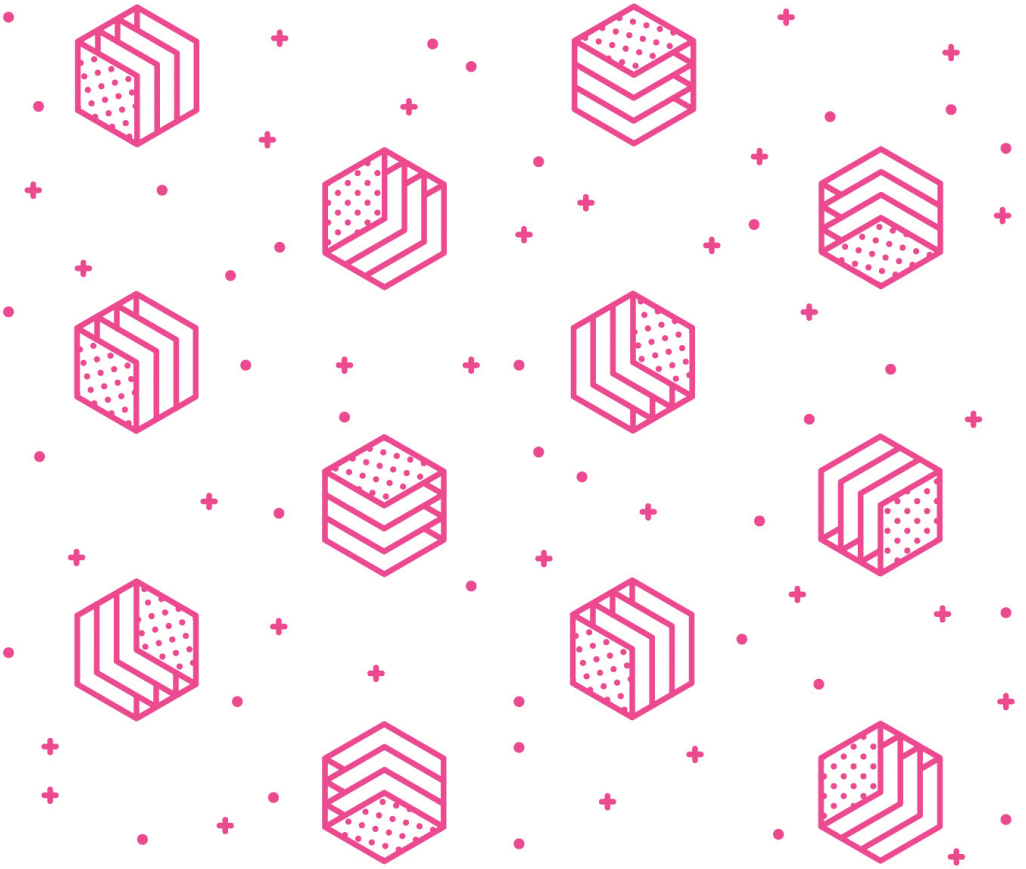
DESIGN TOOLS

A reflection towards the definition of a taxonomy

Carmen Bruno, Silvia Maria Gramegna, Francesca Mattioli,
Vanessa Monna, Martina Rossi



D.I. FrancoAngeli
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1. Challenges and needs around the future of design tools and methods

by Carmen Bruno

1.1 Introduction

Design has been exploring progressively complex scenarios, leading to a transformation in design culture and an evolution in the approach taken to projects, requiring a consequent transformation of design education and practice (Burns et al., 2006).

The social, cultural, economic, and technological evolutions of the XXI century are strongly contributing to the changes in the design discipline since they affect the human being and their habits, the ways in which people live, work, and more generally, human needs and requirements (Sahin, 2009). In the last century, the developments in technology act as one of the main drivers in the rise of the overall level of societal complexity reaching its acme in the last decades requiring professionals in many fields to be able to deal with it (Sargut & McGrath, 2011).

New digital devices, sensors, robots, and applications are changing how people process information, behave, socialize, the skills and the mindset they need to thrive in an increasingly complex world. Ubiquitous, invisible, and affective computing, artificial intelligence, machine learning, big data analytics, robotics, virtual/augmented reality and all the emerging technologies are changing skills requirements and capacity building for the 21st-century digital economy (Bruno & Canina, 2019). The digital transition is impacting the process of creation and innovation, and the Post-Information Society will continue to enable new forms of human-machine collaboration (Floridi, 2015), changing the ability to create and make

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innovation and providing new opportunities and threats that need to be managed and appropriately guided.

As human beings, we are transforming society through machines and technologies; therefore, a challenging goal is to build a just and democratic society in which people are at the centre of technological progress. Technological innovation requires social innovation and social innovation requires a broad social commitment.

We must learn how to live well with digital technologies and how to manage a radical change that will occur in less than a generation without suffering them.

A Digital Humanism[1] is needed to encourage technological design according to human values and needs instead of allowing technologies to shape human beings. In this transition, current and future designers' roles should not only contain the negative aspects of digital technologies but stimulate people in human-centred innovation.

Therefore, as designers, we must transform people towards digital enhancement and digital wisdom (Prensky, 2009), meaning the ability to find practical, creative, contextually appropriate, and emotionally satisfying solutions to complex human and social challenges through the conscious application of digital technologies generating positive implications in the world and achieving large-scale innovation.

This requires designers to enhance and facilitate the strategic and creative abilities of people, enabling them to creatively guide technological development, envisioning their future implications on society. Therefore, also design tools and methods should face these challenges and be transformed accordingly. Design must be aware of the evolution of this century and acquire the fundamental knowledge to update its toolbox for the next digital generation of designers.

In this evolving context, designers should prepare people to face the multiplicity of uncertain futures, to anticipate possible scenarios to guide innovation and to be able to take full advantage of the innovation capacity of digital technologies.

The chapter aims to briefly present some of the main forces that will transform and characterize design tools and methods in the next

1. The Digital Humanism Initiative is an international collaboration seeking to build a community of scholars, policy makers, and industrial players who are focused on ensuring that technology development remains centered on human interests. They developed a Vienna Manifesto on Digital Humanism https://dighum.ec.tuwien.ac.at/dighum-manifesto/.

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decades. In particular, from the observation of the changes of this century, three main clusters emerged, transversal to any field, each one representing a direction for the development of new design tools for both practice and education. These are: i) the need of developing and empowering creative thinking skills and multidisciplinary team working skills to find innovative and creative solutions to complex digital challenges ii) the need to lead an ethical, sustainable and future-oriented design to develop digital solutions in a complex future; iii) the need of augmenting human abilities to design and create by exploiting the opportunities provided by the emerging digital technologies.

1.2 Design tools for nurturing digital creativity skills

Creativity has consistently been recognized as a key to economic growth and social transformation (Florida, 2014) since it represents the intangible substrate for innovation (Kozbelt et al., 2010).

In this current scenario of digital transformation, creativity has gained much more importance since it has been considered one of the most distinctive human skills to nurture, to manage at best the powerful collaboration between human and machine (Corazza, 2018).

Indeed, the probability of a specific job to be shifted from humans to computers is inversely proportional to its intrinsic creativity content (Bakhshi, Frey, & Osborne, 2015). Any form of routine work, or in the limit any sort of employee position, will progressively lose its appeal or sense for humans in the future.

In the digital transition, "our creativity-driven role will be to generate surprising ideas and then carry them on to realization to produce tangible or intangible goods or services. No one should be denied the right to take advantage of artificially intelligent systems." (Corazza, 2017, p. 603).

Therefore, creativity is the fundamental skill (The Partnership of 21st-century skills, 2008; World Economic Forum, 2016) that can support people in facing the complex and continuous social, technological and economic changes we are going through, having a competitive advantage over others in a world dominated by the need

to achieve and accumulate. Creativity must be motivated and nurtured in a multitude of ways, by creative people themselves and by the places and environment we live. With the advent of the Internet and other digital technologies, creativity started to be considered as a social process and a social activity (Fischer et al., 2007) where people work together to solve problems supported and enabled by computer media and digital technologies.

«As digital innovation has permeated our daily lives, creativity has started to take a new shape: **Digital Creativity**» (Lee & Chen, 2015) defined as the human ability to create an innovative and original digital outcome and to strategically exploit the opportunity of digital technologies (Bruno, 2021). This ability is driven and empowered by the interconnection of different human factors that are shaped and influenced by the digital age and its digital technologies (Bruno & Canina, 2021).

Most of these factors intervene at an individual level referring to an individual's propensity to be creative, defined by personal ability, personality, motivational variables and cognitive processes that anticipate and result in individual digital creativity. It involves, also, skill sets that encourage creativity and the ability to remember a large amount of information accurately to be able to recall it when needed to improve the capability to create links between different ideas to solve problems.

At the same time, some other factors intervene on a collaborative level when a team of individuals have to create together. Factors of team digital creativity are related to the ability to spontaneously and actively share knowledge, information, expertise and ideas in a group setting with the purpose of reaching a broader understanding of the problem. This is a critical aspect for a creative team because it incorporates individual-level knowledge into team one's to solve problems and complete tasks for the related project. Also, trust and empathy occur within members during teamwork, influencing how knowledge is shared, viewed and integrated by team members. Team trust in its essence represents the predictive understanding of another's behaviour.

In a transitional era, design must analyse current transformations and play the role of a guide by enabling and empowering individual

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and team digital creative skills and mindset, educating people to face the complex digital transformations of our century. People should understand how to cooperate with digital technologies, apply these creative abilities to adopt digital opportunities to generate innovation for future global challenges, and to manage the threats opened by the digital evolution.

A space for new design tools and methods has been opened by the need of empowering various aspects of Digital Creativity, from emotional[2] to cognitive to social aspects, transforming people toward Digital Maturity.[3]

Reaching a Digital Maturity for humans refer to a «continuous and ongoing process of adaptation to a changing digital landscape» (Kane, 2017), allowing them to continuously understand the foreseeable opportunities as well as the threats that will be offered by the digital evolution, developing a strategic approach to the adoption and application of such technology. Indeed, digital progress and evolution cannot be stopped and or even slowed down, and as human beings we have to state our role towards them.

Digital Creativity empowerment is intrinsic and transversal to the five key abilities to become digitally mature which are (Kane, 2017): (a) the ability to collaborate in cross-functional design teams (b) the ability to innovate, having a digitally-minded cultures, visions and experiences, (c) a continuous learning ability creating enjoyable learning environments (d) the ability to scale small digital experiments into wider initiatives that have business impact, and (e) the ability to plan a long term vision/strategy to face the changes emerging in the digital landscape.

New design tools and methods are needed to enable the 5 key abilities that lead to the increase of the digital maturity level of people. The nurture and development of such digital creativity skills of the future professionals is becoming also a compulsory step for design

2. Matter mind studio has developed a series of emotion centred design methods to empower the emotional aspects of creativity. https://medium.com/emotion-centered-design.

3. Digital Maturity is a concept emerging along with the growth of the digital economy and industry 4.0, as a response from an organization to cope with rapid development in technology through an adequate reaction. Indeed, Digital Maturity has been defined by Aslanova & Kulichkina (2020) as "a gradual process of integration and implementation of organization processes, human, and other resources into digital processes and viceversa" (p. 444).

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education that will form the next generation of professionals able to guide organizations to continuously adapt to an evolving digital landscape to achieve Digital Maturity. Indeed, in the current scenario of digital transition companies are facing an unprecedented transformation to start a process of digitization and transformation, where people and skills play a crucial role over technologies.

1.3 Design tools for developing a sustainable and ethical digital future

The approach, mindset and toolbox of designers have so far allowed companies to deal with human and social structures of increasing complexity to achieve large scale innovation and be competitive on the market. There is an embedded understanding of the design ability to impact not only the present emotions or actions of those who come in contact with it in terms of organizational development and success, but also the long-term view of everything from political thought to social evolution – even the power to shape the "big picture" of entire cultures or generations (Evans & Sommerville, 2007). Design Thinking (DT) tools and methods have always supported in designing products interfaces and services, focusing on human needs and looking for new perspectives in order to open a window on the future. However, DT in its original form seems not suitable to deal with the complexities of such futures because the scope of its methods and tools is centred on providing human-centred solutions in a foreseeable, probable future (Canina et al., 2021). For this reason, DT really requires a foundation in the dynamics of Future Thinking (FT) to be most effective in reaching its full potential as a tool for creating in our age of uncertainty and complexity. A new space for design tools opens in this direction, where it becomes fundamental to rely also on disciplines such as anthropology and sociology to be able to anticipate the future. In this space new tools and methods should be developed to support professionals in different fields in anticipating needs, shaping the future and making radical innovations even in an uncertain and complex future. These tools should be

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inspired by FT methodologies which already present several methods, approaches, and tools that can allow us to shape the future.

Future institutions and design agencies have already started to develop tools and toolkits to merge future methods in design consultancy. The School of International Futures, working for Save the Children, have selected foresight tools widely used in the public and private sectors, and adapted them to serve the particular needs of Save the Children of delivering a better future for children. The toolkit[4] can be used to explore drivers of change, visualise alternative future scenarios, and understand the implications of our thinking to learn how to prepare for and influence the future. *Untangling Alternatives* (Tangity, 2021) enable professionals exploring a flood of futures and being able to collect insights and clues to stimulate a debate and to deal with the uncertainty of our times – in terms of individuals, societies and businesses. *Near Future Design* (Nefula, 2021) is a transdisciplinary methodology through which is possible to face with a present in rapid evolution and experience near future scenarios, in order to improve the quality of decisions about which futures we want. As technology moves faster, predicting futures has become more difficult to anticipate. *Actionable Futures Toolkit* (Nordkapp, 2018) contains a modular set of tools coming, from game design and science fiction, developed to build and align a future for an organisation, service or a product, taking in account the ethical aspects of technological innovation.

Future responsible innovation is indeed the next critical wave of Design Thinking (Lane, 2020). Today's technologies provide terrific opportunities to augment human abilities across a range of scenarios. At the same time, technologies without appropriate grounding in human-centered thinking, or appropriate mitigations and controls, present considerable challenges. These technologies have potential to injure people, undermine our democracies, and even erode human rights – and they're growing in complexity, power, and ubiquity. Data systems and algorithms can be deployed at unprecedented scale and speed – and unintended consequences will affect people with that same scale and speed.

4. Strategic Foresight Toolkit – making better decision: https://resourcecentre.savethechildren.net/node/16327/pdf/strategic_foresight_toolkit_online.pdf.

People often don't consider ethics a design problem, but with the evolution of digital technologies it becomes a mandatory aspect to consider when creating and innovating.

How can we always make sure we're putting people first when designing large scale systems? Especially when those systems will change over time, even evolving without direct human supervision?

Here is where design tools have an important role today: helping people and tech builders learn to exercise their moral imagination (Moberg & Seabright, 2000). Expanding human-centered design to emphasize trust and responsibility is vital for building an ethical future. When designing with data and AI systems we must learn and guide people in considering the ethical implication of their project. As stewards of technology, we realize that today's decisions may have irreversible and destructive impacts. This creates an urgent need to minimize disasters, conserve resources, and encourage responsible technological innovations. IDEO developed the *AI Ethics Cards*[5] which is a tool to help guide an ethically responsible, culturally considerate, and humanistic approach to designing with data. The deck is meant for use by teams working on the development of new, data-driven, smart products and services.

The Ethics and Society organization at Microsoft, based on their experiences and learnings from developing AI technologies, launched the *Responsible Innovation Practices Toolkit*[6] to facilitate the process of responsible innovation and exercise our moral imagination to consider the socio-technical implications of what we are creating.

Designers come across ethical issues at various stages of a design project. Handling these issues calls for a set of skills that people should develop more than ever today despite the domain in which they operate and design. Design tools and methods can therefore be developed to guide people in the development of these ethical skills and mindset.

5. IDEO's AI Ethics Cards: www.ideo.com/blog/ai-needs-an-ethical-compass-this-tool-can-help.

6. Responsible Innovation Practices Toolkit: https://aka.ms/responsible-ai.

1.4 Augmenting humans through design tools

In the last years, the integration of new digital technologies has been used not only to innovate products and services, but also to support and foster the creative design process (Shneiderman, 2005). The digital transition is indeed widely affecting the design tools that designers adopt to facilitate the steps of the design process such as gathering and sorting different information or generating project opportunities and identifying new directions. A new generation of digital design tools is rapidly emerging requiring the contributions of many disciplines such as design, computer science and psychology, where design facilitates their collaboration and contamination. The literature in Human Computer Interaction presents and offers many digital systems, tools, and environments specifically designed to advantage individual and collaborative creative design processes in different ways. Traditional techniques of stimulating creativity have been replaced and enhanced by technology-driven tools, such as virtual rooms, decision cockpits, various communication tools and interactive dashboards (Hisrich & Soltanifar, 2021). Companies and artists have already started to use and built their own digital interface to support their creative process as well as to propose tools that can empower the human potential. For example, the use of the IoT has now made it possible for ideas to be sourced from virtually anywhere, going beyond the capabilities of manpower.

A deep exploration of the literature highlighted four main modes of interaction with which digital design tools can support and augment humans in design activities (Bruno, 2021). These can both exist individually and be played simultaneously within the same digital tool or platform.

The first and the most ambitious vision of human-computer collaboration for designers and creators is when **digital technology acts as human co-creators.**

Emerging cognitive technologies, such as Artificial Intelligence (AI) and Machine Learning (ML), have the potential to autonomously learn and interpret information, combine concepts to generate new ideas or start a dialogue with human beings. In some cases they can replace humans in routine activities but in other cases they can even

augment human capabilities to perform faster, smarter and richer. Ferrero, in 2017, launched the "Nutella Unica" project[7] where, thanks to an AI algorithm, they generated 7 million of unique versions of Nutella jars' label. Thanks to this technology, they were able to obtain a number of different graphic identities that are outside any human possibilities.

Digital technologies can be also used as «an expert system, knowledgeable in creativity-relevant techniques that can help the user to go as far as possible» (Lubart, 2005, p. 367). By replicating human cognitive processes, they can speed up and enrich human thinking, augmenting work and learning processes becoming an **inspirational and feeding partner**.

A relevant example is NeuroCreate[8], an AI-powered platform that provides a suite of digital tools that, as brain prosthesis, support people in the exploration and generation of ideas by extremely speeding up and expanding their cognitive processes reaching peak performances of the creative process. However, it is important to clarify that digital tools are just a catalyst to initiate, stimulate and augment the human creative processes and cannot be an optimal solution in all situations.

Digital technologies can also be used to modify the environment and the space in which the creative activity takes place to generate digitally created artificial worlds. Indeed, the surrounding environment is considered an important element that can inspire the creator. Some digital technologies, such as Virtual Reality (VR), can indeed provide immersive realities to generate imaginary, symbolic or a simulation of the real world by altering the surrounding space and objects (Fuchs, 2006; Rieuf et al., 2016).

Other technologies such as Augmented Reality (AR) can have a role of a **guide and trainer in the creative process** providing visual support that show users the path for learning how to solve an activity or part of the process[9]. This is another mode for technology to support the creative design process. Digital interactive systems are designed to

7. Algorithm designs seven million different jars of Nutella: www.dezeen.com/2017/06/01/algorithm-seven-million-different-jars-nutella-packaging-design.

8. www.neurocreate.co.uk.

9. Another Reality is a digital studio specialized in the development of immersive solutions in Extended Realities (XR) to provide visual guidance in many different contexts. www.anothereality.io/portfolio_page/med-3d-lab-medical-laboratory-in-vr.

provide real-time feedback to support humans in immediately changing strategy when designing. This is also a kind of guidance useful to accelerate decision making and test different ideas and solutions quickly in the creative design process.

Lastly, digital technology represents an opportunity for interacting, communicating and co-creating with other people. Digital technology is a **networker and a facilitator of communication in collaborative processes**.

The empowerment of individual digital creativity involves communicating and sharing one's ideas with an audience that can evaluate, interpret and provide suggestions for the idea improvement. Today, individual creators indeed can find a larger support from a wide audience in the different moments of the creative process, from the collection of information, idea generation and ideas evaluation. Open platforms, such as OpenIDEO[10], are totally growing on the idea of leveraging an online community to create solutions for social issues supporting the connection of people from all over the world to build on each other's skills and ideas. Digital technologies can provide new digital spaces augmenting the communication, collaboration and co-creation between small teams working together from distance[11] (Bourgeois-Bougrine, 2020).

New digital design tools to facilitate distance brainstorming among a team are growing, but much more work and development is needed to improve them and design them keeping a central focus on human needs and human factors.

1.5 Conclusions

The chapter illustrates some of the main forces and challenges that are now triggering the evolution and development of design tools and methods. These forces are strictly connected to the digital transformation we are facing and have been deeply analyzed and

10. www.openideo.com.

11. For example Think Space is a Virtual Reality software that allows to brainstorm in different type of extreme and unconventional environments such as the desert or a remote island – https://vrtodaymagazine.com/think-space-work-with-brainstorming-in-vr-on-a-remote-desert-island/.

observed through research (Bruno, 2020) and projects (IDEActivity, 2017) carried out by the author.

Human beings are co-evolving with digital technologies changing also the society, its culture, economy and mindset.

In this transition, design has the fundamental role of guiding and facilitating the changes by educating and training people to face them. Design tools and methods are one of the powerful means that can be used to play this role. They could support the development of a design approach and mindset as well as enable people to reflect on urgent and relevant topics to act better making them agents of change.

Therefore, also design education should evolve to provide the right skills to both design students and educators to prepare the next digital generation of designers and provide new creativity-driven design tools that will form the future designer toolbox. It has become fundamental to train future professionals to face the complex real-world challenges brought by the digital transformation, and its implication, fostering sharing of cross-cultural knowledge from academia to industry and vice-versa.[12]

Surely, other forces shaping future design tools can be identified especially when each specific branch of the design discipline is explored vertically.

This means that the panorama of design tools is in continuous growth and evolution according to the changing affecting our human and social existence. Therefore mapping the scenario of Design Tools @POLIMI is also an attempt to map and keep track of the forces that are shaping the tools and more broader the design discipline.

12. This is one of the main goal of the Erasmus+ project, "Digital Creativity for developing Digital Maturity future skills": www.dc4dm.eu.

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2. Design tools: rise and affirmation in the disciplinary debate

by Francesca Mattioli

One of the main drivers that initially inspired this research is the complexity and blurriness that surround the term *design tool*. The interest in understanding how this term is being used is due to its increasing resonance both in design practice and design research, followed by a growing recognition of design tools as disciplinary instruments. From one side nowadays design tools are on the lips of many design practitioners and scholars, but on the other side the meaning of the term is so broad that it can potentially be used to describe a pencil, a web app, an activity or a cards deck. The aim of this chapter is to review the main contributions that introduced and shaped the term design tool to its current popularity, but also to dig deeper into the reasons that motivate the growing disciplinary debate around design tools. Not of secondary importance, the chapter aims to propose a semantic clarification regarding the term design tool, not to provide a universal definition but rather to prepare the ground for understanding the following chapters and the foundational assumptions that drove the research presented in the book.

2.1 Design tool: buzzword or disciplinary milestone?

Engaging with this research around design tools the first step we took was to engage with a desk research concerning the use of the term within the design discipline. Through this step we acknowledged that a certain degree of confusion exists around the term, which is possibly

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amplified by an even greater confusion around the two words that compose it, “design” and “tool”.

The semantic confusion around the word *design* is widely discussed in literature, together with its underpinning reasons (Blackler et al., 2021).

> Any book on design has to face a difficulty that stems from the English language. The word “design” is ambiguous, as it covers both planning (of products and systems), and also what most other European languages would loosely call “formgiving”. The latter meaning is more restrictive than the former, which may cover anything from hair and food design to designing airplanes (Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2011, pp. 7-8).

The word design is a very common word with many levels of meaning, which makes it a word without precise boundaries and complex to define (Heskett, 2002). Moreover, the indetermined nature of design goes beyond the semantic sphere, because design is an activity (and a discipline) that exists at the intersection of different disciplines and is positioned between art and science (Rampino, 2018). Innumerable times scholars and eminent researchers attempted to provide a definition for the word design: discussing all of them or providing a new one is well beyond the scope of this chapter. Given the vagueness of the term “design”, it becomes even more complex to find a definition when we combine it with the word “tool”, which adds another element of indeterminacy. In the research community, moving beyond the design field, the terms “tool” and “method” are used almost interchangeably, and often also referred to as “approach” and “methodology”. Acknowledging this confusion Rampino & Colombo (2012) proposed a semantic clarification and provided a definition of research tool:

> A research tool, or instrument, is a structured procedure sharply focused on a precise objective […]. It is often characterized by the prescriptions to follow in order to obtain the result in a valid way […]. Example of research tools in the social sciences and psychology include questionnaires, interviews, and the focus group, whereas, in design, research tools mostly correspond to the tools of design practice, and are thus often specific to one field of design […] (Rampino & Colombo, 2012, p. 89).

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We assume that the term "design tool" possibly originated in the '80s from the term "research tool", with specific regard to qualitative research (as it will be discussed in the next paragraph) and therefore this clarification is also important for our discussion. In our research we acknowledged a great interchangeability between the design tools and methods as well; it's not our interest to give a precise definition of these terms but rather address why design tools have become so relevant in the disciplinary debate and how are they conceived or used. despite the semantic confusion surrounding design tools, they are widely discussed in the relevant literature and have become a relevant topic. The closing statement of Bürdek's introductory chapter appears to be particularly insightful for our discussion:

> All the same, there are diverse attempts, not least at design schools, to understand design as a "world-bettering" discipline. While this no end of good to the consciences of the protagonists, it changes nothing in the technological, economic, and social circumstances under which design is practiced. On the one hand, design is today anything from urban design to nail design. Everything is design. On the other, much thought is now being devoted to developing and describing design as a discipline. The latter is the topic of this volume (Bürdek & Basel, 2015, p. 14).

Following Bürdek argumentation for his introduction, energy and thought are now devoted to design tools conception, implementation and dissemination and this is what our research is about. Rather than strive to define design in general or design tools specifically, we'd prefer to provide an overview and our interpretation of how this theme developed in the disciplinary debate and how design tools are today present within it. This will help us to establish a framework to define design tools in our community of practice, the design department and school at Politecnico di Milano.

2.2 From the Technical to the Human Perspective: the rise of design tools

To understand the reasons underpinning the contemporary debate around design tools it's necessary to analyse the evolution of design as a discipline. To this extend the "Evolving Perspective" framework

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proposed by Rampino (2018) is assumed as the main reference; in the book, industrial design and the role of designers are analysed and interpreted in light of four main perspectives, meaning the four most relevant economic, socio-cultural, technological and environmental changes that shaped western society from the industrial revolution to nowadays. The first, the Technical Perspective, grounds its roots in the consumer economy where standardisation and mass production strongly influenced in shaping the design discipline. Indeed, starting from the Industrial Revolution, designers focused more on the manufacturability, technical details and production optimisation of goods, looking for the best solution within these domains.

> At the very core of mass production is producing a large number of identical items in shorter timeframes and thus at lower cost. These reduced manufacturing costs work to the advantage of both manufacturer and clients. The significant increase in number of identical items to be produced in a shorter time required standardization, i.e. using a small range of identical components. Therefore, mass production and standardization are two strictly related concepts (Rampino, 2018, pp. 55-56).

In other words, from the Technical Perspective, design follows the dominant positivistic paradigm of the hard sciences, where the new product development process is conceived as technology-driven and tools are mainly quantitative and inspired by engineering or science (van der Bijl-Brouwer & Dorst, 2017). The rise of design tools can be identified within the second perspective described by Rampino (2018), namely the Human Perspective. Indeed, starting from the early 1980s, design lived a substantial paradigm shift influenced by the affirmation of the so-called experience economy, where mass produced goods start to be conceived as experiential objects aimed at respond to users' desires.

> […] it can be said that throughout the twentieth-century design was marked by two opposing tendencies: mass-production and standardization on one hand, with a strong product-centered focus, expression of artistic individuality on the other, and a parallel shift towards user-centered design (Rampino, 2018, p. 95).

The recognition of the importance of product-human interrelations determined a substantial shift from a positivistic paradigm toward a

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constructive one: designers needed to know the rules for mass production but also to be able to be interpreters of stakeholders' desires and willing. It is within this context that the design discipline starts to borrow methods and tools from the research domain of the humanities and the social sciences (i.e. sociology, anthropology), especially to conduct qualitative research on users (Mattioli, in Rampino, 2018). This new approach to design is still very present and often identified by the term human-centered design, which is broadly discussed in literature and variously defined by different scholars. Adopting Friess (2010) definition it could be said that human-centered design is an approach to design that follows two main principles:

- Conducting research with real people who are likely to use the product, and
- using that research to drive the design solution

(Friess, 2010, p. 41).

In our view, it is with the introduction of human-centered design that the discipline started borrowing methods and tools from qualitative research, thus inherited the semantic blurriness surrounding these terms which, as previously mentioned, could be indeed reconducted to the wider research community. The design tools celebrity was certainly strengthen starting from the early 90s by the affirmation of IDEO, a design consultancy that offered to its clients tools to support the creative process of new product development.

An American design consultancy, IDEO, became famous thanks to its strong and detailed processes especially concerning users' needs. Specifically, they developed ad hoc tools such as "Method Cards: 51 Ways to Inspire Design" to support the interaction with users (Abecassis-Moedas, Ben Mahmoud-Jouini, Dell'Era, Manceau, & Verganti, 2012, p. 325).

With IDEO and other design consultancies, design thinking and its tools became popular and expanded beyond the design discipline, being adopted by companies worldwide as a managerial asset for innovation (Rampino, 2018). Since these types of consultancies based their offering on specific design tools that served to formalise the design thinking process (Abecassis-Moedas et al., 2012), it follows that design tools became rapidly known and popular.

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2.3 Digital and Social Perspectives: the affirmation and proliferation of design tools

In the last decades, the massive advent of digital technologies changed the world and a new perspective pervaded industrial design, namely the Digital Perspective (Rampino, 2018). Three digital revolutions have taken place over the last half century, taking us from analog phones to the internet, personal computers, smartphones and the latest digital fabrication technologies (Gershenfeld, Gershenfeld, & Cutcher-Gershenfeld, 2017). Digital technologies opened up new global scenario for knowledge production and exchange, but also determined a greater interest for technological features of product to be designed. Accordingly, since the early 2000s an increasing number of design scholars start to present, review and categorise digital design tools (e.g. Aldoy & Evans, 2011; Busby, Parrott, & Olson, 2000; Malakuczi, 2017; Mothersill & Bove Jr., 2017; Ramoğlu & Coşkun, 2017; Treadaway, 2007). In the same time span, also the last perspective, Social one start to acquire more relevance.

> In general, human-centered design is founded on an understanding of human beings as individuals. In the emerging social perspective, our new relationships with the natural world and with the socio-technical systems are questioning this prior understanding […]. For design, the focus of attention is shifting from finding the best solution, whilst considering an artefact and its individual user, to finding the right balance in each project, considering society as a whole (Rampino, 2018, p. 184).

The raising awareness of the downsides of industrialisation shed a light on the need for industrial design to consider sustainability as a fundamental aspect for new product development. According to this perspective new design tools and toolkits were conceived to embed the environmental, the economic and the social pillars of sustainability in the design process, leading to their exponential proliferation and revealing a vast panorama of tools devoted to sustainability (e.g. Angheloiu, Chaudhuri, & Sheldrick, 2017; Lockton, Harrison, & Stanton, 2013; Marseglia, 2017; White & van Koten, 2016). In the last decades a growing attention to the impact of industrial design on the environment has prompted a reconsideration of the footprint of materials and production processes, seen as the main means by which

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the intangible becomes tangible and thus an idea becomes a product. This dimension, known as the environmental pillar of sustainability, triggered the development of tools and toolkits for designers to wisely evaluate their material and manufacturing choices in light of their impact on the environment: a vast collection of these tools could has been collected by the European funded project called the International Learning Network of networks on Sustainability (LeNSin) and made accessible on its open platform (LeNSin, 2021). Similarly, scholars and experts began to analyse the industrialisation shortcomings concerning the economy, debate that contributed to the affirmation of design tools related to the economic pillar of sustainability. A well-known example is represented by the work of the Ellen MacArthur Foundation, which promotes the circular economy also by disseminating design tools to this extent, for instance the Circular Design Toolkit or the Toolkit for Policymakers (Ellen MacArthur Foundation, 2017). However, among the three pillars, the social one has consolidated the most the design tools' role in contemporary design. The current debate around design tools is indeed strongly intertwined with another emerging approach within design practice and literature, namely codesign.

> From public consultations, to codesign sessions, civic hackathons, and other forms of creative meetings or workshops: a great variety of participatory events and programmes are popping up all over the world, within companies, governments and organisations in general. This is also because the practice of collective creativity is considered promising in tackling the most pressing societal challenges: in order to solve complex problems it is necessary to include a multitude of diverse players. The notion of codesign is precisely based on the idea that people having different voices should collaborate within a design process: this practice has been around for almost forty years under the label of participatory design, while the use of the expression "codesign" is a more recent conceptualisation (Meroni, Selloni, & Rossi, 2018, p. 17).

As described by Meroni et al. (2018), codesign could be regarded as a recent result of the merging of two traditions two tradition, namely the North American human-centered design and the Scandinavian participatory design, an approach characterised by a view of the user as an expert that can become partner of the designer in the idea generation. The advent of codesign is strictly related to the social pillar

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of sustainability, because in contemporary times this approach has become the key mean by which designers reflect on the role of design in and on society.

> This social conversation is, to all intents and purposes, a co-designing activity: a dynamic process in which participants intervene bringing their own particular knowledge and designing capacity. Among these there are obviously also design experts who express their skills and abilities in social innovation design. We can say, then, that design for social innovation is the expert design contribution to a co-design process aiming at social change. In practical terms, it is a blend of different components: original ideas and visions (from design culture), practical design tools (from different design disciplines), and creativity (which is a personal gift), within the framework of a design approach (deriving from previous reflexive design experience) (Manzini, 2015, p. 63).

According to Manzini, when dealing with social innovation, design tools and toolkits that foster codesign approaches are crucial for designers. This interpretation is supported by existence of numerous published works that addressed the theme of design tools for codesign and co-creation (e.g. Donetto, Pierri, Tsianakas, & Robert, 2015; Hussain & Sanders, 2012; Sanders & Stappers, 2008; Sanders & Stappers, 2014; Steen et al., 2013; White & van Koten, 2016).

This brief overview on the three pillars was aimed at showing how the theme of sustainability, both considered as a whole or divided in its component, massively contributed to affirm the role of design tools and toolkits, which in the last years became a paramount design knowledge.

2.4 Disciplinary evolution and the contemporary relevance of design tools

By reading the design tools evolution from the lenses of the Four Perspectives proposed by Rampino (2018) it's clear that design tools are now a paramount for design practitioners and scholars. Each perspective does not substitute the previous ones but rather adds some new elements to the discipline and therefore contributes with a new layer in shaping a multifaceted perspective of industrial design. For this reason, since design tools have taken hold, they have increasingly become part of the disciplinary culture being often intended as catalysts and support for the

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entire design process. Design tools flourished worldwide and spread rapidly through the web, becoming one of the fundamental knowledges taught to novice designers and students. Consequently, also universities and design schools are gradually including design tools in their educational practices and researches. However, the blurriness surrounding the concept of design tools allowed a wide degree of freedom in the way they have been defined in literature and consequently designed. In this scenario our community of reference, the Department of Design at Politecnico di Milano is on the front line when it comes to designing, testing, using, promoting or teaching design tools. However, being a vast research community, it is complicated to organically collect and monitor the design tools that can be attributed to our scholars and researchers so far. To organise this expanding area of knowledge is indeed the main rationale behind the Design Tools @POLIMI project, which primarily aims at defining what design tools are within our community and to organise them into a taxonomy.

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3. The Design Tools @POLIMI Manifesto

by Carmen Bruno, Francesca Mattioli

The multiplicity of design tools' scopes and natures had led to the coexistence of several features which together describe and define "what a design tool is". This variety in literature corresponds to an equal richness in our community. Design Tools @POLIMI was first conceived and funded with the aim to valorise all the design tools of the Department, and therefore we decided the definition of "what a design tool is at Politecnico di Milano" would have been the most inclusive at possible to respect this inherent variety. This fundamental insight became the grand on which we shaped our research questions:

- How to give a definition of design tools to effectively identify those belonging to a specific institutional context?
- How to enhance the diversity of the design tools of a large institutional community, but at the same time trace the contours between "what a design tool is (for that community) and what it's not"?

The chapter presents how the researchers addressed the research questions, outlining an inclusive definition that resulted in the creation of a manifesto (i.e. Design Tools @POLIMI Manifesto) rather than a formal definition. The manifesto serves as an alphabet for supporting the collection and organisation of the already existing design tools produced by our community, and for the creation of new ones, because it provides an "identikit" of what it is considered a design tool within the community itself. In this regard, a manifesto seemed to be the most suitable mean to inclusively consider the multifaceted aims and natures of our design tools. The manifesto should be therefore intended not only as a result of the research process described in the

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paper, but also as an important output that serves for the next steps of the research project Design Tools @POLIMI.

3.1 Building the Manifesto

The construction of the manifesto followed three main steps:

- a literature investigation that allowed to formulate and build its basic structure;
- an expert assessment through which the basic structure has been implemented and confirmed;
- a community assessment where the manifesto has been presented to a larger academic community of designers, researchers and professors that allowed to verify and refine the contents.

An extensive body of literature have examined and discussed the nature, role and functions of design tools within the design practice. Within this literature, we selected a reference bibliography taking into account the most recognized and quoted authors on this topic (Sanders & Stappers, 2012; Hanington, 2003; Lockton, 2013; Sanders, Brandt & Binder, 2010). Two main lenses have been adopted for the selection. On one side, the main references that study the topic from a theoretical perspective have been considered. According to these references it was possible to gain a deeper understanding about the strategies that have been adopted to create taxonomies or frameworks and to provide definitions to conceptualise design tools. On the other side, researches that built and adopted design tools within a professional practice have been analysed. In this regard, we identified the most relevant toolkits created and implemented by practitioners and design agencies (e.g. IDEO, Frog, MJV) which broadly apply design tools in different fields, with many scopes and addressing various kinds of targets.

The literature analysis, together with our design background and professional expertise on design tools, allowed to identify the following three main thematic clusters on which we based the construction of the manifesto:

- fundamentals, the essence of a design tool;
- form, the nature of a design tool;
- scope, the objective for which the design tool has been conceived.

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Each of these clusters represents a Pillar of the manifesto. Each pillar contains aspects which have been formulated based on the literature analysis, that contribute to the definition of "what a design tool is". A second step has been pursued by presenting the pillars and the variables to an expert team constituted by 6 researchers, including us, of the Department of Design of Politecnico di Milano with various expertise and backgrounds ranging from research on creativity to design education and to service design. All the researchers of the group shared the experience of adopting design tools in their professional work and the majority of them previously developed design tools for educational and research purposes. Through the expert evaluation, further relevant aspects emerged and have been added to the existing three Pillars. The expert's evaluation also led to the identification of a fourth remarkable pillar, "community", which addresses the community of reference for which the manifesto has been built (i.e. the Department of Design at Politecnico di Milano).

The last step consisted in a participatory activity opened to the whole community of researchers and professors of the Department. This step was carried during an event where the manifesto was presented and discussed. All the participants had the opportunity to share their professional experiences (e.g. research, teaching, design) and through this participation we collected insightful feedbacks. Indeed, this participatory activity with the broader community of experts has been extremely relevant to integrate and refine the manifesto and to broaden the aspects identified in the previous steps. Since they represented the community addressed by the manifesto, their evaluation and consensus has been also considered as a required validation factor.

3.2 The Manifesto

The Design Tools @POLIMI Manifesto is intended as the main result of the described methodology; its four thematic pillars are presented in the following subparagraphs.

As mentioned above, the whole manifesto should be intended as an explanation of "what a design tool is" in the context of the Department. Therefore, each pillar is made of sentences that provide information

about the aspects that a design tool must have or could have in order to be considered part of the population of design tools of the Department of Design of the Politecnico di Milano.

It is beyond the scope of this chapter to offer more than an overview of the discussions that led to the final result; hence we will report the manifesto and highlight the most relevant contributions that supported the definition of its structure.

A general remark on the manifesto structure is that each quality is followed by an example that has been reported to support the reader's understanding.

Pillar #1 – Fundamentals

Table 1 – Pillar #1 of the Design Tool @XXX manifesto

	A Design Tool @XXX...	*Example*
1.1.	… is an artifact used as a mean to an end, which is employed through a designed set of instructions.	It could be a deck of cards with its guidelines designed to collect insights, it could be a digital platform with a walkthrough designed to spark new ideas.
1.2.	… is replicable and therefore could be employed by others.	It could be used not just by those who designed it.
1.3.	… must have a significant degree of novelty either in its design and/or in its application	It could be an already existing design tool used with a novel set of instructions or aimed at achieving a different purpose.
1.4.	… can be a singular element or a combination of more elements organised in a toolkit.	It could be singular canvas or a set of them useful to generate new insights or to detail a project.

Pillar #1 aims at representing the essence of a design tool by describing the most significant intrinsic properties or attributes by means of which a design tool can be identified as being what it is. These intrinsic properties emerged through the review of some authors within the reference literature that provided definitions of design tool.

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Sanders & Stappers (2012), in their book *Convivial Toolbox*, collected a series of design tools used in the context of Participatory Design activities, defining a tool as «a physical thing that is used as a means to an end». A tool is applied through a technique which suggests the way in which the tool is employed.

Alves & Nunes (2013, p. 219) provide a similar definition of tools and technique: «A tool is anything used as a means of accomplishing a task or purpose whereas a technique is a systematic procedure, formula, or routine by which a task is accomplished».

Recently, Mothersill & Bove (2018) whose research is focused on the studies and design of computational design tools, stated that «...a computational design tool is therefore an aid that uses a somewhat defined set of instructions to guide the process of designing something, and hence can include anything from the rules of brainstorming to a complex optimizing CAD...» (p. 1264).

Even by changing its nature (physical or digital). a design tool can be considered as an artefact that derives from an intentional transformative process by the human being, to reach an objective, and that can be applied through a set of instruction (1.1).

The set of instruction ensure therefore the replicability of the design tools by other people and in different situation (1.2), giving them a validity as a scientific design method.

Observing especially design agencies (e.g. IDEO, MJV, Frog), we identified that set of tools conceived to reach a specific purpose are often collected within toolkits, that includes also guidelines on how to apply the different tools.

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Pillar #2 – Community

Table 2 – Pillar #2 of the Design Tool @XXX manifesto

	A Design Tool @XXX…	*Example*
2.1.	… is designed by members of the XXX Department and School of Design.	It could be designed by a researcher, a professor, a designer.
2.2.	… is conceived to support the design practice.	It could support designers in the development of any design project (i. e. products, services, strategies, interiors, etc.) both inside and outside the academia (i.e local communities, companies, institutions, etc.).
2.3.	… may be designed to support the design education.	It could support researchers, professors and designers in training the design practice, both inside and outside the academia (i.e local communities, companies, institutions, …).
2.4.	… could be addressed to both professional designers and/or non-designers.	It could be designed to be used by a team of professional designers, or by a specific cluster of stakeholders (i.e. teachers, managers, etc.).

Pillar #2 aims at specifying the target group and the domain addressed by the design tools. The experts evaluation highlighted that many design tools are used to educate and to train non-designers in developing a design approach and mindset (IDEActivity, 2017), or to train and improve collaboration within design teams in design education (author paper, 2018). Therefore, they can be used by design professors, design researchers, design students as well as professional designers. On the other hand, design tools are used in the everyday design practice, to support communication and co-design with stakeholders (e.g. Shape[1]), to improve and facilitate the different activities of the design process from context analysis to idea

1. www.shape.space.

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prototyping (e.g. design kit[2], Service Design Tools[3]). to improve collaboration within the team (e.g. Miro). Therefore, within the manifesto we decided to include design tools addressing both the design practice and the design research (2.2, 2.3).

Pillar #3 – Form

Table 3 – Pillar #3 of the Design Tool @XXX manifesto

	A Design Tool @XXX...	*Example*
3.1.	… could be tangible.	It could be constituted by physical elements, such as a game-board or a deck of cards.
3.2.	… could be intangible.	It could be constituted by computational or conceptual elements, such as a digital platform or a model.
3.3.	… could mix tangible and intangible elements.	Il could be constituted by a deck of cards that interacts with a digital platform.

This pillar aims at specifying the form and nature of a design tool. Many of the tools that are used in participatory co-design sessions have a tangible nature and can be found in several forms according with their scope of use. Few examples are cultural probes (Gaver et al., 1999), design games (Brandt, 2006), generative toolkits (Sanders, 1999), and context mapping paper (Visser et al., 2005).

Some of them are also interactive objects that through real time feedbacks support the process of quick reflections and idea refinement in participatory processes (Bellucci et al., 2014)

A design tool can be used by a person alone or by groups of people working together in remote. In this case, with the advancement in digital technology application, many design tools have been digitized or have been built to support the ongoing needs of working at

2. www.designkit.org.
3. https://servicedesigntools.org/

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geographical distances, without time and physical constraints (Fischer, 2004).

Therefore, within this manifesto, we decided to specify that a design tool can be tangible (3.1), intangible (3.2) or a mix of tangible and intangible elements (3.3), drawing on McCullough (1998) (cited by Mothersill & Bove, 2018) who suggest that «a tool is not merely a utilitarian instrument; it can be any physical, digital, or conceptual mechanism that enhance our design abilities».

Pillar #4 – Scope

Table 4 – Pillar #4 of the Design Tool @XXX manifesto

	A Design Tool @XXX...	*Example*
4.1.	… is designed to reach a specific objective.	It could be designed to help people in express their own idea about a topic.
4.2.	… is designed for a specific field.	It could be designed to help teachers in express their own idea about the evolution of education.
4.3.	… could be re-employed in a new field, different from the one it was designed for.	A design tool that supports students to generate ideas on a new product, could be re-employed to help managers to generate ideas on a new strategy.
4.4.	… could be re-employed to reach novel objectives, different from the one it was designed for.	A design tool that support designers to explore a new field, could be re-employed to help them to generate ideas.
4.5.	… aims at generating a positive impact either on the design process, its outputs and/or the users.	Enhancing cognitive and/or design abilities, generating new knowledge or stimulating inquires.

Pillar #4 aims at underlining the purpose for which a design tool is built and what impact attempts to generate. According to Hanington

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(2003), design tools and methods are situated and designed in a specific context (4.2) and for a specific goal (4.1).

> It is clear that there is a vast inventory of research methods from which to choose. The key challenge lies in making an appropriate, purposive connection to goals in the selection of methods used at any given time in the design and research process (Hanington, 2003, p. 12).

According to Dalsgaard (2017) design tools can be seen as instruments of inquiry that «augment designers' ability to carry out certain actions, augment their cognitive abilities to see and understand certain design opportunities, conceive of and evaluate possible solutions, and bring potential futures into form so they can be examined and communicated» (p. 21).

In early phases of design projects, design tools can be used as sources of inspiration, as is the case with many card-based design techniques (Wölfel & Merritt, 2013). They can support user in imagine and express their own ideas about how they want to live, work and play in the future (Sanders, 1999). Mattelmäki (2005) describes how design probes can serve as a means for dialogue with future users. As design concepts take shape, mock-ups (Ehn & Kyng, 1991) can offer hands-on experiences and insights about potential future products.

3.3 Conclusions

The manifesto was validated from the community itself as a powerful and effective mean to define what a design tool is and how it should be conceived within the community. The variety of aspects that have been included within the manifesto, supports the wider inclusion of different types of design tools. At the same time, it contours the borders between "what a design tool is and what is not" within the reference community. The participatory aspects, represented both by the research steps 2 and 3, have been necessary to tailor the research to better suit the specific context, which in the case of this research was the Department of Design of Politecnico di Milano. However, the validation could have included a more extensive inquiry with other experts from the Department to collect other

qualitative in-depth data (e.g. focus groups, interviews). Another limit of the presented research is the literature analysis that could have been extended to a wider portion of literature on the topic.

Nevertheless, the output is consistent within the overall research project and constitutes a solid foundation for the upcoming activity, namely the implementation of a design tools' taxonomy. Future activities will also include further participatory sessions to further define the manifesto itself.

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4. A taxonomy of Design tools

by Vanessa Monna

4.1 The relevance of design tools

As mentioned in Chapter 2, the evolution of social paradigms sees the designer, among their traditional roles, as a process enabler (Rampino, 2018), facilitating collaboration between different actors and designing tools to activate their participation (Manzini, 2015). The evolution of the design profession leads design tools to gain a central role. Design tools are intended as tools to support design in the educational, professional and public fields, as well as an object of discussion in the scientific discipline debate. In this scenario, the topic of design tools emerges. Design tools are here intended as tools aimed at catalyzing and supporting the entire design process (Shneiderman, 2007). Quoting Krippendorff (2005):

> design tools enable to realize what did not exist before, to introduce desirable changes in the world, to project the technological, social, and cultural consequences of a design.

Nowadays, design tools are widely discussed in research (Sanders & Stappers, 2012), as well as in design practice (IDEO, 2011; Cross, 2011). They are adopted in many fields with the most diverse aims: to study the contexts in which artefacts are used (Visser et al., 2005), to stimulate creativity during the design process (Michalko, 2010), to support collaboration between different actors (Brandt et al., 2004), and to enable experimentation with new technologies or materials (Ellen MacArthur Foundation, 2017).

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Designers may choose among a wide variety of tools designed to support the needed inspiration and creativity, to involve audiences in the design process, to enhance the creation of tailored business models, to evaluate the impact of an artefact in a specific field of application, etc. Designers make use of them to understand relations and problems, to envision and create new products and services, and to explore and test potential solutions (Dalsgaard, 2017). On one side, there exists a multitude of highly formal techniques and methods that provide step-by-step instructions or "recipes" to reach those goals, namely strongly coded design tools, which encompass a series of instructions to follow, supported by graphic elements or forms to fill – digitally or manually – that has to be used in specific phases of the design process. At the same time, there are also highly unstructured and more exploratory approaches, such as open brainstorming sessions, physical activities, such as creative walking or observations, aimed at stimulating out of the box thinking, used by designers to reach the same objectives.

Instead of another, the use of a specific design tool may influence the development and production, the expression, visualization, and perception of design ideas (Anderson, 2017). Some design tools are common to different design disciplines: for example, some creativity tools such as sketching or brainstorming. This leads the way to understand and treat design tools differently in distinct disciplines. Thus, in some design fields, there is a strong sense of what constitutes a core set of tools that every designer must be able to master. In other cases, there is a more exploratory approach to the use of design tools and a strong openness and need to develop new ones.

In this significant complexity, designers need to produce and express their ideas in a more effective way. In this vast panorama, organizing design tools would be helpful to practitioners adopting them in/with/on different organizations, channels, contexts, platforms and devices. Therefore, the definition of a taxonomy of design tools is considered of great value. Before further deepening the matter on this, a clear description of what taxonomies are, is deemed necessary.

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4.2 What is a taxonomy?

As stated in the Merriam-Webster Collegiate Dictionary, a taxonomy is defined as:

a. the study of the general principles of scientific classification;
b. an orderly classification of phenomena according to their presumed relationships.

The first part of this definition describes the original meaning of this term, which was first coined by the botanist De Candolle in 1813. The word comes from Greek and is a compound of *taxis*, meaning order, and *nomos*, meaning science. De Candolle coined the term to describe the laws to be adopted in systematics. Since then, it has been employed almost solely within the biology discipline. «Nevertheless, within the field of logic, it has a wider meaning» (Currás, 2010, p. 39).

Following the second part of Merriam Webster's definition, Friedman (2003) describes a taxonomy as «a model of existing data» which «demonstrates the relationships between and among facts» (p. 518). The main aim of a model is to deliver a simplified representation of reality, primarily helpful in visualizing relationships (Sanders, 2008). Hence, a taxonomy can also be defined as a representation of a subject area or domain (Morante & Walker, 2003).

In its simplest form, a taxonomy is a related list of words organized in a structure obeying some recognizable logical criteria (Pérez-Montoro & Codina, 2016). We may envision indented lists or trees turned upside down, with the root as the topmost element when thinking about taxonomies. This kind of representation is the classical one, and it constitutes an enumerative hierarchical taxonomy. As Denton (2003) states, hierarchies are used when the taxonomy elements are organized through only one dimension of classification. «*Hierarchies divide and redivide things into groups where each new group is a sub-species of its parent group; everything that is true of a group is also true of its sub-groups and so on down*» (Denton, 2003). This kind of taxonomy is built by splitting a complex universe into concepts, which are progressively more precise. The most known hierarchical taxonomy is Linnaeus' animal kingdom taxonomy, where animals are classified through a hierarchy of physical attributes, which are the only dimension through which the taxonomy is built.

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In 1933, the mathematician and librarian Shiyali Ramamrita Ranganathan proposed a different way to organize information, the Colon Classification System. He came up with this classification after noticing that hierarchical types would create a significant number of compound concepts, i.e., concepts inheriting properties of multiple categories (Dakka et al., 2009). To simplify compound concepts into relationships among elementary concepts, Ranganathan formulated his Two Points Classification, also known as Faceted Classification or Analytic-Synthetic Classification. This classification system acknowledges many attributes in one universe of discourse and seeks to synthesize these attributes to describe them more appropriately. When elements «are classified under more than one concept, an organization by facets is normally used» (Dakka et al., 2009).

These attributes are an array of semantically cohesive categories associated as needed to generate an expression of a concept. Scholars refer to these attributes as "facets", describing «*clearly defined, mutually exclusive, and collectively exhaustive aspects of a subject*» (Joudrey et al., 2015). Facets make this classification quite flexible since it is not limited to already defined concepts, yet the resulting expression of topics is complex (Svenonius & Elaine, 2000). Moreover, the use of facets minimizes the redundancy of elements in the taxonomy, hence reducing the complexity of the resulting taxonomy, even improving the exploration expressivity of its navigation (Dakka et al., 2009).

Many classifications and taxonomies combine both enumerative and faceted techniques to organize information into relevant categories. These categories are not decided beforehand since the classificatory elements are guided by the individuality and specific characteristics of the entities to be ordered (Currás, 2010). The categories and sub-categories define a classification unit, which Crowson (1999), among others, defines as a *taxon*. A taxon is a group of elements that a taxonomist establishes belonging together since the same set of shared features describes them.

Taxonomies clearly display the general architecture of the categorization of a knowledge base. A set of topics or subtopics can constitute a taxonomy if they are able to satisfy and evidently represent the logical criteria beneath it.

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Categories represent partitioning aspects of the universe of discourse, and they are «*primitive concepts which partition the corpus into disjoint sets*» (Dakka et al., 2009). As an example, Dakka (2009) cites how an encyclopaedia is partitioned by primitive concepts such as "art", "science", and "history".

In addition to categories, the other primary tool characterizing taxonomies are, as already mentioned, facets, describing the semantic properties of each element of the taxonomy. Facets differ from partitioning concepts since they «*are rather cross aspects and tend to cover the entire corpus, rather than partitioning it*» (Dakka et al., 2009). Hence, they are usually more numerous than the taxonomic categories. Elements may be associated with a few categories and sub-categories but can be related to many facets to ensuring they are appropriately described.

The partitioning and faceting process is guided by multiple principles, which Spiteri (1998) simplified in a model grouping them in two fundamental groups: the principles for selecting an attribute and the principles guiding the ordering of the attributes. Among the many, the essential principles are the Principle of Division, stating that a set of single criteria has to be used to subdivide the universe of discourse; hence a facet must represent only one characteristic of division of the parent universe, the Principle of Mutual Exclusion, asserting that no two facets produce an overlap in content, and the Principle of Relevance, declaring that division is performed according to criteria that are useful for access (Dakka et al., 2009, pp. 176-177). In practical terms, «*it is possible to establish categories within a classification depending on how relationships of similarities (the interaction principle), or relationships of interdependence (the duality principle), will be determined*». In the first situation, the taxonomy would grow horizontally, illustrating the relationships between taxa. A hierarchical taxonomy would result from the second case (Currás, 2010, p. 39).

A taxonomy makes the relationships through which contents are organized visible to the users, enabling them to skim through the taxonomy's contents effortlessly. Users browse through categories to circumscribe the search: in this way, users avoid contents outside of their area of interest by limiting the volume of material that must be searched.

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Among the principles ordering the attributes in the taxonomy, and in particular the principles of Consistent Succession, Ranganathan proposed five fundamental categories to describe the entire universe of ideas:

- P (Personality, or Who): what the object is primarily "about". This is the "main facet";
- M (Matter, or What): the material of the object;
- E (Energy, or How): the processes or activities which take place in relation to the object;
- S (Space, or Where): where the object happens or exists;
- T (Time, or When): when the object happens or exists.

(Dakka et al., 2009, pp. 186-187).

These categories are pretty interesting for designers: they are more known as the "6ws" (with the addition of a sixth w -*why*-, which was not initially present in Ranganathan's categories) and support practitioners and researchers in the design process and in the clinical research phase.

Finally, taxonomies should be reviewed periodically. Indeed, the maintenance of a taxonomy not only incorporates new elements in the existing structure, but it also adjusts its structure by including new categories to accommodate new elements not fitting into it, by modifying some categories or, lastly, by eliminating some of them, re-assigning their contents to other categories. A taxonomy's maintenance is not an activity carried out daily because it's time-consuming and typically quite expensive. For this reason, besides traditional taxonomies, whose attributes are fixed and don't evolve, an innovative approach, primarily used in information search engines, combines searching with classification to produce "dynamic classification" in real-time.

To better understand all these concepts and see how they work in practice within design tools, some case studies of taxonomies of design tools (and methods) are presented next.

4.3 Taxonomies of design tools: some case studies

As already mentioned, the design tools panorama is quite broad and diverse, thus creating a demand for the organization of these design

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tools. This demand has already been acknowledged by some institutions, research centres, universities, and consulting companies, with the aim to not only classify their design tools but also to disseminate them.

Generally speaking, within the field of design practice, more numerous than collections and classification of design tools are libraries of design methods. To cite a few: within the area of Service Design, the Method Library designed by This Is Service Design Doing (www.thisisservicedesigndoing.com) is a collection of methods used in the field, presenting them in four categories referring to the phases of the design process. The Design Exchange (www.thedesignexchange.org) has collected many methods, organizing them in five partitioning categories, referring again to different actions occurring during the process of design. There are also cases in which a categorization is not done on tools or methods, but on aspects interesting for the work of a designer: for example, the Id Studio Lab at TU Delft University designed the Design for Happiness Deck of cards (Delft Institute of Positive Design, 2017). This deck is meant for designers to deeply understand three essential aspects of designing for happiness (pleasure, personal significance, virtue), which become the three main categories for the collection. The card deck categories are directly based on the Positive Design Framework; hence, the taxonomy becomes part of disseminating the knowledge produced by the research group.

Even if fewer, some taxonomies of design tools do exist.

Perhaps, the most known "organized collection" of design tools (and methods) is the IDEO Method Cards. IDEO designed this deck of cards to disseminate their Human-Centred Design (HCD) collection of tools and methods. The cards support design practitioners in seeking new inspiration and in gaining new perspectives.

This collection could be considered a taxonomy since it uses both partitioning attributes and facets. Indeed, it organizes tools and methods into four partitioning attributes, all obeying the logical criteria of representing different ways to empathize with people: learn, look, ask and try. The elements are partitioned in these categories and also present two facets, one describing how to use it and the other when to use it.

Another well-known taxonomy of design tools is the platform "Service Design Tools" (https://servicedesigntools.org/), initially designed by Tassi in 2009. The platform collects tools used in service design and enables the users to navigate them in many different ways. Indeed, a user might go through the whole list of tools or select just a few of them by choosing from categories and subcategories. In this case, each category (when, who, what, how) presents one level of hierarchical subcategories, logically based upon their parent category. This taxonomy presents many compound elements, inheriting features from many sub-categories. However, this doesn't make this taxonomy less effective: on the contrary, what's quite interesting about this taxonomy, is the fact that it's possible to select one subcategory for each category in order to identify the tools satisfying the features of all the selected subcategories. While choosing the subcategories, an increasingly specific query appears, acting as a compass for the user. This makes the navigation of this taxonomy really expressive and user-centred.

Staying within the Service Design field, Alves and Nunes (2013) have collected 164 service design tools and methods, made a selection of the most used ones and categorized the resulting 25 into a taxonomy. They rooted their taxonomy «*in the four stages model (discover, reframe, envision and create) (Mager, 2004), which is analogous to the Analysis-Synthesis Bridge Model (Dubberly & Evenson, 2008)*» (Alves & Nunes, 2013). Their taxonomy is built using the "6ws", building on Ranganathan's PMEST categories.

Observing the experience of other realities, the effectiveness of structuring a collection of best practices for disseminating practices related to the design and application of design tools emerges.

4.4 The value of a taxonomy of design tools

Defining a taxonomy of design tools created and used by an organization would have many advantages.

I've already mentioned that a taxonomy could considerably support the work of design practitioners and academics, enabling them to select the appropriate tool for a specific case, influencing the

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development and the production, the expression, visualization and perception of design ideas (Anderson, 2017). Indeed, a taxonomy of design tools would represent tan organisation's ecosystem of design tools, hence facilitating the definition of research and training models that are increasingly tailored to the needs of the professional and business world. This highlights the strategic potential of a taxonomy to enhance the relationships between an organization and the business, research and academic spheres. Certainly, a taxonomy would provide all the parts involved of a common set of references, language and tools, which is «*the main challenge in supporting cooperation between disciplines»* and *«models play a critical role to overcome it*» (Alves & Nunes, 2013). Friedman (2003) defines a taxonomy as «a model of existing data»; hence taxonomies may be considered one modelling approach overcoming the gap existing between diverse competencies. This is clearly the case of IDEO Methods Cards, which helped IDEO become a reference point when talking about Human-Centered Design.

Similarly, structuring an adequate taxonomy of design tools facilitates the professional world's identification of collaborative opportunities for innovation and change. Surely, the systematization of a collection of design tools helps to position, disseminate and promote not only new tools but also the organization itself within the research and practice networks, as we've seen in the case of Design for Happiness Deck.

Finally, a taxonomy of design tools could be of great value in higher education institutions because it would support some aspects of training and innovative teaching activities.

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5. The Design Tools @POLIMI taxonomy

by Martina Rossi

Taxonomies of design tools are of varied nature and format. They could be organized by different features that are supposed to be the most relevant for the reader or the practitioner looking for the right tool to use in a specific situation.

In the previous chapter, we showcased and analyzed some of the most representative design tools taxonomies from which we got the inspiration to develop a taxonomy to collect and organize the tools designed within the Design Department of Politecnico di Milano.

In order to do that, we came back to who we are addressing this publication. We believe that the taxonomy could be of interest both for researchers and practitioners, but in either way we imagine them to be designers.

We imagine designers in the process of approaching a project, deciding where and how to start, understanding who the right people are to involve, wandering what are they looking for. Or we imagine designers who have a very clear idea on the goal they want to achieve and people they want to involve, but they are looking for inspiration and references on how to do that.

After long discussions and some experiments, looking at the collection of tools that we organized, we agreed that there are some **"decisional categories"** that are primarily guiding the search of a tool from the perspective of the designers.

In order to make the final decision on the configuration of the taxonomy, we initially referred to PMEST theory of categorization by Ranganathan (Ferreira et al., 2017), who describes the entire universe of ideas as:

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- P (Personality, or Who): what the object is primarily "about".
- M (Matter, or What): the material of the object;
- E (Energy, or How): the processes or activities which take place in relation to the object;
- S (Space, or Where): where the object happens or exists;
- T (Time, or When): when the object happens or exists.

(Dakka et al., 2009, pp. 186-187).

This categorization is nowadays more known as the "6ws". In the 6ws is considered an additional category, the "why", which refers to the reason why an object exists.

Some proposals to give an order to those categories have been provided by Dubberly & Evenson (2008) and Beckman & Barry (2007). Those authors provided frameworks to connect cognitive categories to the design or innovation process.

In particular, the guiding principle in the abovementioned proposals is the design process, therefore the "when", which is, in fact, one of the categories that drives the selection in our taxonomy. We believe that the taxonomy should reflect the mental process that researcher/designer performs while choosing a tool for his/her design activity.

The **"decisional categories"** are the ones that drive the first choices that the designer should take when deciding which tool to use and they answer the question "why" and "when" to use it. We may also add "where" to these two, which adds to the decisional categories the disciplinary field of the design activity. The figure below (fig.1) shows the combination of "why" and "when" in a unique framework, which is the guiding model of the whole taxonomy.

To complement the "decisional" categories we added a set of other characteristics that are meant to enrich the information about the tool. We title them **"descriptive" categories** and they are the categories of "what", "how" and "who".

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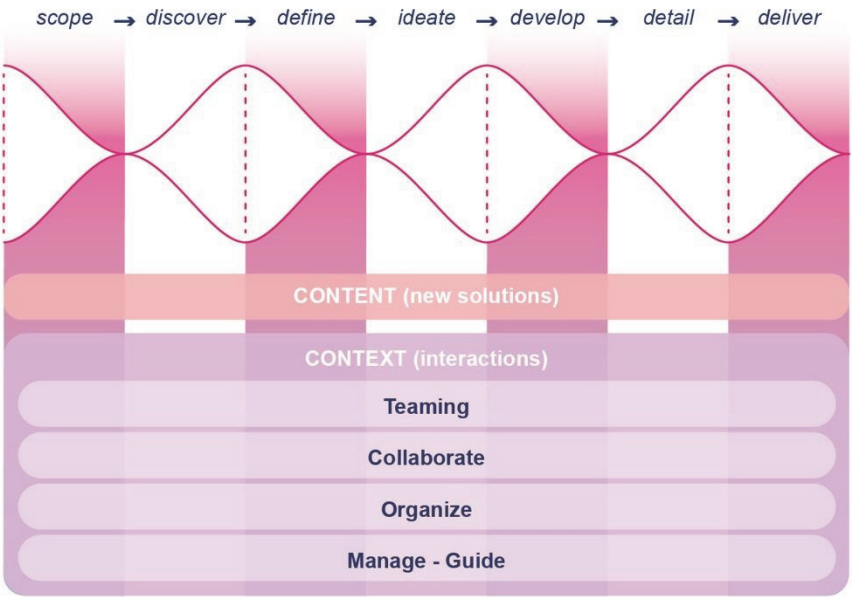

Fig. 1 – The framework that guides the taxonomy: the decisional categories.

5.1 The decisional categories

The decisional categories are the ones that indicate the path towards the most suitable tool to use (fig. 1).

If we think about the taxonomy in the form of a digital platform, we could imagine the decisional categories as complementary filters that guide the selection among the collection.

WHY

"Which is the aim of the tool?"

It refers to the final aim of using the tool. In particular, it refers to the goal of the design activity. The broader question here would be: "Is the activity aimed at developing a new solution or is oriented to work on the interactions among the people who are undertaking the process?".

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This differentiation calls out to the concept respectively of "content" and "context" of design activity. These aspects of a design activity represent the core elements that shape the intent of the process itself:

- **Content**: we consider as "content" everything that relates with the "subject-matter", the object of the design activity (Meroni et al. 2018). It includes everything that refers to the sake of the project and relates to the output of the design, the product-service that it aims at developing.
  Since the development of every product-service follows a design process, the "content" category is directly linked to the specific phase of the process in which to use a tool. Therefore, the category "when" is linked and consequential to the choice of the category "why" as the "content".
- **Context**: the "context" instead, consists of everything that surrounds or enhances the design activity, which needs to be designed as well. It includes spaces, people and processes that guide the activity. Within our contribution, we will limit the spectrum of "context" to people and specifically on the group dynamics that occur among them.
  From the early stages of studying interpersonal dynamics indeed, there has been a clear distinction between 'the interpersonal underworld' group dynamics which are largely unseen and unacknowledged, as opposed to "content" issues, which are nominally the agenda of group meetings (Schutz, 1966).
  This is given by the fact that all the tools that we could classify within the "context" category were regulating people's interactions and none of the other context-related elements.
  To make an example, the tools related to context aim to manage members of a team, enhance collaboration, support the team's guidance throughout the process, and more.

The "why" category could be therefore valued with either "content" or "context".

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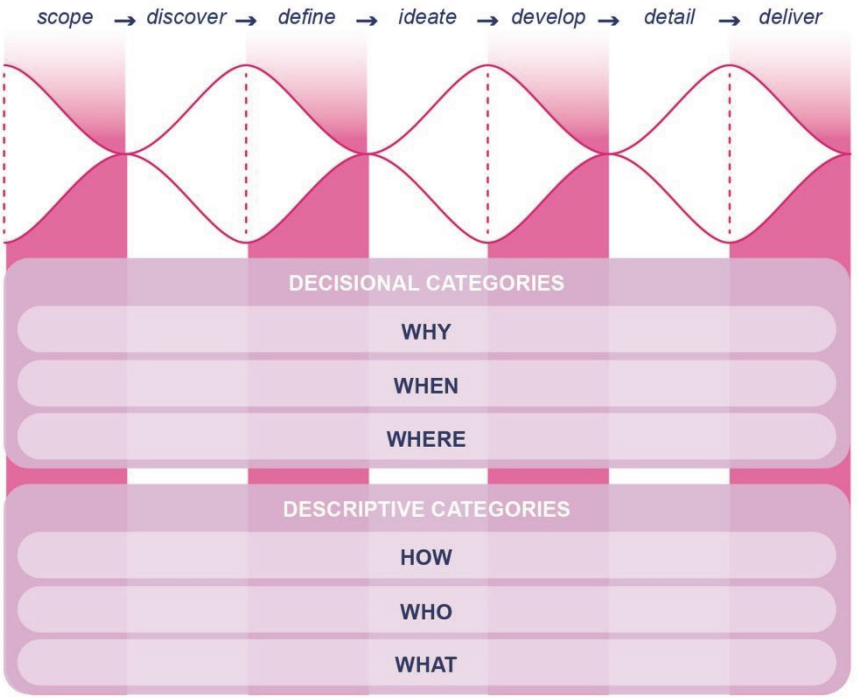

Fig. 2 – The framework that guides the taxonomy: summary of decisional and descriptive categories.

WHEN

"In which stage of the design process the tool is used?"

As said, within the field "content" related to the category "why" we propose the subsequent category "when". This category refers to the phase of the design creative process.

In order to identify these phases, we took as initial reference the Double Diamond model conceptualized by the Design Council (2014) because it is the most used and recognized model within the research groups in our Design Department.

However, many researchers and practitioners within and outside the Department have conceived extended versions of the Double Diamond to comprise additional phases or give more granularity to the existing ones.

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Some examples in this sense from outside our system are given by Nesta (Casasbuenas, 2018) that experimented with a preliminary diamond, which transforms the Double Diamond into a Triple one, dedicated to defining the scope of the project or by the Design Council itself (2017) that enriched the original framework with other dimensions related with specific design principles, a collection of methods and some conditions about the engagement of the stakeholders.

With similar intents, different research groups in our Department developed an extended version of the framework in order to better guide the projects they were undergoing.

IDEActivity Lab divided the process in two main consequent stages, Explore and Generate, and a total of four explicit process steps, each one with specific objectives, and each one characterized by specific activities. The activities have been determined and integrated thanks to the literature investigation on creativity and design principles.

The activities integrated within Explore are *Searching*, *Empathising*, *Clustering/Visualizing*, *Open possibilities*, *Prospecting,* while Generate includes *Inspiring*, *Conceiving*, *Selecting*, *Making*, *Reflecting* (Canina & Bruno, 2021).

Bruno (2020) in her PhD dissertation structured a process that takes into account the main human creativity factors intervening in the different steps of the process as well as the thinking style to adopt in each step. The process named "Creativity 4.0" adds a half diamond called Engage whose aim is to identify the motivation and the vision to bring into the process.

Another proposal in the same direction is elaborated by the POLIMI Desis Lab that unveiled an extended version of the Double Diamond comprising three and a half diamonds where the first one and a half is devoted to "understanding", the second to "designing" and the third to "delivering".

Within the Department, also Rossi (2020) within her PhD dissertation developed a framework titled "Human Resource Design" based on an extended version of the double diamond that adds two additional diamonds upfront and after the original ones.

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Moreover, she introduced the differentiation between "content" and "context" levels which are characterizing also our taxonomy.

Besides this latter enrichment, the common factor that characterizes the variations described above is the extension of the Double Diamond from two sides: a preliminary phase dedicated to scope the project and limit the perimeter of the action, and a final one that regulates the implementation phase.

Hence, based on literature and on the varied versions developed within our Department we came out with a proposed framework of the extended Double Diamond process that we used to break down the phases:

scope

convergent phase

- **Scope**: It is aimed at understanding the specific focus of a project or consulting the highest levels of an organization/top influential stakeholders/policy makers on the context analyzed to understand the strategic direction to take.

The output of this phase is often defined as a "vision".

discover

divergent phase

- **Search**: First gathering of different sets of information, retrieving of data and facts through qualitative and quantitative research.
- **Empathize:** study and analyze users (or potential users) behaviors in order to gain empathy and receive information about their needs, emotions and actions.

Here we include observational activities on field such as shadowing, interviews, and more.

define

convergent phase

- **Visualize:** clustering data according to specific criteria and create relationships and connections. It is needed to organize information, identify patterns and get ready to deduct relevant interpretations.

- **Interpret:** converting the information into insights. Adopting a specific point of view. Linking insights, and interpret them to develop possible alternative scenarios.

The output of this phase is the definition of the design challenge and the specific "how might we…" questions.

The "how might we…" questions represent the specific problem or challenge to be solved with the design solution.

ideate

divergent phase

- **Inspire:** searching for inspiration to get new ideas, fostering creativity by looking for stimuli. Inspirational activities can include for example cross-pollination from a different context or socio-technological trends.
- **Brainstorm:** generating novel ideas which can be meaningful for the design challenge. The objective is to go for quantity over quality in this phase.

develop

convergent phase

- **Select:** evaluating and prioritizing ideas or combinations of ideas according to defined criteria such as impact or feasibility.
- **Pre-totype:** "thinking by hands" and giving a first shape to the selected concepts in low resolution. Testing and implementing user feedbacks while building.

detail

divergent phase

- **Refine:** collecting and systematically analyzing feedbacks to reframe or refine the initial concept. Brainstorming to integrate and enrich new features into the solution.
- **Prototype:** building and visualizing the future envisioned solution by creating iterative cycles of test and learning.

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deliver

convergent phase

- **Assess:** validating the final version of the solution by anticipating all possible implications.
- **Plan:** implementing a delivery plan and disseminating the solution to all the stakeholders involved.

WHERE

"What is the disciplinary field of application of the tool?"

The disciplinary fields in our framework correspond to the disciplines that are part of the Design System of Politecnico di Milano.

The Design System comprehends the research staff (the Department of Design), the teaching staff, which is composed of both research staff and external practitioners (the School of Design), and the partially private consortium POLI.design which offers executive education and Master programs.

The tools have been shaped by students or academics of the Design System who belong to different disciplinary areas, those areas represent the items of this category:

- Communication Design
- Design and Engineering
- Digital Manufacturing
- Fashion Design
- Interaction Design
- Interior and Spatial Design
- Product Design
- Service Design
- Strategic Design

Despite the disciplinary area where the designer of the tool belongs to, most part of the tools of the taxonomy is classified as applicable to multiple disciplinary areas. This means that the tools in most cases are flexible and non-specific regarding the "subject-matter" of the design activity, they rather refer to guide the way, the method, with which the design activity should be performed.

5.2 The descriptive categories

The descriptive categories are not directly guiding the selection of the tool. They provide additional information about the format of the tool, the process to follow when using it and who are the people involved.

These elements are not meant to drive the selection process, but they can obviously influence it. In fact, based on the available resources of the designer, the confidence with specific technology and the context of the design activity the choice could target one tool instead of another, but we believe that the first filter should be guided by the decisional categories.

WHAT

"What kind of tool is it?"

Describes the kind of artifact that the tool represents. It indicates if it's analog or digital and adds details about the format, the material, the shape, and more.

Some examples of descriptions included in this category could be: sorting cards of various formats, web applications, canvases to be printed or used online, 3d models and characters, infographic, gameboard, diagrams…

The nature of the tool also provides some elements about how the tool should be used and the kind of interactions (if any) that this could activate.

The "what" represents a descriptive category because it adds specifications to the tool, but it is not a criterium that guides the choice of the designer throughout the collection.

The increased level of remote work brought by the pandemic of Covid-19 impacted also co-design processes. Designers found themselves reinventing interaction and creation dynamics to suit digital formats, therefore adjusting the tool to the media used for the interaction.

The collection of the tools underwent before the pandemic, so most part of the tools described have been conceived to be used in presence,

but we believe that a post-pandemic update could significantly increase the presence of digital formats.

HOW

"How to use the tool?"

This category gives information on the modalities of use of the tools.

It reports details upon:

- instructions on the process to follow: step-by-step guidance in using the tool. Tasks to be accomplished and goals for each step.
- guidance: tools can be used autonomously by an individual or a group or under the guidance of an expert facilitator.
- individual or collective: tools are designed to be used individually or by a group of people which can have particular characteristics specified in the category "who"

In the case of a toolkit, the "how" becomes particularly relevant because it informs on the order to follow and on the goal of each tool that composes the toolkit.

WHO

"Who uses the tool and who to engage?"

The who states the characteristics of the people that use the tool and of the facilitator.

The individual or group who is using the tool could represent expert designers, stakeholders of various kinds, possible users of the solution to be developed, citizens, and more.

The facilitator could have specific expertise (e.g. an expert designer or a psychologist/sociologist) and a peculiar style of guidance according to both his/her background and the aim of the activity.

The facilitator indeed should adopt a specific style of guidance according to the phase of the design process and the goal to achieve.

The posture of the facilitator within the above-mentioned correlation has been studied by Meroni et al. (2018) throughout a

series of massive co-design actions. In the book, the authors propose a framework that regulates the style of guidance of the facilitator that guides a group in a co-design activity while using design tools.

To give an example, when the co-design activity is exploratory and the aim is more similar to a consultation on a topic rather than the development of a concept, the style of the facilitator is more neutral.

On the contrary, when the co-design is devoted to implementing a concept the facilitator should adopt a "steering" style of guidance, aimed at influencing and directing the group toward promising solutions. In the latter case, we are talking about a designer facilitator because he/she needs to have expertise in concept and solution development.

In the next chapter, we will go through an initial collection of tools mapped out within the Design Tools @POLIMI project.

They represent the first dataset that inspired and shaped the taxonomy.

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6. Design Tools @POLIMI Collection

by Silvia Maria Gramegna, Vanessa Monna

The taxonomy presented in the previous chapter has been developed within the research project Design Tools @POLIMI. This research project was first proposed and structured with the aim to give value to the design tools developed within the Design Department of the Politecnico di Milano, which represents the context of study of the research.

6.1 The wide field of expertise of the Design Department at Politecnico di Milano

The Design Department of the Politecnico di Milano was founded in 2013, re-organising a previously existing department comprising Industrial Design, Arts, Communication and Fashion. The Design Department is composed of professors and researchers active in the design field, and it is deeply connected to the Faculty of Design, born in 1993 as an architecture degree course, which became an independent course of study in 2000, and which finally was named School of Design.

Adopting the new name, the Design Department abandons the different declinations of the design disciplines and affirms the term Design in all its strength, versatility, beauty and ambiguity. Under this wide roof, multiple concepts and ideas from different cultures meet, confront each other and are able to find an environment in which to express a shared approach and intention. Through the years this approach has been commonly referred to as “Politecnicità” (“the

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essence of being poly-technic") and it is intended as the concomitance, also factual, with very wide and diversified polytechnic disciplines, in which Design plays a role not only as a mediator, but also one as a critical element and guide to design aims and methods. Moreover, it is characterized by the ability to range in different production processes, of tangible and intangible assets, with attention to the centrality of the individual, the group, the community, and society as a whole. As a natural result, the Design Department of Politecnico di Milano operates, in both research and practice, in the areas of product, communication, service, sustainability, environment, interior spaces, fashion, interaction, mobility and new materials. The result is an increasing sharing of methods as well as design tools in continuous evolution, as a key element of support to the project. The various natures of the different areas of research contaminate each other on methods of analysis, narration, representation, communication, design and production.

6.2 Design Tools @POLIMI

As aforementioned in Chapter 2, Design tools are an emerging and wide discussed topic in the design discipline debate. Within this panorama, the research project Design Tools @POLIMI aims at defining a taxonomy able to represent the ecosystem of design tools that coexist within the Design Department of the Politecnico di Milano. Design Tools @POLIMI, carried out by Silvia Maria Gramegna, Francesca Mattioli, Carmen Bruno, Martina Rossi, Vanessa Monna & IlariaVitali, explores and analyzes the wide panorama of design tools developed within the Department of Design of Politecnico di Milano, to better define underlying connections, overlapping research areas, exploration and definition of new fields, common goals and practises between researchers and designers involved in the process of shaping and developing new design tools.

The main objective of this research project is enhancing the variety of approaches and cultural dynamics adopted in the Department, and to consistently present the multidisciplinarity of the academic context they were born in. Moreover, it attempts to facilitate the definition of

research and training models more appropriate to the needs of the professional and business world. Finally, defining a taxonomy represents a first step to facilitating the dissemination and the use of tools both on the local dimension among the system stakeholders, as well as at the academic level on the international scene.

The definition of a taxonomy links different disciplinary areas, which have contributed to their conception and application within the teaching, research and design activities of the Design Department of Politecnico di Milano. In order to easily draw from different disciplines, and, at the same time, to maintain a broader and more heterogeneous view on the wide spectrum of best practices collected from other researchers of the same Design Department, the research project has been developed by a multidisciplinary group of Fellow Researchers and PhD Candidates.

6.3 Methods

The initial phase of the research encompassed the collection, through an open call, of design tools developed by the researchers' community within the Design Department, covering different areas from interior, to communication, service, product, interaction and fashion design.

The research team developed an online survey aimed at identifying the existing design tools generated by the members of the Design Department of Politecnico di Milano, defining their aims, purpose, context of use, delineating the users, the designer role and the fields of application. Each researcher was asked to autonomously answer the survey, describing their own tools/toolkit.

After this collection, the research team conducted semi-structured interviews with the designers/researchers who answered the open call. All the participants in the open call are currently active members of the Design Department, and all have at least two years experience in research in design, and in many cases considerably more. Educational backgrounds varied and included Architecture and Spatial Design, Communication Design, Fashion Design, Interaction Design, Product Design and Business Management. The semi-structured interviews

aimed at deeply understanding the approach used by the researcher to develop their own tool, and at thoroughly comprehending the intended use of the tools. In some cases, the research team asked to try the tool, under the guidance of the designer/researcher.

At the same time, the research team has reviewed the literature produced by members of the Design Department regarding Design tools, collecting other tools in addition to the ones gathered through the open call.

The outcomes of the open call, the semi-structured interviews, and the literature review were then analyzed, to identify emerging themes within and across participants, and to try to visualize connections between the design tools in terms of scope, use, aim, approach, and positioning within a design process. These visualizations led finally to the formulation of a Design tools taxonomy, which has been introduced in the previous chapter.

6.4 Design tools production within the Design Department at Politecnico di Milano

When it comes to designing, testing, using, promoting or teaching design tools, our community of reference, the Department of Design at Politecnico di Milano, is on the front line regarding different fields and contexts of application.

Among the activities we cite, for example, the design of tools for social innovation and sustainability for the public sector (Kimbell, 2014), the creation of tools for the development of new business models or tools to identify new design and research scenarios enabled by the use of new technologies, the development of tools for the envision and visualization of future scenarios, the creation of tools to prototype and test new feasible solutions, etc.

Reflecting the aforementioned concept of "Politecnicità", the work of designing, studying and developing design tools touches on several disciplinary areas.

In this paragraph we give a brief overview of the wide and rich production of design tools in continuous evolution among our

community of reference, the Department of Design at Politecnico di Milano.

Firstly, an extensive group includes tools aimed at stimulating creativity during the design process. The design process encompasses different articulated phases, in which it is crucial to foster creativity to enhance the development of novel and original solutions.

In this category, some tools are specifically addressed to design students, or conceived to be used in academic or teaching contexts. Among them, Mybias by Francesca Mattioli, Silvia Ferraris & Venere Ferraro (2018) is a web-based tool designed to improve design teams' dynamics by making students more aware of their biases from the beginning of the design process, with special attention given to their impact on heterogeneous teams' dynamics.

In the same contexts, Laura Varisco developed the Data Impact Tool. Varisco, Pillan & Marti (2019) actively work in the field of wearable product/service solutions supporting and tracking everyday activities. They analyzed the issue of personal data tracking, and in particular, the impact on individuals, societies and organizations coming from the huge amount of personal data generated and collected by these digital services. Their tool aims at stimulating the discussion on impacts related to the use of personal information to improve design choices in quick design processes and design courses. The involvement of design students in its development process was crucial, both to understand its limitations and impact on future designers.

Design students require more and more proper learning environments able to support and enhance their learning process. Thus, in the framework of teaching activities and learning environment development, Andrea Manciaracina (2022) developed Hyco, a tool

> for educational actors to start to reflect on creating new hybrid processes where the physical and digital setting in which students perform their work, including all the tools, documents, and other devices, coexist together to create a learning environment.

Of course, Covid-19 pandemia aroused the awareness that in the future we could rely on digital settings and tools to provide a wider and more engaging teaching experience to students. This unique

historical event introduced new paradigms and mindsets, demonstrating the urge to design new ways of interacting, teaching and communicating. In this framework, this tool does not aim to design the physical features of a learning environment but to deepen the relationships between physical and digital environments, relate them through technological tools, in order to support a hybrid approach that incorporates physical and digital in the teaching activities, enabling students engagement and new learning processes.

Furthermore, the Design Department of Politecnico di Milano largely produced tools specifically intended to improve designers' performance and enhance the design process with different new external hints and inspirations.

As an example, the Experience Map (Camere & Bordegoni, 2015) is a tool aimed at supporting designers in their intuitive choices to design pleasurable products able to elicit meaningful and engaging multisensory experiences for people. Following the authors words:

> Experience Map can provide a clear and synthetic visualization of a Multi Sensory, experience-driven process, from the beginning to the end… Designers can be stimulated to consider all the sensory modalities, with new possibilities to enhance the user experience of the product (Camere & Bordegoni, 2015).

On a similar path, Nicolò Becattini, Gaetano Cascini & Francesco Rosa, in 2016, developed the Biomimicry Taxonomy, a tool to support the search for natural sources of inspiration so as to spark new ideas in designers along Bio-Inspired Design activities. The tool leverages the correlation between the NIST Functional Basis and the Biomimicry Taxonomy, to allow designers with no or scarce biological knowledge to search already existing databases of natural phenomena (Becattini et al., 2016).

This wide group encompasses, also, tools which can be applied both within design contexts (in teaching experiences and in design practice processes) and non-design ones (i.e. professionals from other fields). As an example, Mindmap through Image Association, developed by Valentina Auricchio, Carla Cesar Sergio & Andrea Rech, is a tool in the form of a card set, which can be used in different moments of the design ideation phase, as it facilitates out-of-the-box thinking and lateral thinking, mainly in brainstorming sessions.

Indeed, through its deck of cards, it encourages the association of ideas by using random pictures to describe a phenomena. Another tool useful in brainstorming sessions, within a completely different field, is the Museum Hexagon Card Set, developed, among the others, by Raffaella Trocchianesi. The card set is a participatory design tool for developing museum experience ideas, by envisioning metaphors and scenarios metaphors and scenarios around new possible ways for extending cultural experiences to a wider public (Vermeeren et al., 2018).

In the last decades, a growing attention to the impact of industrial design on the environment has prompted a reconsideration of the footprint of materials and production processes. This dimension triggered the development of tools and toolkits for designers enabling them to evaluate the impact generated by the development of a certain project, the use of certain materials, manufacturing processes, etc.

As an example, Carlo Vezzoli, coordinator of *LeNS, the Learning Network on Sustainability,* together with Emanuela Delfino, since 2016, developed the E.DRE tool, an Estimator of Distributed Renewable Energy load/need and production potential. This tool is developed to support the design of DRE systems, in order to evaluate the energy demand and need. The tool, integrated with existing databases, allows for envisioning the best system configuration and estimation of energy production potential.

Moreover, in the last years, a vast collection of these tools have been collected by the European funded project called the International Learning Network of networks on Sustainability (LeNSin) and made accessible on its open platform (LeNSin, 2021). An interesting example is the one carried out by Azzi, Vezzoli & Conti (2019) in which Design-Orienting Scenario, the Sustainable Fashion Scenario tool to inspire and inform designers towards possible futures on specific topics, has been adapted to Sustainable Product-Service System (S.PSS) applied to fashion/clothing system. The tool presents four visions narrated as interactive videos accessible through a navigator file and it is aimed at inspiring designers and stakeholders to design radically new social, economic and technical solutions, environmentally sustainable. The main objective is to raise people's

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consciousness so that sustainability does not only represent a trend but it becomes a real design behaviour.

In a similar direction, Density Design Lab. developed an open source web tool named RAWgraphs. Following the authors:

> RAWgraphs is an open source web application for the creation of static data visualisations that are designed to be further modified (Mauri et al., 2017).

Originally conceived for graphic designers to provide a series of tasks not available with other tools, it evolved into a platform that provides simple ways to map data dimensions onto visual variables. Any user can access the platform and create complex data visualizations, supporting people without technical skills to create data visualisations, and enabling rapid prototyping for skilled ones.

Another open source web tool is "MappingTheIoT Toolkit" developed by Ilaria Vitali & Venanzio Arquilla (2018). This web tool is meant to support multidisciplinary teams in the design of Internet of Things (IoT) products. Indeed, IoT has received enormous attention as it is seen as a huge market for innovative products and as an interesting opportunity for many organizations to evolve.

> Designing for the Internet of Things means considering different levels of complexity, in which products are in a relationship with users, with each other and on a wider network. Without an exhaustive design process, it is easy to treat this topic superficially, and eventually develop tech gadgets with little perceived value, especially in the B2C market (Vitali & Arquilla, 2018).

Another interesting phenomena which triggered the development of different design tools and toolkits is represented by the Digital DIY. In fact, we are living in a society where designers are considered as social actors in a diffused process in which "everybody designs" (Manzini, 2015). Within this framework, DIY generally refers to any creation, modification or repair of objects without the aid of paid professionals. While the DIY phenomenon is surely not new, the widespread availability, versatility, and flexibility of digital tools are generating something new, with the potentiality of a game changer (Canina & Bruno, 2019). An interesting design tool developed within this frame is the DiDIY Factor Stimuli, designed to support people in

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applying the potentialities of this social innovation phenomenon, in different contexts. Following Canina & Bruno (2019):

> The star tool called "DiDIY Factors Stimuli" is composed of six extremities that joined together, form a unit. A star shape has been chosen to visually express the concept that only the intersection of all the fundamental elements of DiDIY at the same time can lead to innovation. It is important to highlight that it is not the single factor itself that generates a meaningful solution, but that only the integration of all of them in a project, creates innovation.

Within the framework of DIY phenomena, the process of creating DIY-Materials for social innovation and sustainability represented an interesting area for the development of design tools. Valentina Rognoli and the Material Experience Lab established an internationally recognised expertise on the topic both in research and education. As an example, she supervised many Master thesis, among which "DIY bioplastic club. Designing DIY starch-based bioplastic toolkit for enabling people DIY", by Ziyu Zhou, who developed the CIY Cardmap (Create-it-yourself Cardmap) to help designers or design students generate their concepts from materials. It puts materials at the start of a design process, referring to Material Driven Design method (Karana et.al., 2015), guiding designers through the design process or introducing a speculative approach in the materials' experience.

The design of tools and toolkits for social innovation represents a well-known area in which design tools have been developed since years. Within this framework, POLIMI DESIS Lab investigates the way design can support and trigger social innovation, combining creativity and visioning with the capability of engaging in co-design processes. Tools are considered here to be a result of design activity since they were concepted, created, prototyped and tested by the research team in direct connection with local communities and stakeholders. Among them, many tools were designed within the service design field. As an example, inspired by the Social Innovation Spiral by the Young Foundation and Nesta and shaped by POLIMI DESIS Lab (Meroni, Rossi & Corubolo, 2016), the Social Innovation Journey toolbox is conceived as an action format, focusing on the sequence of steps social innovators may go through acquiring the

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skills and capabilities they need to grow and increase the level of positive impact on the wider society. Another tool developed by Martina Rossi is Collaboration Blueprint, a tool derived from the existing "service blueprint", largely used in the service design field (a visual representation of a service or process functions both above and below the line of visibility of the user). The Collaboration Blueprint uses the same logic, but instead of tracking touchpoints, backstage processes or systems, it is conceived to track interactions between people that need to improve collaboration.

Lastly, a domain encompassing a strong design tools production is entrepreneurship, and the application of design thinking within entrepreneurial contexts. An interesting example is the one developed by Lucia Rampino, Sara Colombo & Cabirio Cautela (2017): a set of Design Thinking tools addressing the specific traits of Design-Intensive Start-ups (DIS) (start-ups that focus on design as primary source for their development) in the steps of their creation and evolution. This design toolkit was designed after observing the emerging demand of freshly graduated students willing to design an unconventional artefact: their own company. Concurrently, more and more incubators, accelerators, and organizations are observing the growth of start-ups differing from the tech-based ones and closer to the design field. The resulting DIS toolkit is composed of five tools, each one addressing one of the five identified DIS features. They represent a first attempt to create a set of tools dedicated to this emerging start-ups species.

6.5 The design tools taxonomy: a first application

The tools collected through both the open call and the literature review have been placed into the taxonomy presented in the previous chapter, as shown in the following figure (fig. 1):

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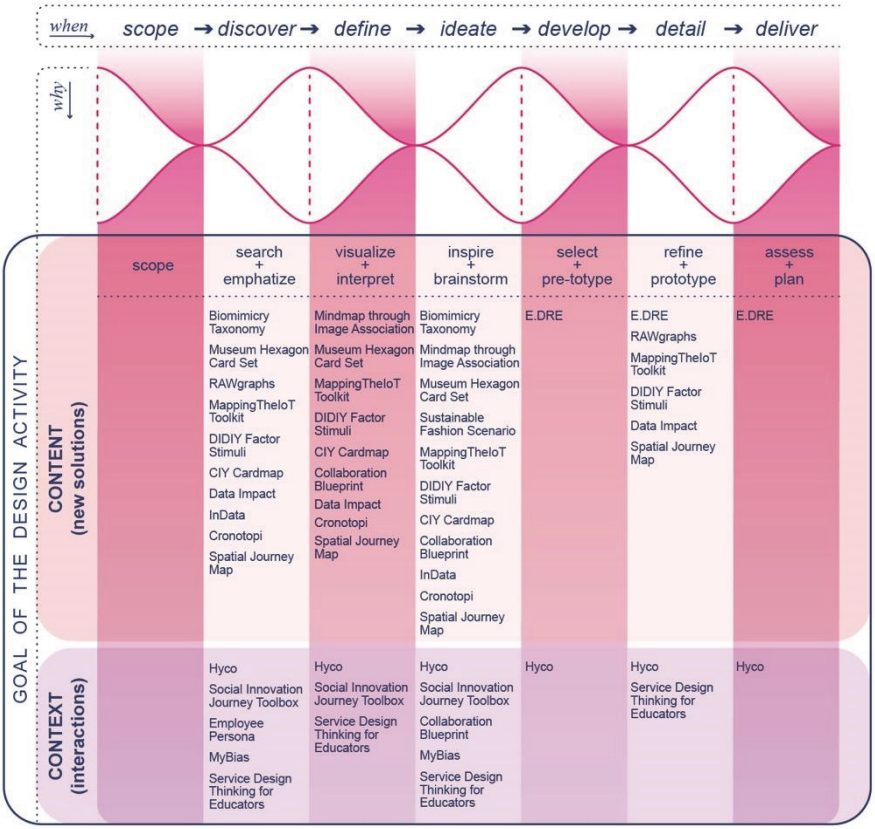

Fig. 1 – A first application of the design tool taxonomy developed within the Design Tools @POLIMI research project.

This first application of the taxonomy highlights some aggregations within some areas, whereas other areas need further exploration.

First of all, looking at the horizontal bands linked to the goal of the design activity, the "content" category, that of the design of a new solution, is certainly more crowded than the "context" one. This is probably because design for context has been developing in more recent years, particularly with the development of service design and design for social innovation.

Looking at the vertical axis, where the categories answering "when?" are present, there is an aggregation towards the "discover", "define", "ideate" phases. This probably happens because they are the phases of exploration of the topic, with identification of the most

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interesting and/or problematic aspects, subsequent definition of the brief and creative ideation of a solution. It is precisely this last phase, the "ideation" phase, which is by far the most creative of the whole process, that is also supported by the largest number of tools, both for inspiring and brainstorming. This is very interesting, as the tools present try to guide a process that is hardly linear. This happens both in "content" and in "context".

The "detail" phase is also crowded, in particular, many of the tools here test the designed solution in an iterative manner.

The "discover" phase crossed with the "context" category is the most crowded in this horizontal strip, as the focus in this area is on team facilitation and team building, for which empathy is a key aspect.

Some other areas are far less explored, such as the "develop" and "deliver" phases.

The "develop" phase is driven by clinical decision-making processes, thus very much tailored on the specific case and scope, and hands-on processes which are likely to be unstructured, and, hence, less tools have been collected. The "deliver" phase is probably less explored because of its more practice-oriented nature. In any case, this phase will probably see more tools in the future, as the whole aspect of assessment and evaluation of the impact of a given solution is receiving much more attention in recent years, also within academia.

Finally, the first phase, the "scope" one, is empty. This could be related to the fact that, by their nature, the choice in the use of a specific tool is determined by needs positioned in certain fields of action. This first phase is perhaps nowadays taken for granted, but it could be useful from an educational point of view to develop tools to support the definition of a scope.

6.6 Conclusions

The transformation of the design profession is leading to an increasing centrality of design tools, understood as tools to support design in educational and professional contexts, and as a subject of discussion in the disciplinary scientific debate. As we've seen, design tools are widely discussed in research (Sanders & Stappers, 2012), as

well as in design practice (IDEO, 2011; Cross, 2011). They are adopted in multiple fields with the most diverse purposes: to study the contexts of use of artefacts (Visser et al., 2005), to stimulate creativity during the design process (Michalko, 2010), to support collaboration between different actors (Brandt et al., 2004), to stimulate experimentation with new technologies or materials (Ellen MacArthur Foundation, 2017). This richness is fully reflected by the polytechnic culture imbued within the Design Department of Politecnico di Milano, distinguished by a multidisciplinary approach to the design and application of design tools.

The evolution of the design profession is accompanied by the development of new tools. The Design Tools @POLIMI taxonomy supports the dissemination of the richness of the polytechnic culture, which deserves continuous actions of enhancement of individual experiences within the national and international scene.

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7. Construction and development of a taxonomy of design tools: the role of cultural factors

by Silvia Maria Gramegna

7.1 The contemporary role of the designer

Design is increasingly important in current economies and societies. The role of design as a valuable source of competitive advantage has long been acknowledged (Bryson, 1997; Hammer & Champy,1993). Along to this, many design theorists defined design as a human capability that everyone has (Manzini, 2015).

Following Papanek (1971),

> the planning and patterning of any act towards a desired, foreseeable end constitutes the design process. Any attempt to separate design, to make it a thing-by-itself, works counter to the inherent value of design as the primary underlying matrix of life (p. 3).

The evolution of social paradigms sees the designer, among their traditional roles, as a process enabler (Rampino, 2018), facilitating collaboration between different actors, and designing tools to activate their participation (Manzini, 2015). Designers are indeed able to deal with complex and systemic issues thanks to the interdisciplinary, connective, polyglot and creative dimension of the design discipline. Design has always demonstrated its capability to combine problem solving capabilities and sense making, to connect the ability to ideate, create artifacts and produce meanings necessary to motivate what it's been done. In the past decades the debate around emerging design has focused mainly on problem-solving skills and pragmatic questions, giving less importance to cultural dimensions (Manzini, 2015). This led to a "solutionists" approach focused on the idea that everything

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can be reduced only to the act of finding solutions to existing problems, rather than focusing on giving a vision of future scenarios.

Nowadays, we are facing a new dimension for the design discipline, in which we are experiencing a «diffuse design attitude» (Branzi, 2006). Due to this attitude, society appears as an extensive experimental lab, which aims at defining new meanings, tools, solutions and social forms. Thus, we are living in a society where designers are considered as social actors in a diffused process in which «everybody designs» (Manzini, 2015). This new attitude includes active minorities and creative submerged communities that are coming up with new ways of being and design artifacts. Nevertheless, designers have to accept that design takes place also outside design studios and that they no longer hold the monopoly on those activities.

Designers became part of a great «diffuse design arena» (Branzi, 2006), in which they assume the role of solution promoters, bringing their skills and expertise, their capacity to envision future scenarios and to develop strategies and approaches to transform those visions into real solutions and artifacts (Manzini, 2005). Within this new perspective, design discipline necessarily needs to enhance its innovative, research-oriented, cross-boundary and cross-disciplinary attitude, in order to adapt and fulfill the ever-changing needs of society. Indeed, in recent years, design discipline has expanded its boundaries, not only focusing on designing artifacts, but also applying its skills in a wide range of fields that encompass services, strategic development, organizational design and management, interaction design, user experiences and social innovation (Wilson & Zamberlan, 2015).

The resulting picture underlies the integrative and adaptive nature of design: the design field today embraces multiple disciplinary perspectives, being able to border-cross other disciplines, and creating unified, sustained and substantial outcomes, where the designer acts as a facilitator in order to develop solutions and tools to fulfill upcoming needs and desires.

Often, this “role” needs adequate tools or toolkits to reach the goal in an easier way, to facilitate collaboration and confrontation between different actors involved in the design process, or to fulfill activities such as for example, the design of tools for social innovation and

sustainability for the public sector, the creation of tools for the development of new business models or to identify new project and research scenarios opened up by technologies.

7.2 Design tools as the expression of diverse cultural drives

Although the debate on design tools is wide, little has been said about the process and cultural context that led to their structuring. The opportunity to analyze a cultural context within which such different variety of design tools have been developed, is given by the research project Design Tools @POLIMI aimed at defining a taxonomy that represents the ecosystem of design tools that coexist within the Design Department of Politecnico di Milano, in order to facilitate the definition of research and training models that are increasingly tailored to the needs of the academic, professional and corporate world.

7.2.1 Building a Taxonomy

The definition of a taxonomy of design tools relates different disciplinary fields, which have contributed to their conception and application within the teaching, research and design activities of the Department and the School of Design.

As aforementioned in this book, a taxonomy is commonly understood as an orderly classification of phenomena underlying presumed relationships, following a set of principles of scientific classification. In the framework of design tools, more and more classifications in the form of taxonomies, collections, libraries, etc. are needed in order to offer tools and toolkits which may enhance the production of more efficient and competitive products, more sustainable design projects, easier the creation of new entrepreneurial entities able to inquiry the market with a different perspective coming from the design field (i.e. design thinking).

The definition of a taxonomy, in the research project Design Tools @POLIMI we carried out in the last 2 years, represents the first step

to facilitate the dissemination and use of the tools both on the territory among the actors of the local system, and at academic level in the international panorama, in order to enhance the variety of approaches adopted and to consistently present the multidisciplinary nature of the Poly-technic culture, extensively inquired in the previous chapter.

It represents a showcase which brings to attention an heterogeneous group of tools and toolkits, which encompass different areas of research and fields of application. Their overlapping and integration brings new perspectives for future further developments, contaminations between different areas and contexts of application. For newcomers, it represents a valid opportunity to experiment tools aimed at boosting and enhancing specific phases of the design process, enabling the users to confront themselves with new interesting possibilities, sustainable perspectives, new frontiers and new challenges within a wide variety of fields of applications and methods.

Ranging from the areas of product, communication, service, interiors, interaction, sustainability, fashion, new materials, entrepreneurship, and so on, it opens up the possibility to support with specific tools ideally any kind of project in a wide range of practice domains. The coexistence of different "souls" within the same Design Department enables a fruitful process of contamination and mutual learning, aimed at nurturing the production of new hybrid tools, capable of responding to the ever-changing needs of contemporary society.

Through our research project we tried to explore, as widely as possible, this multiplicity of souls. Through the narration of each individual experience, thanks to the collaboration of different researchers who responded to our open call, we tried to depict the different approaches to design discipline embodied in our community of reference, contributing to the formulation of a vision of design tools specific to the Design Department of Politecnico di Milano community.

In the phase of defining the taxonomy, in which we clarified the categories contained within it, we gave importance to the research process that guides the choice of a certain tool over another, in relation to the project or actions to be undertaken. As presented earlier in this volume, we agreed that from the perspective of the designers there are

some **"decisional categories"** that are primarily guiding the search of a tool, and the decision on which tool to use in a specific design phase.

Those "decisional categories" are crucial in order to shape the main structure of the taxonomy, but they are not sufficient in order to shape an articulate one, which can encompass the wide panorama of design tools being produced in our community of reference. This is mainly the reason why we added to the taxonomy structure some **"descriptive"** categories which explore the nature of some tools, the reasons why it has been developed, and so to whom it is designed for (i.e. special categories of users, stakeholders, etc.), if they are applicable in a specific phase of the creative process, and if they seek to inquiry certain results or impact.

Moreover, we had to take into consideration that most of the tools of the taxonomy are classified as applicable to multiple disciplinary areas. This means that in the majority of the cases, the tools developed in the Design Department of Politecnico di Milano more than being specifically related to a unique subject, they more likely guide the way, the method, with which the design activity should be performed.

7.2.2 Cultural context

From a cultural perspective, this research project opens a debate around the relationship between design and culture, encompassing two different levels:

- an exogenous level, looking at the current cultural, social, and economic challenges in design originating into the real world;
- an endogenous level, looking at the cultural context in which design tools have originated.

Part of the tools developed at the Design Department at Politecnico di Milano have been generated within Ph.D. programs, internal research projects, research fellowships' programs, research units and master thesis at the School of Design. All these tools result from solely endogenous pushes, aiming at extending many specific and different sides of the polytechnic culture. The novelty of these tools ranges from providing new sets of instructions or new templates, to supporting new approaches and methods.

Endogenous drives within the design field tend to be open towards the real world. This is clearly evident in the development process of some tools. Indeed, a part of the investigated tools were developed for an internal use, but later became open-source. Other tools were still developed within the design field, but involved other people in its creation and testing, such as other fields' experts and consultants. In this perspective, inter- and cross-disciplinary conferences, and international research programs (for example the Horizon2020 Programme), which explicitly require a multidisciplinary participation in the research projects are a fruitful space for elaboration.

Little by little we are moving towards an exogenous level. Here, we can find tools using a design approach mostly meant to be applied in a non-design context, and tools created in order to answer the demands of external bodies and organizations.

The fact that some tools are generated under endogenous pushes and later can answer exogenous demands is part of the innovation process in which universities are involved. Indeed, the Design Department of Politecnico di Milano produces new knowledge (hence, new design tools) to later translate them into design practices. Furthermore, the analysis suggests that the exogenous and endogenous levels are deeply interconnected and not precisely defined. This happens because of the intrinsic nature of Design (and, thus, design tools), which is a direct expression of the material and immaterial (sub)cultures of a society, an organization or another kind of body (Klein, 1996).

Moreover, this research highlights how a border-crossing approach influences the development of design tools, especially within a poly-technic attitude. Indeed, Design now, perhaps necessarily, transcends many traditional subject areas, as the problems of society are increasingly complex and interdependent and ever-changing. These problems are not isolated to particular sectors or disciplines, and they are not predictable. Labelled as "wicked" and "messy", they resist being tamed, bounded, or managed by classical problem-solving approaches. As a result of this, Design today is characterized by fluid, evolving patterns of practice that regularly traverse, transcend, and transfigure disciplinary and conceptual boundaries. Design not only is a projective activity, but its nature as an integrative discipline places

it at the intersection of several fields, such as the field of thinking and that of practice at diverse dimensions (Friedman, 2003). This deeply influences the design of new tools, as confirmed by part of the interviewed people: many design tools were born because of the need to work at the edge of other fields of study or application, to cross-existing boundaries and explore new solutions driven by the support of complementary expertises.

Finally, building the taxonomy was not an easy task, as boundary-crossing blurs the categories traditionally adopted within the design field. Indeed, many of the investigated tools were born at the edge of the discipline and, thus, they are expressions of the attitude to work at the margins.

As boundary-crossing stimulates the formation of trading zones of interaction, interlanguages, hybrid communities and professional roles, new institutional structures, and new categories of knowledge (Klein, 1996), we suggest that design tools play a fundamental role within these trade zones. In fact, design tools play a productive role in mediating among cultural, social, competence-related differences during the projective design process. Design tools should open a "space for exchange" enabling communication, discussion, and networking in order to develop shared goals, concrete ideas and measures, and assessment. Moreover, it's interesting to pinpoint that, from a scientific point of view, design tools appear

> as if they are somehow independent of context and exist outside the temporality (Göransdotter et al., 2018).

Why does that happen? We suggest that, as tools have a mediating role between different actors, designers tend to develop them keeping in mind the ideas of versatility and being adequately universal. In this way, design tools are robust enough to maintain unity across practices, yet sufficiently flexible to be manipulated in specific practices, happening in different times, places, scales.

Consider our taxonomy as an on-going project, an open platform in continuous development, according to the new tools and toolkits developed among designers and researchers of the Design Department of Politecnico di Milano. Our research has been a fruitful experiment, which hopefully will stimulate the establishment of a collective of

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competent and active researchers, transversal and cross-disciplinary to the various research areas, deeply involved and motivated to investigate, deepen and promote the theme of design tools.

7.3 Conclusions

As the evolution of social paradigms sees the designer as a process enabler, who facilitates collaboration between different actors, and who designs tools to activate their participation, the topic of design tools, intended as tools aimed at catalyzing and supporting the entire design process, emerges. Moreover, understanding the social roles, habits and values that lead to the development of a certain tool in its specific cultural background, appears relevant within the current debate in design discipline. This breaks new ground to understand the development process, the usage, the values, the potentials and the cross-disciplinary connections subtended in each design tool, in correlation to the cultural background in which it was generated.

As a consequence, structuring an effective taxonomy of design tools facilitates the professional world's identification of collaborative opportunities for innovation and change. The definition and development of a taxonomy and collection of tools also supports some aspects of training and innovative teaching activities, but also the implementation of design thinking strategies and methods within other fields, and the enhancement of design processes through the use of innovative tools and instruments.

Developing a taxonomy represents an opportunity to enhance and extend the good research practices already present within a reference community, in our case the Department of Design of the Politecnico di Milano, facilitating structured positioning in networks and scientific communities of reference, both national and international. It is certainly an open project, under continuous development over time, which will be enriched with new tools as new fields will be explored.

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This book aims at encompassing the panorama of design tools being developed, tested and adopted by researchers and professors at the Department of Design of Politecnico di Milano.

The tools are organized in a taxonomy that reflects the path of choice of a possible user in need for the right tool for a task to be performed. The taxonomy is based on a formalization of the design process proposed by the authors, which characterizes the Design System at Politecnico di Milano.

The book essentially offers two main contributions: an original taxonomy that guides towards the organization of design tools and their usage with different actors; a representative collection of design tools developed within the Department of Design of Politecnico di Milano with specific instructions on how to use them.

Design Tools is addressed both to practitioners and academics in the field of design that are interested in getting to know more about the discourse around design tools in general and in particular how this discourse takes a shape within Politecnico di Milano and resolves in usable and shareable tools.

FrancoAngeli
La passione per le conoscenze