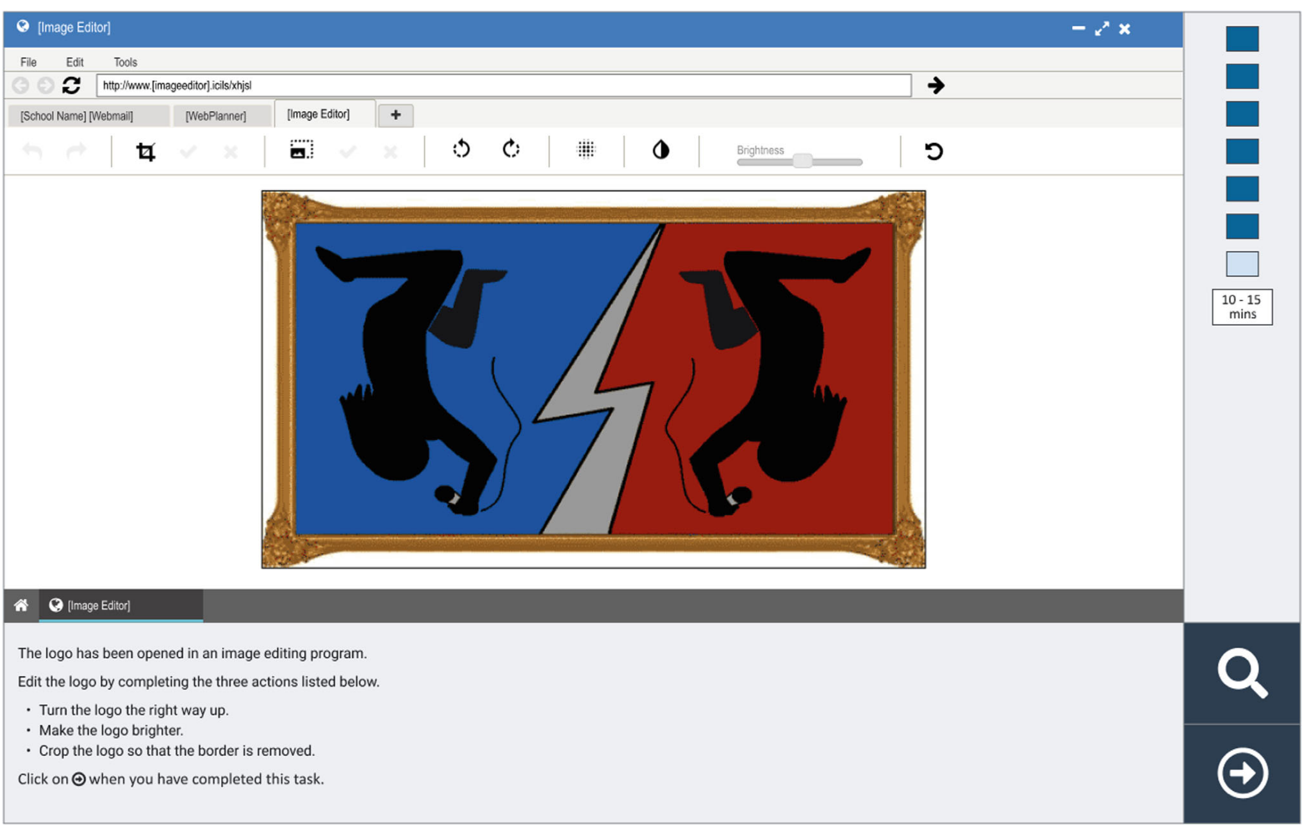

Fig. 5.10 Example task 5 (simple authoring task from *Band competition* presented in the ICILS 2023 test interface)

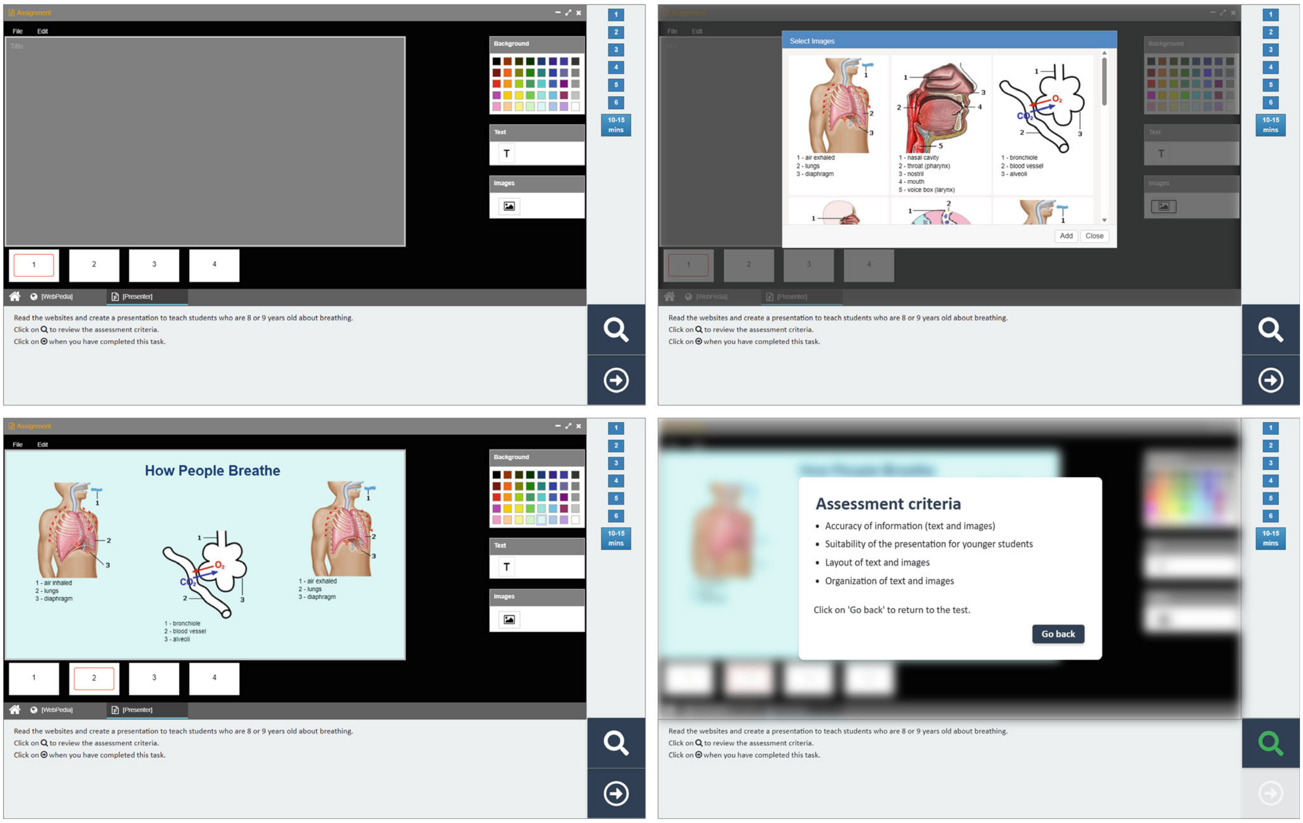

Fig. 5.11 Example task 6 (complex authoring task from *Breathing*)

that can be moved and resized. The final information product is saved, stored, and then presented to scorers for evaluation against a set of criteria. The scoring criteria for all complex authoring tasks vary according to the software environment, information content, and communicative purpose of each task. However, they all are developed to reflect aspects of two broad conceptual categories: (1) students' use of the available software features and (2) students' use of the available information.

Evaluation of students' use of the available software features can include criteria associated with students' formatting of text elements, their use of color and images, and on the overall layout of the information product they have produced. These criteria typically have an internal hierarchy based on the degree to which the software features are used to enhance or support the communicative effect of the information product. The highest level of credit is awarded to student work that demonstrates the ability to use the software features to enhance the communicative effect of the information product. The lowest level of credit is given to work that shows no application of the relevant software feature, or uncontrolled use (such as extremely poor color contrast or overlapping text) that inhibits comprehension of the product.

Evaluation of students' use of the available information can include criteria associated with the relevance and accuracy of information selected and used by the students, their adaptation of information according to the communicative context and purpose, and the appropriateness of selected information for the target audience. The purpose and target audience for ICILS complex authoring tasks are always explicitly specified. Students' use of information is assessed only in relation to the information provided to them in the task. The range of criteria available to evaluate example task 6 means that this single task collects evidence of student achievement relating to two aspects of the CIL construct: aspects 3.1 (transforming information) and 3.2 (creating information).

5.1.8 Types of Assessment Task: CT

The ICILS CT assessment includes information-based response tasks and nonlinear skills tasks with similar structures to these task types when used in the CIL assessment. However, the CT assessment also includes task types that are specific to the CT assessment. To illustrate this, example tasks from two CT modules, *Automated bus* (ICILS 2018) and *Farm drone* (ICILS 2018) are used.

Task Type 4: Nonlinear Systems Transfer Tasks

Nonlinear systems transfer tasks require students to interpret, transfer, and adapt algorithmic information, so that the results of applying algorithmic instructions can be visually displayed. Example task 7 (Fig. 5.12) requires students to interpret a node graph representing the travel directions and locations of a bus route (right panel) and to transfer and adapt this information to a set of configurable menus (left panel). Successful completion of this task demonstrates students' understanding of the visual representation of a system and the ability to decompose the elements of that system into an algorithm. Students responses are automatically scored based on the correct sequence of rows, where both the instruction and location/direction match the route, up to the first mistake. Full credit is given for correctly sequencing all rows (seven in total) while partial credit is awarded for correctly sequencing six or five rows. This task is associated with aspect 2.2 of the CT construct (developing algorithms, programs, and interfaces).

Example task 8 (Fig. 5.13), shows a different format for a nonlinear skills transfer task—an interactive node graph.

Students are presented with a network graph that visually represents a series of routes from a "Sports event" to a "School". Students are instructed to click on the nodes to establish a potential route, with the corresponding travel times automatically recorded in a table. Each node in the graph indicates a waypoint, and the time required to travel between these waypoints is displayed on the connecting lines. A node can only be selected if it is directly connected by a line to currently selected. When a valid node is selected, the line color changes from green to red, with an arrowhead indicating the direction of travel and the newly selected node. Selecting a table row restores the state of the associated route facilitating comparisons of the visual representation of a route and the total travel time associated with that route.

The task captures evidence of students' ability to interpret data in graphical form and apply algorithmic thinking to solve a real-world problem–namely, determining the most time efficient route while dealing with the visually longer paths

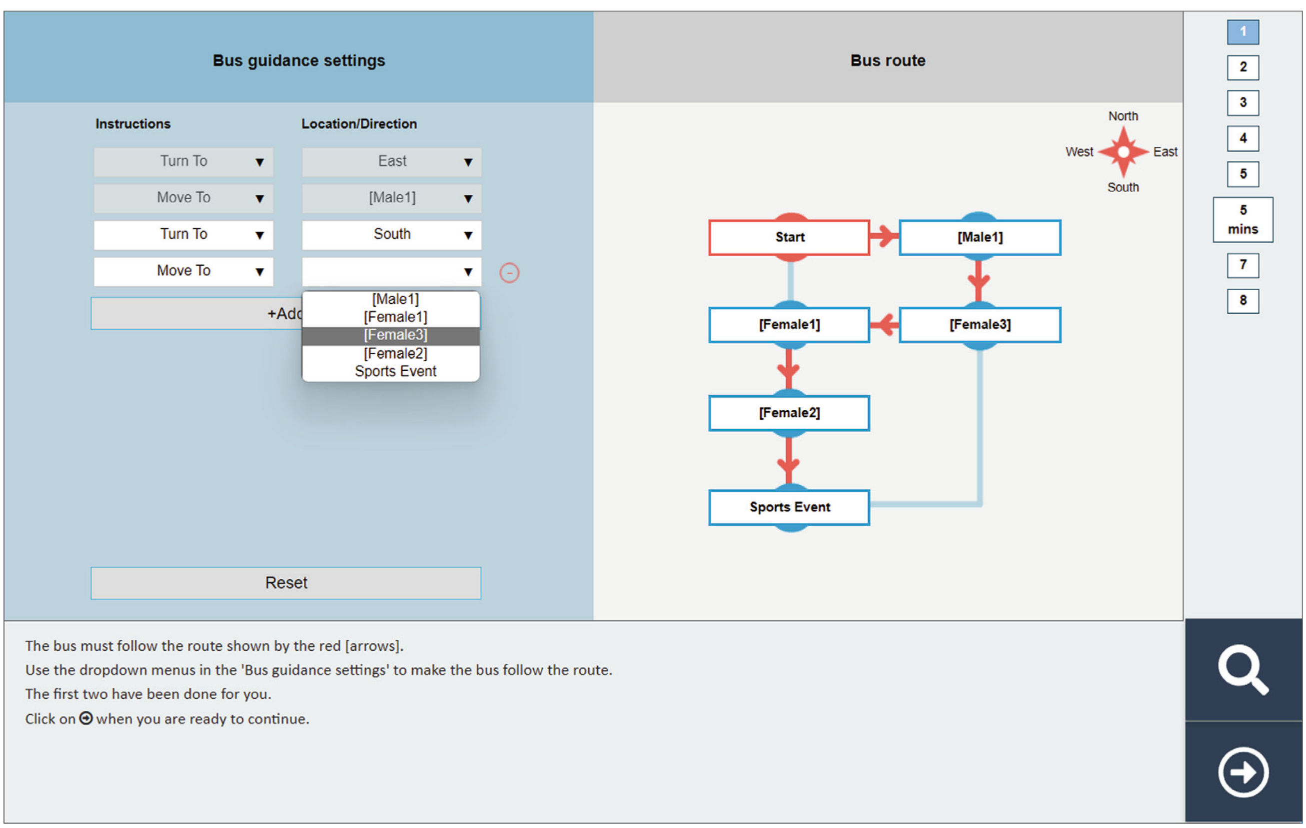

Fig. 5.12 Example task 7 (Nonlinear systems transfer from *Automated bus*)

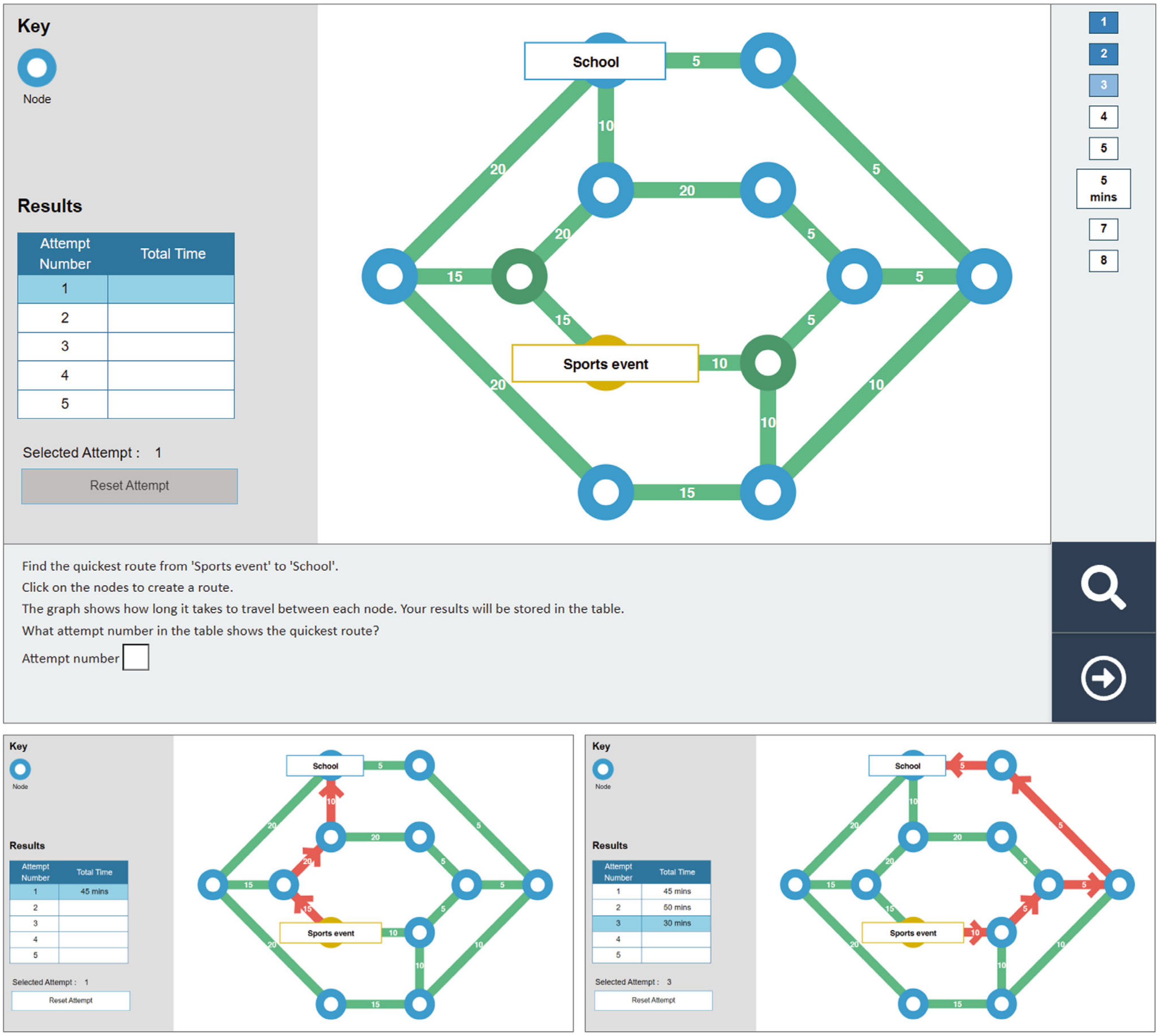

Fig. 5.13 Example task 8 (Nonlinear systems transfer from *Automated bus*)

corresponding to shorter times. The task measures their capacity for decision-making by requiring them to identify which of their attempts resulted in the quickest route, thereby also evaluating their problem-solving efficiency and relates to aspect 1.3 of the CT construct (collecting and representing relevant data). Full credit was awarded to students who identified the fastest route (30 min) using the network graph and entered the corresponding row number from the results table to show their answer. Partial credit was awarded to students who did not find the fastest route using the network graph, but correctly entered the row corresponding to fastest route from their set of attempts to show their answer.

Task Type 5: Simulation Tasks

Simulation tasks require students to set parameters, run a simulation to collect data, and interpret the data to answer a research question. Example task 9 (Fig. 5.14) requires students to configure the simulation tool and run simulations to identify the largest distance the automated bus can correctly recognize the cyclist.

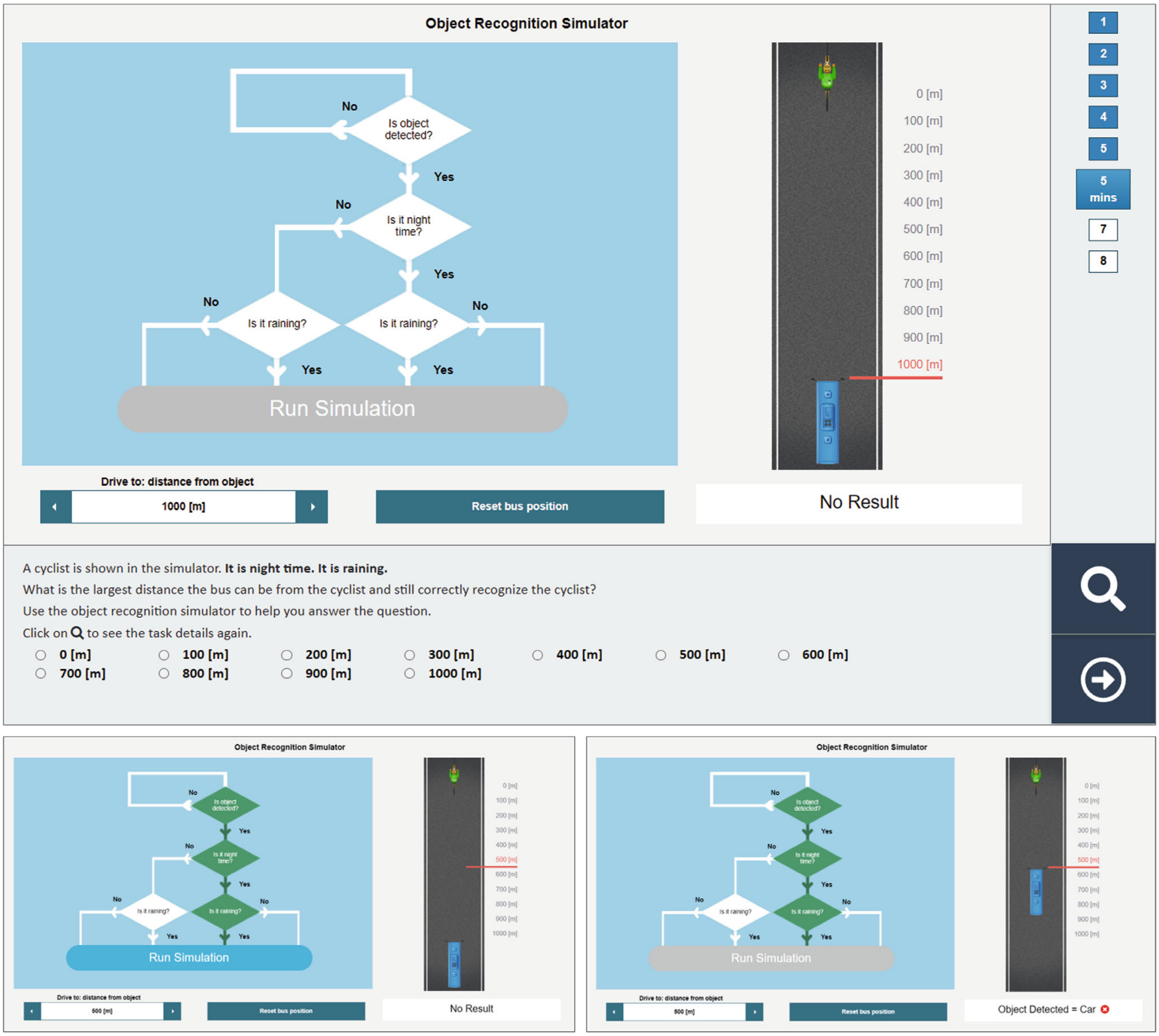

Fig. 5.14 Example task 9 (simulation task from *Automated bus*)

The decision tree (see left panel of Fig. 5.14) is used to configure the conditions affecting the result of the simulation. The student can then vary the distance from the cyclist and run the simulation to identify the largest distance. Simulation tasks such as example task 8 typically relate to aspect 1.3 of the CT construct (collecting and representing relevant data).

Task Type 6: Block-Based Coding Tasks

Block-Based Coding Environment

The overarching objective for the block-based coding environment developed for *Farm drone* was for students to complete coding tasks relating to the function of a drone used in farming. The block-based coding environment included the following key elements:

- A work space in which code blocks could be placed, ordered and re-ordered, and removed from the work space.

- A space containing the code blocks that could be selected and used in the work space. These included code blocks controlling movement of the drone, some simple configurable commands for the drone to execute, simple loops, and conditional statements.
- The facility for students to execute the code any number of times and at any time, and to see the consequent behavior of the drone as the code was being executed.
- The facility to reset the code in the work space (to the default state of each task) and to reset the starting position of the drone before executing code.

Algorithm Construction Tasks

Algorithm construction tasks require students to develop their own solution to a problem by iteratively adding code blocks to the work space and executing the algorithm to see the results. These tasks typically allow for a variety of solutions with differing complexity (variety of code blocks) and depth (the number of levels deep nested codes are executed). Student responses are scored with respect to the accuracy with which the code achieves the specified goal, as well as the efficiency of the code, taking into account the number of code blocks used and the students' use of looping and conditional logic in the algorithm. These tasks relate to aspect 2.2 of the CT construct (developing algorithms, programs, and interfaces).

Algorithm Debugging Tasks

Algorithm debugging tasks require students to modify an existing algorithm (changing the structure of the code and parameters of the code blocks in the work space) to solve the problem presented by the task instructions. In these tasks the students are presented with an existing set of code blocks in the work space, a description of the intended outcome of executing the code and an indication that the code is not working and needs to be corrected. Students can freely modify the code and also reset the code blocks in the workspace to the default state of the task (i.e., reinstating the original incorrect code requiring debugging).

The solutions are evaluated according to: (1) the accuracy with which they address the task requirements (in this case both the number of crop tiles with the correct resource dropped on them, and the absence of any resources being dropped on grass tiles), and (2) the efficiency of the code solution (measured by the total number of code blocks used). Full details of how this scoring is applied are provided in the ICILS 2018 Technical Report (Fraillon et al., 2020a).

These tasks relate to aspect 2.1 of the CT construct (planning and evaluating solutions) (Fig. 5.15).

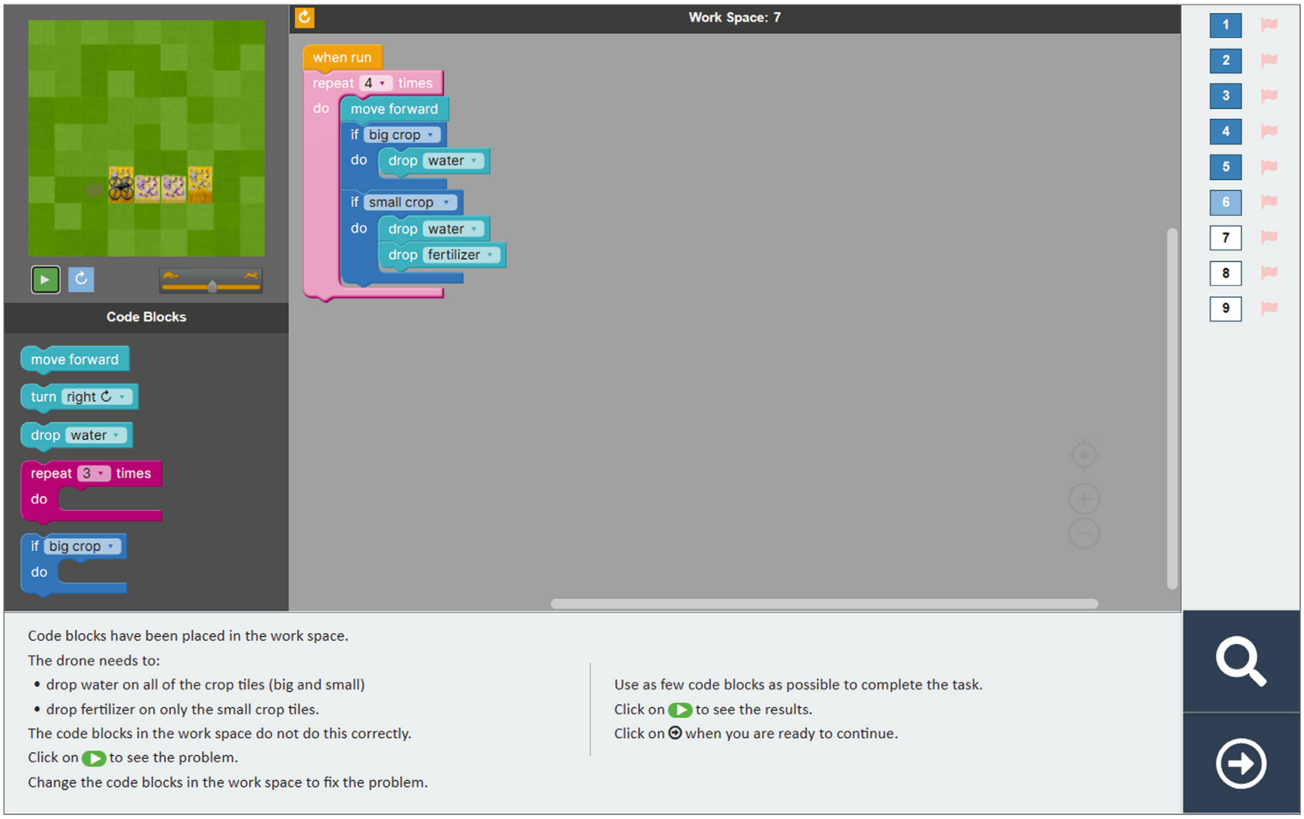

Fig. 5.15 Example task 10 (algorithm debugging task from *Farm drone*)

5.2 Mapping Test Items to the CIL and CT Constructs

The CIL and CT constructs (see Figs. 2.1 and 3.1) are central to the process of instrument development because they provide the theoretical underpinning for the assessment and a way of describing its content. The ICILS tasks are designed to collect information about specific aspects of the relevant construct (CIL or CT), and each module typically includes content that addresses most, if not all, aspects of the construct. However, the test design of ICILS does not require that equal proportions of all aspects of the CIL and CT constructs are assessed. In contrast, the ICILS test instruments were developed to ensure some coverage of all aspects as part of an authentic set of assessment activities. The number of items and score points for each aspect of the two constructs is summarized in Tables 5.1 and 5.2, showing how the content of constructs was operationalized.

In the CIL test, more items and score points per item relate to strand 2 and strand 3 than the other strands of the CIL construct (see Table 5.1). The main reason for this is that the tasks at the end of each module are authoring tasks (see Sect. 5.1.7) that focus on students' creation of an information product and therefore require each of these tasks to be assessed using multiple criteria with multiple score categories. The CIL skills and knowledge assessed with the authoring tasks reflect aspects 3.1 and 3.2, and together these contribute the largest number of score points across the CIL test modules. The spread of items and score points across the different aspects of the CIL construct also reflects the proportion of time that students are expected to spend completing the different tasks. The allocation of score points to aspects for the CIL construct in ICILS 2023 are very similar to those of ICILS 2018 (see Fraillon et al., 2020a).

While there is a similar number of items assessing each of the two CT strands, the number of score points available for strand 2 (operationalizing solutions) is approximately double that for strand 1 (see Table 5.2). This reflects the emphasis in the CT construct on assessing students' operationalized solutions (typically their block-based coding solutions to specified problems). The allocation of score points to aspects for the CT construct in ICILS 2023 are very similar to that of ICILS 2018 (see Fraillon et al., 2020a), however, in ICILS 2023 there is a slightly increased emphasis on aspect 2.1 (planning and evaluating solutions).

Table 5.1 Mapping the CIL test items to the CIL framework

CIL strand/aspect	Total (Items)	Maximum total (score points)*
Strand 1: Understanding computer use		
Aspect 1.1: Foundations of computer use	3	3
Aspect 1.2: Computer use conventions	9	12
Total (strand 1)	12	15
Strand 2: Gathering information		
Aspect 2.1: Accessing and evaluating information	18	27
Aspect 2.2: Managing information	9	15
Total (strand 2)	27	42
Strand 3: Producing information		
Aspect 3.1: Transforming information	16	26
Aspect 3.2: Creating information	31	55
Total (strand 3)	47	81
Strand 4: Digital communication		
Aspect 4.1: Sharing information	11	17
Aspect 4.2: Using information responsibly and safely	10	19
Total (strand 4)	21	36

Notes: *This is an estimated maximum number of score points at the time of writing. The exact number of score points will be confirmed as part of the analyses of ICILS 2023 CIL data

Table 5.2 Mapping the CT test items to the CT framework

CIL strand/aspect	Total (Items)	Maximum total (score points)*
Strand 1: Conceptualizing problems		
Aspect 1.1: Knowing about and understanding digital systems	5	11
Aspect 1.2: Formulating and analyzing problems	2	5
Aspect 1.3: Collecting and representing relevant data	3	5
Total (strand 1)	10	21
Strand 2: Operationalizing solutions		
Aspect 2.1: Planning and evaluating solutions	8	18
Aspect 2.2: Developing algorithms, programs and interfaces	12	30
Total (strand 2)	20	48

Notes: *This is an estimated maximum number of score points at the time of writing. The exact number of score points will be confirmed as part of the analyses of ICILS 2023 CT data

5.3 The ICILS Questionnaires

ICILS 2023 includes five questionnaire instruments. These are:

- The student questionnaire (completed by all students)
- The teacher questionnaire (completed by up to 15 teachers of the target grade in each school)
- The ICT-coordinator questionnaire (completed by the ICT-coordinator in each school)
- The principal questionnaire (completed by the principal in each school)
- The national contexts survey (completed under the oversight of the national center in each country).

All questions are to be completed by all respondents. ICILS includes a small number of questions listed as *international options*, that countries may choose to include and are common across countries that use them, and *national options*, that are country-specific questions administered only in the country that has proposed to use them.[4] Data from countries choosing to include the international and or national options are available to be reported in the ICILS international reports and are included in the ICILS international database.

The questionnaires use a mixed format, mostly closed response format questions with the exception of parental occupation questions in the student questionnaire which require students to enter short text responses that are later coded according to the International Standard Classification of Occupations (ISCO-08) by trained coders in each country.

Respondents select their responses to closed response questions using radio buttons, check boxes or dropdown menus depending on the question content. The questionnaires are not timed, allowing respondents the flexibility to return and change their responses to previous questions if necessary. The student questionnaire is designed to take approximately 20 min, while the teacher, ICT-coordinator, and principal questionnaires should take no more than 30 min each. Where the student questionnaire is completed as part of the student test session, the teachers, ICT-coordinators and principals are at liberty to complete their questionnaires at their convenience, over a period of several weeks using as many sessions as they require.

The National Contexts Survey (NCS) collects system-level data on the structure and overarching policy and program context for CIL and CT education within each country. One NCS is completed under the supervision of the National Research Center in each ICILS country and benchmarking participant. This questionnaire contains a mixture of question formats (as describe previously), including some free text responses to support explication or elaboration of information.

[4] National options are included only with permission of the ICILS International Study Center. The amount of national option content that can be included is limited so that it does not compromise collection of the core ICILS international data.

5.3.1 Student Questionnaire

The student questionnaire is based on the review of previous research, including the outcomes of previous cycles of ICILS, as discussed as part of the contextual framework (see Chap. 4), and is designed primarily to collect data that address Research Questions 4 and 5 for both CIL and CT:

RQ 3 *How do students' levels of access to, familiarity with, and self-reported proficiency in using computers relate to students' CIL and CT?*

RQ 4 *What aspects of students' personal and social backgrounds (such as gender, and socioeconomic background) are related to students' CIL and CT?*

Data gathered from the student questionnaire are used for two purposes. Firstly, these data are used in analyses that examine the relationships between student-level factors and measured CIL and CT. Secondly, these data are used to provide descriptive information about patterns of computer access and use across and within countries.

The student questionnaire is designed to generate data reflecting the following aspects of student and home background:

- Students' age (in years)
- Students' gender
- Students' expected highest level of educational qualifications
- Students' immigrant background
- Students' language use at home (test language or others)
- Students' parents' highest occupational status
- Students' parents' highest level of education
- Student reports on home literacy (number of books at home)
- Student reports on access to ICT resources at home
- Students' experience with ICT.

The student questionnaire contains questions to generate data reflecting the following aspects of ICT use and attitudes related to ICT:

- Students' use of ICT within and outside of school
- Parental restrictions on students' computer use (national option)
- Student reports on learning about internet-related tasks within and outside of school
- Student reports on learning about ICT functional tasks within and outside of school
- Student reports on learning about responsible ICT use at school
- Student reports on academic media multitasking
- Students' use of ICT in school subject lessons
- Students' use of ICT tools in class
- Students' ICT self-efficacy
- Students' perceptions about the impact of ICT for society
- Students' expectations of future ICT use for work and study
- Student reports on the extent of learning about approaches to CT at school.

5.3.2 Teacher Questionnaire

The teacher questionnaire is largely concerned with information about teachers' perceptions of ICT in schools and their use of ICT in educational activities in their teaching. The questionnaire also includes a small amount of content relating to leadership for technology within the school. Together with questionnaires completed by the school principal and ICT coordinator, the teacher questionnaire is based on the contextual framework (Chap. 4) and designed to collect data that address Research Question 2 for both CIL and CT:

RQ 2 *How is CIL/CT education implemented across countries, and what aspects of schools and countries are related to students' CIL/CT?*

The assumption is that the extent to which ICT is used in schools, and the ways in which ICT is used in schools to teach CIL- and CT-related competences, will impact on the development of students' CIL and CT. Information from the teacher questionnaire will also be used to describe the use of ICT in pedagogy among countries and major teaching areas.

It will not be possible to link teacher-based information to individual students. Rather, that information can be used to generate school-level indicators for potential two-level regression analyses in conjunction with student-based data.

The population for the ICILS teacher survey is defined as all teachers teaching regular school subjects to the students in the target grade (generally grade 8) at each sampled school. Fifteen teachers are selected at random from all teachers teaching the target grade at each sampled school to complete the teacher survey.[5] This cluster size is required to produce:

- School-level estimates with sufficient precision to be used in analyses that examine associations with student outcomes
- Population estimates with precision similar to those generated from student data.

The teacher questionnaire consists of questions about teachers' backgrounds, their familiarity with ICT, their use of ICT in teaching a reference class, their perceptions of ICT at school, and their training to use ICT in teaching.

The teacher questionnaire is designed to provide the following indices regarding teacher background:

- Teachers' gender
- Teachers' age
- Main subjects taught (at least 4 lessons per week)
- Number of schools taught at
- Teachers' experience using ICT for teaching purposes.

The teacher questionnaire is designed to generate data reflecting the following aspects of teacher perceptions regarding ICT and its use in education:

- Teachers' ICT use within and outside of school
- Teachers' ICT self-efficacy
- Teachers' learning about ICT in initial teacher education
- Teachers' participation in ICT professional development
- Teachers' perceptions of collaboration for ICT use
- Teachers' awareness of school vision for ICT use
- Teachers' perceptions of shared understanding of ICT use at their school
- Teachers' perceptions of adequacy of resources at their school
- Teachers' positive views regarding the use of ICT in teaching and learning
- Teachers' negative views regarding the use of ICT in teaching and learning
- Teachers' use of ICT across teaching activities in class
- Students' participation in ICT-related activities in class
- Teachers' use of ICT tools in class (national option)
- Teachers' emphasis on developing students' CIL capabilities in class
- Teachers' emphasis on developing students' CT capabilities in class (national option)
- Teachers' beliefs about knowledge, learning and cognition (national option).

5.3.3 ICT-Coordinator Questionnaire

The ICT coordinator questionnaire focuses on the provision of resources and support for the use of ICT in teaching in the school. The ICILS 2023 questionnaire includes questions associated with the implementation of the school vision associated with the use of technology in teaching and learning.

The ICT coordinator questionnaire includes questions designed to generate data reflecting the following ICT-related aspects:

[5] In small schools this means all teachers of grade 8 students.

- School experience in using ICT
- School policies towards the use of ICT at school
- The computer-student ratio at school
- The provision technical resources at school
- The provision of technical and pedagogical ICT support for teachers
- ICT coordinators' perceptions of hindrances to the use of ICT in teaching and learning at school
- ICT coordinators' perceptions of school emphasis on teaching activities to develop students' CT skills
- ICT coordinators' awareness of school vision for ICT use
- ICT coordinators' perceptions of shared understanding among teachers of ICT use at their school
- Monitoring and support for the implementation of the school vision for ICT use.

5.3.4 Principal Questionnaire

The school principal questionnaire focuses on characteristics of the school and broad policies, procedures, and priorities for ICT in the school and includes questions associated with the implementation of a school vision associated with the use of technology in teaching and learning.

While the ICT coordinator and school principal questionnaires should ideally be completed by different people, ICILS 2023 makes provision for the possibility that both may be completed by the same person in a small school where there is no identifiable ICT coordinator.

The principal questionnaire includes questions designed to collect data about the following contextual aspects at the school level:

- School principals' use of computers for school-related purposes (frequency)
- School size (student enrollment)
- Student-teacher ratio
- School structure and management
- Economic background of students
- School principals' perceptions of the importance of ICT use at school
- School principal reports on their expectations of teachers' ICT skills
- School principal reports on ICT policies and procedures
- School principal reports on teachers' professional development for ICT use
- School principal reports on school priorities for ICT use in teaching and learning.

The launch of ChatGPT on 30 November 2022 very rapidly led to widespread recognition, interest in, and use of artificial intelligence applications based on large language models. During the first half of 2023, it became clear that ChatGPT and similar tools were already having an impact on the work of schools in many countries. In ICILS, we made the decision to offer an optional addition to the ICILS principal questionnaire to collect national baseline data on school principals' first responses to and impressions of such tools. The decision to include this content at such a late stage of the study, and outside the conventional development practices of the study, was seen as an appropriate and nimble response to the very sudden and dramatic rise to prominence of these tools. ICILS countries were offered the option, at the national level, to include a set of additional questions associated with recognition of, attitudes toward and use of artificial intelligence tools based on large language models (referred to as "ChatGPT or similar tools") in schools.

5.3.5 National Contexts Survey

The national contexts survey is intended to collect data that primarily addresses Research Question 2 for both CIL and CT:

RQ 2 *How is CIL/CT education implemented across countries, and what aspects of schools and countries are related to students' CIL/CT?*

The assumption underlying Research Question 2 is that the opportunities to use ICT impact on opportunity to learn about CIL and CT and therefore on the development of student outcomes in these domains.

Data from the national contexts survey will be used to compare profiles of CIL and CT education in participating education systems. In addition, the data will provide information about contextual factors concerned with structure of the education system and other aspects of education policy for the analysis of differences in approaches to ICT-related learning across education systems. Data from the national context questionnaire will be used for two broad purposes:

- To provide systematic descriptions of policy and practice in the use of information and communication technologies in school education across participating ICILS countries
- To provide systematic data that can be used as a basis for interpreting differences among education systems in ICT-related learning outcomes as well as patterns of relationships among factors that are related to ICT-related learning outcomes.

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Organizations and Individuals Involved in ICILS 2023

A

International Study Center

The international study center is located at the International Association for the Evaluation of Educational Achievement (IEA). Center staff at IEA are responsible for designing and implementing the study in close cooperation with the National Research Coordinators (NRCs) in ICILS 2023 participating countries.

IEA is also responsible for coordinating and implementing ICILS. IEA Amsterdam, the Netherlands, is responsible for membership, translation verification, quality control monitoring, and publication. IEA Hamburg, Germany is mainly responsible for field operations, sampling procedures, and data-processing.

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RM Assessment

RM Assessment was responsible for developing the software systems underpinning the computer-based student assessment instruments for ICILS 2023. This work included development of the test and questionnaire items, the assessment delivery system, and the web-based translation, scoring, and data-management modules.

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ICILS Sampling Referee

Marc Joncas was the sampling referee for the study. He has provided invaluable advice on all sampling-related aspects of the study.

National Research Coordinators

The national research coordinators (NRCs) played a crucial role in the development of the project. They provided policy- and content-oriented advice on the development of the instruments and were responsible for the implementation of ICILS in the participating countries.

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