

Routledge
Taylor & Francis Group

The Design Journal
An International Journal for All Aspects of Design

ISSN: 1460-6925 (Print) 1756-3062 (Online) Journal homepage: https://www.tandfonline.com/loi/rfdj20

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To cite this article: Muhammet Ramoğlu & Aykut Coşkun (2017) Scientific Craftsmanship: The changing role of product designers in the digital era, The Design Journal, 20:sup1, S4497-S4508, DOI: 10.1080/14606925.2017.1352946

To link to this article: https://doi.org/10.1080/14606925.2017.1352946

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Published online: 06 Sep 2017.

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DESIGN FOR NEXT
EAD12-ROME

doi: 10.1080/14606925.2017.1352946

Design for Next

12th EAD Conference
Sapienza University of Rome
12-14 April 2017

Scientific Craftsmanship: The changing role of product designers in the digital era

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Abstract: In this paper, we provide a brief historical account that examines how technology and society influenced the design practice in 20th and 21st centuries. By focusing on the recent changes in the design profession, we discuss how digitalization changed the types of issues designers deal with, tools they use, and outcomes they produced. Based on these parameters, we propose *scientific craftsmanship* as a new definition of design activity in the digital age. This definition is concentrated on four major aspects: 1) working with physical and digital materials and tools, 2) fabricating in domestic scale, 3) using scientific methods and theories from other fields, and 4) creating with others.

Keywords: 21st century design, design science, maker, design practice

1. Introduction

The postindustrial era witnessed many changes in the design discipline. Researchers have indicated that these changes mostly focus on the nature of the design practice, tools in the design process, and purpose and outcomes of design activity (Danish Designers, 2010; Findeli, 2001; Lawson, 2005; Wormald & Rodber, 2008). For instance, the concept of *product* has changed. Today, designers are not only working with physical artifacts but also services, systems, and experiences (Buchanan, 2001; Findeli, 2001; Kiernan & Ledwith, 2014). Correspondingly, new designer's titles and job descriptions like interaction designer, service designer, and experience designer have emerged as a response to this change. There have been other changes in the way designers work. First, the rise of design approaches such as participatory design, co-design, and open design along with increased complexity of problems that designers face, have led to the use of scientific methodologies and theories from other fields in design practice compared to the past. Today, designers more often collaborate with people from other disciplines including but not limited to engineering, psychology, and management. Second, technological developments such as electronic prototyping platforms, 3-D printers, and software tools have decreased limitations of mass manufacture. Such tools have provided designers with an opportunity to experiment with new materials, new ideas and new methods in design practice. These changes have also motivated the design community to revise the definition of the

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discipline. For instance, World Design Organization (WDO)[1] has recently revised the definition of industrial design:

> "Industrial Design is a strategic problem-solving process that drives innovation, builds business success and leads to a better quality of life through innovative products, systems, services and experiences." (WDO, 2015)

In this paper, we expand on this discussion by suggesting a new definition for the design practice in the digital era. Based on our investigation of how technology and society have influenced the design practice of the 20th and 21st centuries, we propose *scientific craftsmanship* as a new definition of design activity. This definition brings two different perspectives: science and craft. The former stands for the use of scientific methodologies in the design process (Cross, 1982; Simon, 1969), and the latter emphasizes the designer's conversation with the material (Louridas, 1999; Schön, 1983), which are a mixture of physical and digital in today's case. Our definition positions designers as scientific craftsmen who work with digital materials, fabricate in domestic scale, use scientific methods and theories from other fields, and create with others as opposed to traditional craftsman and 20th century designers (Table 1).

Table 1. Position of scientific craftsmanship according to design approaches before digitalization

	Similarities with scientific craftsmanship	Differences of scientific craftsmanship
Traditional craftsmanship	Practice-based Self-manufacturing	Methods over tradition Materials are not only substances
Design approach in 20th century	Using scientific methodologies	Self-manufacture over mass-manufacture Products are not only physical objects

2. Design Profession

The focus of design profession has been shifted from feasibility to form, function, marketing, user, and sustainability with the changes in design movements in the last century (Figure.1). First, designers were supposed to design products according to new manufacturing methods to reduce production and logistics cost. Thereafter, aesthetic values had become more important as a reaction to industrialization. During this era, art spread out of galleries and came to the streets as products and graphics. While a group of designers followed previous art movement, others adopted a functional approach and searched standards for household goods (Raizman, 2003). After World War II, designers helped companies sell dream houses and dream cars with big advertisements. Then in the 1980s, designers questioned user needs and put the user in the center of design while scientific computers evolved into personal computers (Weiser, 1991). When the world realized our harmful

	Feasibility	Form	Function	Marketing	User	Sustainability	???
When	Mid 19th century	Late 19th - Early 20th century	1910s-1940s	1940s -1960s	1970s-2000s	1990s -2010s	2010s-
Where	Great Britain	Western & Central Europe	Austria & Germany	United States	Around the world	Around the world	?
Condition	Industrial Revolution	Romanticism - Reaction to industrial revolution	Industrializing liberal Germany	Post war	Computers	Insufficient resources	?

Figure 1: How designers' focus has been changed acorrding the time, place and conditions. A similar timeline also drawn by Broadbent and Cross (2003).

[1] Formerly known as International Council of Societies of Industrial Design (ICSID)

impact on environment and insufficiency of current resources, designers began to create sustainable, recyclable, energy efficient design solutions (Lees-Maffei & Houze, 2010).

Design activity in the 20th century was mostly affected by technological developments but *designerly thinking* (Cross, 1982) had also changed and design scope was expanded. The WDO changed the industrial design definition and included experience, service, and systems as products. The original definition from 1959, focused only on "shape, color, surface finishes and decoration". The first time *user* has mentioned in a definition was in 1969. Then, the organization decided to remove the definition in 1971. All previous definitions emphasized the industrial production until the last definition in 2015 (World Design Organization, n.d.).

The effect of technological improvements and social changes on the definition of design cannot be denied. The some of the popular social media websites, today's mainstream media channels, were founded in the 2000s (Boyd & Ellison, 2007). Besides, smart phones have changed the way we access to information. First Apple iPhone was released in 2007. Android, an open source operating system for smartphones and tablets, was introduced in 2008. Today it is the most used operating system and has a wide application area aside from touchscreen mobile devices. These technologies have not only influenced our daily lives but also affected industries. Google Play and Apple Store contain more than a million mobile applications that emerged an entirely new industry. Many big companies of the 21st century do not even have a physical product but offer either or both a service and experience via digital products. These digital products such as mobile applications, websites, and software demand design for a better user experience and this has raised new designer titles in the last decade.

The increase of digital design professions can be seen by looking at the results of two studies conducted in 2005 and 2014. Yang, You and Chen (2005) examined job titles in various job searching websites and found that only 0.8% of job titles in design profession was *Interface Designer* where 51% and 24.5% were *Industrial Designer* and *Mechanism Designer* respectively. However, Kiernan and Ledwith (2014) showed that the second most preferred jobs among product design graduates were interaction/user experience/graphic designer positions. This preference is significantly higher than the previous study, illustrating an increase in digital design occupations. These results are supported by search trends in the popular search engine Google. We compared several designer titles in Google Trends[2] to understand transition in the interest for titles in design profession and found that interest in the *Industrial Design* keyword was decreasing, search *for User Experience (UX) Designer* and *User Interface (UI) Designer* increased in the last decade (Figure 2). We also analyzed

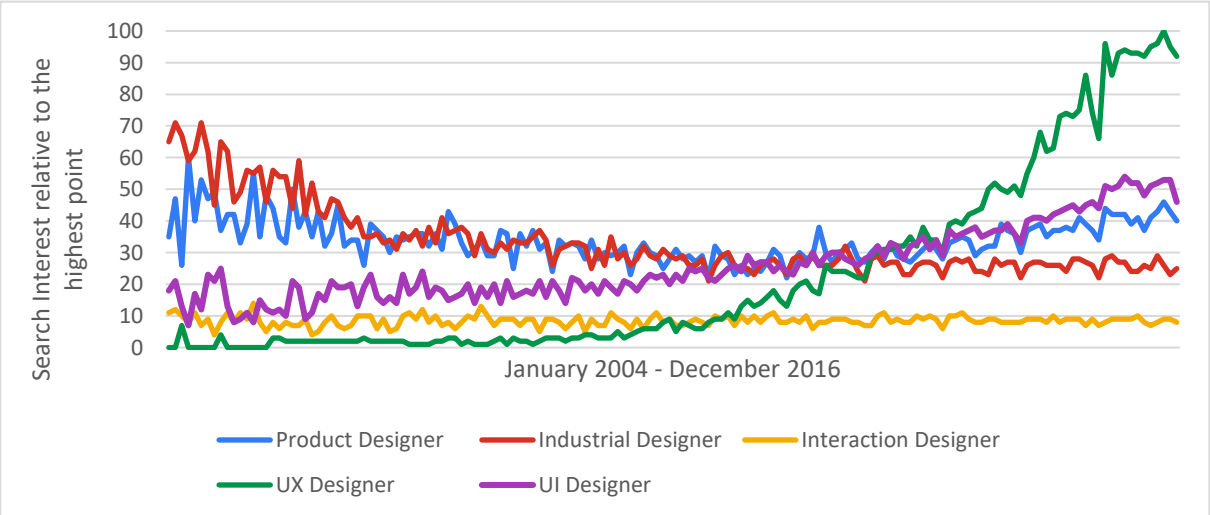


Figure.2: Search trends of keywords

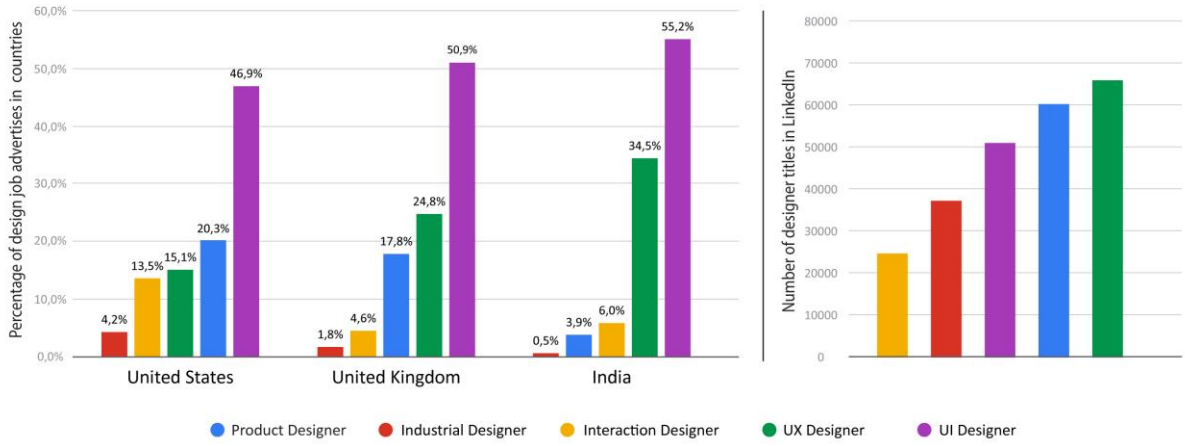


Figure.3: Number of design job advertisements in three countries (left) and number of designer titles in the world (right), retrieved from LinkedIn, November 8, 2016. Product Designer title has a high number of usage mostly because it contains professionals who design physical and digital products (Tharp & Tharp, 2009).

job ads and titles appeared in LinkedIn[3], a professional networking website (Figure 3). We followed a similar method with the previous study (Yang et al., 2005) and searched for five designer titles. As LinkedIn limited job search with location parameter, we selected United States, United Kingdom, and India. We chose them among the countries that have English as an official language from different parts of the world. We found a rising trend in titles such as *UX Designer* and *UI Designer* in design job advertisements and titles of designers. This trend might be attributed to the ubiquity of computers in our everyday lives, and their influence on the demand for professionals who can devise the interaction between people and these computers. LaBarre (2016) indicates that new designer titles might emerge due to fast growing technological developments, for example, Augmented Reality Designer, Chief Design Officer, Chief Drone Experience Designer, Embodied Interactions Designer, Human Organ Designer, Intelligent System Designer, Machine-Learning Designer, Real–time 3-D Designer and Nanotech Designer.

3. Digital Design

We use the term *digital design* to explain digitalization of design process that results in both digital and physical products. Designers of today are increasingly using software programs in the design process and instead of papers, they deliver digital data for manufacturing a product or constructing a building (Mitchell, 2005). Oxman (2006, p.232) supported this by saying “Buildings are now designed, documented, fabricated and assembled with the assistance of digital means.” Digital tools are also used to analyze or simulate products for production and real life conditions. For example, a designer can create a 3D model of a chair, choose its material and test its strength by applying force to the chair with a software which saves time, energy, and resources. In addition, computer abilities have increased with digitalization. For example, Artificial intelligence (AI) programs have been writing scenarios (Newitz, 2016), generating graphic arts (DiPaola & McCaig, 2016) and composing music (Ghedini, Pachet & Roy, 2016). In the near future, other AI programs might help designers in idea generation or form creation that could evolve the design practice.

[3] https://www.linkedin.com/

3.1. Digital Tools

Computer programs and manufacturing technologies have been improving and affecting product design practice lately. Knowledge of digital tools for 3D modeling, graphic design, and rendering are the main requirements for industrial design job applications in the current industry (Yang, You, & Chen, 2005). 3D surface or solid modeling programs help designers conceptualize their designs and create the data for manufacturing. Computer-aided design (CAD) has been trending in both industry and design education. Designers are not only using computers for design but also for manufacturing.

Computer-aided manufacturing (CAM) methods have been in use for a long time. Many advanced factories of today are fully automated. Computer numeric control (CNC) machines which are controlled by a computer, process material according to digital data. Thus, designers need to design their final products in a digital environment for modern manufacturing methods.

3.2. Self-manufacture

Technological developments have not only affected mass production but also have provided new possibilities for self-manufacturing. Rapid Prototyping technologies such as 3D printers and laser cutters allow people to produce at home or in a small workshop with basic knowledge of manufacturing methods (Richardson & Haylock, 2012; Troxler, 2011). Since 3D printers have become very popular, they have also influenced new domestic manufacturing tools such as a desktop vacuum former[4]. 3D printers are not only useful for creating early prototypes in design studios without the high cost of molding, but also for creating inspiring design solutions. For example, designers developed the idea of 3D printing joint parts of furniture and connecting simple wood components that can be bought from any hardware store (Derringer, 2014; Bernier, 2015; Williamson, 2016). This idea creates numerous opportunities for design. In a future scenario, when a dishwasher is broken the system shows which part is broken and the component can be printed at home and replaced without calling a mechanic. Various 3D models for printing have been already available on websites such as Thingiverse[5] and GrabCAD[6]. If we will have such a future, a designer should design products that can be manufactured locally.

Rapid prototyping tools and open source culture provide new possibilities to designers for innovation that is not limited by mass-manufacturing, corporate structure or intellectual properties (Richardson & Haylock, 2012). Digital fabrication technologies create an alternative design profession in which individuals can produce and sell their own products on a domestic scale. Actually, there was a similar approach in the 20th century where designers sold their products in galleries. However, in the digital era, designer-makers could sell their products online via shopping websites such as Etsy[7] and AHALife[8]. This indicates how products and the market have changed in the digital age.

3.3. Maker Movement

So far, we focused on physical products. However, in the 21st century, designers have also been producing mobile applications and websites. Another example of self-manufacturing is crafting a computer code into digital products that only need a computer and specific programs. Besides digital products and traditional products, there are affordable open source hardware systems such as

[4] https://www.mayku.me
[5] http://www.thingiverse.com
[6] https://grabcad.com
[7] https://www.etsy.com
[8] http://www.ahalife.com

Arduino[9] and Raspberry Pi[10] that enable self-manufacture electronic products at home. Self-manufacture is also related to the do-it-yourself (DIY) movement which contains diverse topics such as sewing, food production, self-publishing games, music or books. However, DIY currently refers to technology-based projects in a maker culture. Makers work with the material, share knowledge and create with others on the Internet or in the physical places such as Fab Labs which are low-cost workshops with digital fabrication tools (Richardson & Haylock, 2012; Troxler, 2011). Designers are part of the maker culture as well as engineers and artists (Martin, 2015). The maker culture is the living example of how craftsmanship and technology can come together. Technological developments bring new opportunities for designers and create new movements in society, and the maker movement is one them.

3.4. Open Design

The open source movement, as we know it, became popular with free distribution of the source code of computer programs, so other programmers can learn, contribute and improve. There were *open* movements before open source software development but this radical action of the digital era has a great impact on society. The main policies of the Pirate Party (which was founded in Sweden first but has also used as a label for political parties with similar opinion) are participation in government, open access for data, and supporting open software and hardware. Fab labs and hackerspaces were influenced by open source and DIY movements where *makers* collaborate on open source projects. This influential movement also affects design activity. The *open design* term was coined by Ronen Kadushin (2005) who designed a chair that can be downloaded and fabricated with a laser cutter. Digital fabrication and the internet provide downloadable products that lead to open design. However, the open design approach also existed before the digital era. Van Lengen (2008) created a handbook for building houses in the 1980s. The book includes detailed explanations of an affordable building method with available resources in nature and it became popular in Latin America. Open design does not only contribute to society, it also creates with society.

Participatory design movement includes users and other stakeholders in the design process that started in the 1970s in Scandinavia (Bødker, 1994). User experience has become the focus of design activity and non-designers also take a role in the design process (Manzini & Rizzo, 2011). A similar method can be found in science with the citizen science approach in which laypeople contribute to scientific studies (Phillips, Baurley, & Silve, 2014). Participatory design and open design have been shifting the design process from design studios to the public. We believe self-manufacturing with digital technologies will spread the maker culture and open design paradigms.

Digital tools created many opportunities for designers and influenced the design and manufacturing process. We are able to visualize, prototype and analyze products before production. With user-centered design, the focus of designer shifted from client to the user. Designers do not design for the client only but also for themselves for selling their product, contributing to the society or just experiencing a material. This freedom has emerged with globalization and the widespread use of the Internet. Thus, the possibility of the designer to make an impact on the world has increased. The effects of digitalization, participation in design and the maker movement on design activity are currently ongoing discussions (Harder, Burford, & Hoover, 2013; Oxman, 2006; Richardson & Haylock, 2012). We want to gather these discussions under our new definition of design activity to understand the role of product designer in the 21st century.

[9] https://www.arduino.cc
[10] https://www.raspberrypi.org

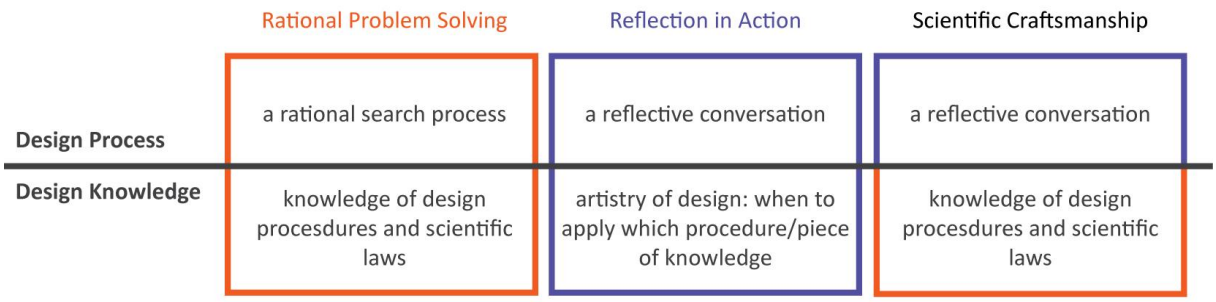


Figure 4. Difference of scientific craftsmanship than previous definitions of design activity (Dorst & Dijkhuis, 1995)

4. Scientific Craftsmanship

Acknowledging the changes in the issues designers face, the methods they need to use and the outcome of a design process, we propose a new definition: Scientific craftsmanship. Our definition, the design activity in the 21st century, includes working with the digital and physical material, fabrication in domestic scale with the help of emerging technologies, using methods and theories from other fields, and creating with others (designers, non-designer professionals, and users). Here, we aim to position the designer of the digital era with this new definition of design activity.

The *scientific* side of design comes from the rational problem solving characteristic that lies in the nature of design. Because society has expanded, our problems have become more complex and designers started to build design knowledge with methodologies instead of traditions (Louridas, 1999; Simon, 1969). The complexity of problems has also evolved design methods because the current methods have become insufficient to solve today's complex problems. Thus, SC tries to solve today's complex problems by using scientific methods and working with professionals from other disciplines more than before. Zimmerman, Forlizzi and Evenson (2007) exemplified the idea with a model in which behavioral scientists bring theory, engineers contribute with the technology and anthropologists provide the field data in interaction design research. Today, design practice and design research are getting closer to science. Scientific craftsmanship differs from scientific design (Cross, 1982) or design approaches in the 20th century by conversation with the material and self-manufacturing instead of mass production.

Craftsmanship and design activity of today have several similarities and differences. With the advent of digital manufacturing tools, design and production have merged again. Self-manufacturing has become available on a domestic scale with the help of computer-aided design programs, computer-aided manufacturing, and rapid prototyping machines. Designers of 21st century work similar to craftsmen, in which the designing and manufacturing occur simultaneously. Technological developments have also led to DIY and the maker movement which are associated with arts & crafts. We mainly constructed craftsmanship in this definition based on Schön's (1983) conversation with the material approach and Louridas' (1999) definition of design as a bricolage activity. However, SC differ from traditional craftsmen in terms of three aspects. First, unlike craftsmen, they do not have a closed universe of tools to achieve the desired outcome (Louridas, 1999). Second, they work with both physical and digital materials. Third, they deal with complex problems and heavily benefit from science to solve these problems.

Dorst and Dijkhuis (1995) collected different definitions of design under rational problem solving (Simon, 1969) and reflection in action (Schön, 1983) approaches**.** Scientific craftsmanship combines these two main perspectives in design theory. While design process is a reflective conversation,

design knowledge comes from scientific knowledge in scientific craftsmanship (Figure 4). Thus, we join scientific and craftsmanship approaches together in our new definition of design activity.

The new definition of design activity is distinguished from both traditional and modern designers in many aspects. The main differences between scientific craftsmanship and design activity before digitalization are materials and products. Designers used to work with wood, metal, and plastic to create physical products. Today, computer code is another material of scientific craftsmen that creates new possibilities for design (Dearden, 2006; Vallgårda, Boer, Tsaknaki, & Svanaes, 2016; Wiberg, 2016). Outcomes of SC could be interactions, experiences, systems and services as well as physical products. As society changes, we have new technologies and new problems that have a great influence on design activity. Industrial designers focused on feasibility, function, and aesthetics in the past. Of course, SC still have been considering these problems, but there are novel issues such as user experience, sustainability, and social problems. SC may play a role in finding solutions to obesity, traffic problems or racism. Besides, they can help to develop business and services via products to improve healthcare, education and energy problems (Kandachar, De Jong & Diehl, 2009; Mikhak et al., 2002). New issues in design do not replace previous issues, but they are stacked on existing problems and SC must consider all of these problems. Rittel and Webber (1973) described societal problems that designers are facing as *wicked problems*. SC collaborate with other professionals and users to solve wicked problems of today. Because of the technological and social changes, we believe problems, methods, and outcomes of SC are different from previous designers.

5. Discussion

It is essential to define design activity for placing design profession, design research and planning the design education. In this paper, we identified social and technological changes that influence design activity and suggest considering these changes to define the designer of the 21st century. Many design researchers will probably discuss the design activity, some will build on what we claimed, others might argue against this paper. In all cases, we need to continue this discussion in order to shape design activity. Design was institutionalized a century ago and research in design has been carried out for a half-century. Because of rapid changes in technology and society, the design field is open for future transitions. As design deals with wicked problems and there is no true solution in design, there cannot be a true definition of the design activity. We present this definition and call on researchers, educators, and practitioners for a debate on it. This paper can be regarded as the description of design activity of today and speculation on its future directions. We finish the paper with further arguments as well as open questions regarding the implications of this new definition for design practice, education and research.

5.1. Design Practice

Digital is not against physical in the new definition of design activity. Designers still use non-digital tools in the design process such as mock-ups and hand sketches. Thus, we do not completely ignore the traditional methods. In fact, we want to emphasize the act of making. Digitalization is an opportunity but does not need to cover traditional methods in design practice. We do not claim that digital needs to be the focus of design activity. We have just pointed out that digital should not be avoided as a tool for design. In addition, it is possible to bring digital technologies and traditional making activities together. For example, tablets and sketch programs provide traditional drawing experience in a digital medium. Moleskine Smart Writing Set [11], allows designers to draw on a paper

[11] http://www.moleskine.com/microsites/smartwritingset

with a special pen that converts drawing on a paper to digital data. Haptic feedback devices are designed to feel the surface when sculpting a 3D model in the computer environment (Aldoy & Evans, 2015; Bordegoni, Colombo, & Formentini, 2006). In short, digital is not against to physical practice, but there is a way to combine digital with traditional making activities.

How can we combine rational problem solving with reflective conversation in practice? Scientific craftsmanship combines the notions of design as rational problem solving and design as a reflective practice. Methodological research, logical analysis, and generalizable results are forming the technical rationality (Simon, 1969) and that is a rigorous way to reach to the knowledge. We suggest designers use scientific knowledge and methods as *tools* in design activity. However, empirical knowledge alone might not include the solution of the problem where designers also need to use their practitioner skills. Every problem is unique and so the solution of a problem does not lie in the cumulative knowledge (Schön, 1983). Hence, although the definition combines these two notions of design, how it can be applied to the design practice is still an open yet a challenging question.

5.2. Design Education

This new definition urges schools to reconsider design education of today. If scientific craftsmanship is accepted as the definition of design activity it might affect design education at several points. As we emphasized the importance of conversation with the material, practice-based design education is relevant to our definition. We argue that *today's design education should be designed with the vision of tomorrow.* Designers of the future need to adapt emerging digital technologies and fabrication methods to work with both digital and physical materials. Researchers have pointed out that design education of today will be out of date when students are employed in the future (Liem & Sigurjonsson, 2014, Schön, 1987). Thus, design students should learn to adapt to technological changes. Furthermore, *interdisciplinary education will be the key in educating SC as it provides diverse paths to follow.*We argue an interdisciplinary definition of design (Liem & Sigurjonsson, 2014; Rittel & Webber, 1973), so that design education might provide paths through the blurry boundaries of disciplines. Then, design students might be able to apply design practice in other fields or use the knowledge from other disciplines in design activity.

What kind of new skills future designers need to have and how we will teach these skills? Adaptation to changes might be the best and most unclear answer. If we try to teach a specific subject we might fail while creating a super-designer that is expert at various topics. For example, teaching programming or make projects with emerging technologies such as virtual reality (VR) most probably will be useful. However, when VR is no longer exist in the daily life of the future or replaced with other technologies, the designer must be still productive. Therefore, design education should be applicable for different cases and prepare designers to adapt their design knowledge in different contexts. Even if design students learn various topics, the problems they face will be different and they need to learn how to deal with unique problems. Still, on top of teaching essential design skills such as creative problem solving, future designers should also learn how to follow new technologies and tools and integrate them into their work.

5.3. Design Research

Today, *the practitioner becomes a researcher, the researcher becomes a practitioner.* When scientific craftsmanship is considered in terms of research, research through design (RtD) approach appears to be the most similar activity to this definition. This approach brings design activity and scientific knowledge together as a research method. Zimmerman et al. (2007) explained how design practice

might be applied in research and this method has been widely used by researchers. They also noted differences between *research artifact* and *design practice artifact* that the purpose of research artifact is not a commercial success for a company or feasibility. RtD approach turned design activity into a research topic. Thus, a product can be a research outcome and it could expand our discourse, *outcomes of design have been changed.*

When design activity is framed different than traditional industrial design activity that focuses on manufacturing and client's expectations, it blurs the barriers between RtD and design practice. In our definition, SC could create commercial products as a professional designer, make an impact on society with critical design projects or contribute to design research. Therefore, *how to distinguish design research and practice* is open for a discussion in our new definition.

6. Conclusion

We analyzed how design problems, tools, methods, materials, and outcomes have changed in the digital era and conceptualized our new definition according to changes in these parameters. Problems have become more complex and outcomes of the designer as a solution for these problems vary from physical to digital products, service, and experience. The designer of today is collaborating with researchers and professionals from other fields and using methods and theories from other disciplines more than ever. Thus, we suggested positioning our new definition in the edges of disciplines. Digital fabrication tools such as 3D printers can shift production into a domestic scale that can affect the industrial design profession and the design process. The digital age has led to the movements such as open design and the maker culture that might have an impact on design activity. In future work, our definition can be extended along with other practice-based professions that are related to design and scientific craftsmanship can be examined as an inclusive title for applied disciplines. In addition, educating the future scientific craftsmen is another track for future studies. Discussion on the definition of design is ongoing. This paper contributes to the current discussion on design activity by positioning design between science and craft. We construct scientific craftsmanship around digitalization to define designer of the 21st century that might open new debates on design theory in the future.

7. References

Boyd, D. M., & Ellison, N. B. (2011). Social Network Sites: Definition, History, and Scholarship. *Journal of Computer-Mediated Communication*, 13(1), 210-230.

Broadbent, J. A., & Cross, N. (2003). Design education in the information age. *Journal of Engineering Design*, 14(4), 439-446.

Buchanan, R. (2001). Design research and the new learning. *Design Issues*, 17(4), 3–23.

Bødker, S. (1994): Creating conditions for participation: Conflicts and resources in systems design. *In Proceedings of the Participatory Design Conference PDC'94*, 13-20. Chapel Hill, North Carolina, CPSR and ACM.

Cross, N. (1982). Designerly ways of knowing. *Design Studies* (Vol. 3).

Danish Designers (2010). The role of design in 21st century. Retrieved December 19, 2016, from http://www.humancentereddesign.org/sites/default/files/Manifesto-UK.pdf

Dearden, A. (2006). Designing as a conversation with digital materials. *Design studies*, 27(3), 399-421.

Derringer, J. (2014, April 17). Keystones by Studio Minale-Maeda. Retrieved November 21, 2016, from http://design-milk.com/keystones-studio-minale-maeda/

DiPaola, S., & McCaig, G. (2016, July). Using artificial intelligence techniques to emulate the creativity of a portrait painter. *In Proceedings of the conference on Electronic Visualisation and the Arts* (pp. 158-165). British Computer Society.

Dorst, K., & Dijkhuis, J. (1995). Comparing paradigms for describing design activity. *Design Studies*, 16(2), 261–274.

Findeli, A. (2001). Rethinking Design Education for the 21st Century : Theoretical , Methodological , and Ethical Discussion. *Design Issues*, 17(1), 5–17.

Gershenfeld, N. (2008). *Fab: the coming revolution on your desktop--from personal computers to personal fabrication*. Basic Books.

Ghedini, F., Pachet, F., & Roy, P. (2016). Creating music and texts with flow machines. *In Multidisciplinary Contributions to the Science of Creative Thinking* (pp. 325-343). Springer, Singapore.

Harder, M. K., Burford, G., & Hoover, E. (2013). What Is Participation? Design Leads the Way to a Cross-Disciplinary Framework. *Design Issues*, 29(4), 1–12.

Kadushin, R. (2005). Open Design Manifesto. Retrieved December 25, 2016, from http://www.ronen-kadushin.com/index.php/open-design/

Kiernan, L., & Ledwith, A. (2014). Is Design Education Preparing Product Designers for the Real World? A Study of Product Design Graduates in Ireland. *The Design Journal*, 17(2), 218-237.

LaBarre, S. (2016). The Most Important Design Jobs Of The Future. Retrieved January 12, 2016, from http://www.fastcodesign.com/3054433/design-moves/the-most-important-design-jobs-of-the-future

Lawson, B. (2006). *How designers think: The design process demystified*. Routledge.

Lees-Maffei, G., Houze, R., & Art, T. V. (2010). *The design history reader*. Berg Publishers.

Liem, A. & Sigurjonsson, J. B. (2014). Positioning Industrial Design Education within Higher Education: How to face increasingly challenging market forces? *Uniped*, 1(02), 44-57.

Louridas, P. (1999). Design as bricolage: anthropology meets design thinking. *Design Studies*, 20(6), 517–535.

Martin, L. (2015). The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research (J-PEER),* 5(1), 4.

Manzini, E., & Rizzo, F. (2011). Small projects/large changes: Participatory design as an open participated process. *CoDesign*, 7(3-4), 199-215.

Mikhak, B., Lyon, C., Gorton, T., Gershenfeld, N., McEnnis, C., & Taylor, J. (2002). Fab Lab: An Alternative Model of ICT for Development. *development by design (dyd02)*. Bangalore: ThinkCycle.

Mitchell, W. J. (2005). Constructing complexity. *In Proceedings of the 11th International In Computer Aided Architectural Design Futures Conference*, 41 – 50. Springer Netherlands.

Newitz, A. (2016, June 6). Movie written by AI algorithm turns out to be hilarious and intense. Retrieved December 18, 2016, from http://arstechnica.co.uk/the-multiverse/2016/06/sunspring-movie-watch-written-by-ai-details-interview/

Oxman, R. (2006). Theory and design in the first digital age. *Design Studies*, 27(3), 229–265.

Phillips, R., Baurley, S., & Silve, S. (2014). Citizen Science and Open Design: Workshop Findings. *Design Issues*, 30(4), 52-66.

Raizman, D. (2003). *History of modern design: graphics and products since the Industrial Revolution.* Laurence King Publishing.

Richardson, M., & Haylock, B. (2012). Designer/Maker: The Rise of Additive Manufacturing, Domestic-Scale Production and the Possible Implications for the Automotive Industry. *Computer-Aided Design and Applications, PACE*(2), 33–48.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, 4(2), 155-169.

Schön, D. A. (1983). *The Reflective Practitioner*. London: Temple Smith.

Schön, D. A. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*. San Francisco: Jossey-Bass.

Simon, H. A. (1969). *The Sciences of the Artificial*. Cambridge, MA (Vol. 1).

Tharp, B. M. & Tharp S. M. (2009, January 5). The 4 Fields of Industrial Design (No, not furniture, trans, consumer electronics, & toys). Retrieved December 18, 2016, from http://www.core77.com/posts/12232/the-4-fields-of-industrial-design-no-not-furniture-trans-consumer-electronics-toys-by-bruce-m-tharp-and-stephanie-m-tharp-12232

Troxler, P. (2011). Libraries of the peer production era. *In Open Design Now: Why design cannot remain exclusive* (pp. 86–97). Amsterdam: BIS Publishers.

Vallgårda, A., Boer, L., Tsaknaki, V., & Svanaes, D. (2016, June). Material Programming: A New Interaction Design Practice. *In Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems* (pp. 149-152). ACM.

Van Lengen, J. (2008). *The barefoot architect: a handbook for green building*. Shelter Publications, Inc.

Weiser, M. (1991). The computer for the 21st century. *Scientific american*, 265(3), 94-104.

Wiberg, M. (2016). Interaction, new materials & computing–Beyond the disappearing computer, towards material interactions. *Materials & design*, 90, 1200-1206.

Williamson, C. (2016, March 10). Open Source Chairs You Can Make at Home. Retrieved November 21, 2016, from http://design-milk.com/open-source-chairs-can-make-home/

World Design Organization (2015). Definition of Industrial Design. Retrieved December 24, 2016, from http://wdo.org/about/definition/

World Design Organization (n.d.). Industrial Design Definition History. Retrieved December 24, 2016, from http://wdo.org/about/definition/industrial-design-definition-history/

Wormald, P. W., & Rodber, M. (2008). Aligning industrial design education to emerging trends in professional practice and industry. *Journal of Design Research*, 7(3), 294-303.

Yang, M. Y., You, M., & Chen, F. C. (2005). Competencies and qualifications for industrial design jobs: Implications for design practice, education, and student career guidance. *Design Studies*, 26(2), 155–189.

Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 493-502). ACM.

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