From a tool for making to a tool for thinking:
Investigation of the potential of 3D printing
in meaning-making

by

Spase Janevski

A thesis submitted to the Faculty of Graduate and Postdoctoral
Affairs in partial fulfillment of the requirements for the degree of

Master of Design

in

Industrial Design

Carleton University
Ottawa, Ontario

© 2019, Spase Janevski

ABSTRACT

The advances in 3D printing technology have an enormous potential to impact how designers learn and develop practical knowledge during the design process. The purpose of this research study was to investigate the potential of 3D printing as a tool for meaningful making. Through investigation of handmade objects and their qualities, this study set out to determine how designers can invent 3D printed objects that make sense to stand alongside handmade objects. Data for the study was obtained using both ethnographic and design research methods, including: an observation, experimental studies and a survey. Results showed that 3D printing has a potential not only to develop meaningful outcomes, but also to drive design processes that make sense to designers. Through engagement and understanding of 3D printing machine, designers can develop not only practical knowledge, but also an understanding of the meaning of their making.

Keywords: 3D Printing, Meaningful Making, Hybrid Craft, Innovation, Practical Knowledge

ACKNOWLEDGMENTS

To my thesis supervisors, Dr. Bjarki Hallgrimsson and Dr. Michael Windover. Thank you for your enthusiasm, guidance and support during the journey. This thesis would never have been possible without your dedication, expertise and understanding.

To my MDes classmates, who listened to me and supported me through this entire process. Thank you for believing in me when I did not believe in myself.

To the School of Industrial Design faculty and staff, especially Valerie who guided me from the first day.

To my family and friends for their unconditional love, support and understanding. Thank you for encouraging me to follow my dreams.

Finally,

To Jana Janevska, the person who came into the world during this journey. Thank you for bringing joy to my heart.

TABLE OF CONTENTS

ABSTRACT	ii
ACKNOWLEDGMENTS	iii
TABLE OF CONTENTS	iv
LIST OF FIGURES	vii
LIST OF TABLES	ix
LIST OF APPENDICES	x
PREFACE.....	xi
1. INTRODUCTION.....	1
1.1. Background.....	1
1.2. Rationale	2
1.3. Research questions.....	4
1.4. Approach.....	4
1.5. Contribution	6
2. LITERATURE REVIEW	7
2.1. Innovation	7
2.1.1. Innovation and tradition.....	7
2.1.2. Innovation and new meaning.....	9
2.1.3. Innovation and craft-based design	10
2.2. Digital fabrication	11
2.2.1. Categorization of digital fabrication	12
2.2.2. 3D printing amateurism	14
2.2.3. 3D printing in Industrial Design education.....	15
2.3. Craftsmanship	17

2.3.1. Traditional craft production	19
2.3.2. Contemporary craft production	22
2.4. New Consumer Culture.....	25
2.4.1. A quest for handmade	25
2.4.2. Mass customization.....	27
2.4.3. Etsy	29
2.4.4. Etsy and 3D printing	30
2.5. Meaning of the objects.....	31
2.5.1. Product semantics	31
2.5.2. Interpretation and memory.....	33
2.5.3. Agency	33
2.5.4. Object Agency	35
2.6. Literature Summary	37
3. METHODS	40
3.1. Philosophical approach	40
3.2. Research through Design	42
3.3. Research methods	42
3.3.1. Ethnographic observation	43
3.3.1.1. Objective	43
3.3.1.2. Data Collection and Data Analysis	44
3.3.2. Experimental studies.....	45
3.3.2.1. Experimental study 1	47
3.3.2.2. Experimental study 2	50
3.3.3. Survey	54

3.3.3.1. Objective	54
3.3.3.2. Survey design	54
3.3.3.3. Data Collection and Data Analysis	56
4. RESULTS	58
4.1. Ethnographic observation results	58
4.2. Experimental study 1 - results.....	61
4.3. Experimental study 2 - results.....	65
4.4. Survey results	67
5. DISCUSSION	72
5.1. Insights	72
5.1.1. Ethnographic observation insights	72
5.1.2. Experimental studies insights	73
5.1.3. Survey Insights.....	78
5.1.4. Insights summary	81
5.2. Limitations	82
5.3. Future research	84
6. CONCLUSION	86
6.1. Contribution to the field.....	88
BIBLIOGRAPHY	90
APPENDICES	99

LIST OF FIGURES

Figure 1: 3D printed chairs by John Briscella	xii
Figure 2: Map of the research approach	5
Figure 3: Bone Armchair by Joris Laarman	11
Figure 4: Researcher's first entry-level FFF 3D printer.	13
Figure 5: Example of crapjects (Taken during Maker Faire, September 30, 2018)	14
Figure 6: Visual presentation of the amount of risk in each stage of making.	20
Figure 7: Contemporary craft production by Gareth Neal.....	23
Figure 8: Etsy's annual revenue.....	29
Figure 9: Example of 3D printed objects available on Etsy	30
Figure 10: The process of sense-making (Retrieved from Krippendorff, 1989)	32
Figure 11: Vases available for download on https://thingiverse.com	47
Figure 12: Visualization of the experimental process of experimental case study 1	49
Figure 13: Visualization of the marbling process in experimental study 1	49
Figure 14: Julia before and after marbling technique	50
Figure 15: Breaking an object with a hammer.....	51
Figure 16: Process of photogrammetry with Colmap	52
Figure 17: Real object (left side) vs scanned object via ReCap Photo (right side)	52
Figure 18: Results of unsuccessful fitting of a broken object with 3D printed object.....	53
Figure 19: Affinity diagrams of photos taken during both events	58
Figure 20: Visual representation of Etsy's vendor stand.....	59
Figure 21: Handmade mugs that illustrate Pye's slip of the hand	61
Figure 22: Results from the first experimental study.....	62

Figure 23: Five vases before and after marbling technique.....	62
Figure 24: Visual presentation of the process of taking photos.....	63
Figure 25: Visual diagram for the results from the software for image comparison.....	64
Figure 26: Artifacts from experimental study 2.....	65
Figure 27: A collection of three cups from experimental study 2	65
Figure 28: Visual representation of Q14 results, divided by groups	70
Figure 29: Visual representation of Q16 results	71
Figure 30: The experimental processes as sense-making processes.....	74
Figure 31: Analysis of the experimental processes according to the visual diagram for workmanship of risk by Loh, Burry and Wagenfeld (2016).....	77

LIST OF TABLES

Table 1: Categorization of survey questions by topic.....	56
Table 2: Categorization of participants based on their background	67
Table 3: Results from questions Q8, Q9, Q10 and Q11	68
Table 4: Results from questions Q13 and Q14	70

LIST OF APPENDICES

Appendix A - Ethics Approval Certificate.....	100
Appendix B – Consent form.....	102
Appendix C – Letter of invitation (email).....	104
Appendix D – Online invitation (social media)	106
Appendix E – Survey questions.....	107
Appendix F – Survey findings.....	114

PREFACE

I was a very creative child. I can recall many instances where I was making things with my own hands. Since throughout my childhood I found a passion for furniture design, I decided that I would study Industrial design at the Faculty of Mechanical Engineering in Skopje. During my studies, I realized that most of my work was virtual. It was not what I expected. I felt that I needed to find my own way to express my creativity in the material world. While I was spending countless hours in CAD (computer-aided design) modelling, rendering and designing perfect posters for my coursework, at home, I was trying to understand who I am as an artist, designer and maker. I vividly remember when I created my first tie, made of an old aluminium sheet. The end of the tie was so sharp, that I was afraid that it would stab me in my stomach if I sat down with the tie around my neck. In my eyes it was more than a tie, it was the thrill of experimentation, combining things, or as Krippendorff (1989) would say “making sense of things”. I was not designing for a user, I was designing for understanding, knowledge and skill.

When I decided to apply for the Master of Design program at Carleton University, I was already aware of the program. I was mentally prepared that this will not be a program where we design and make, but a program where we conduct research of theoretical design issues. Given my prior interest in 3D printing technology and furniture design, I decided that I would conduct a research study on 3D printed chairs. At that time, I was just impressed by the grandiosity of the forms. That summer, I collected detailed information about 60 chairs made by 3D printing technology. During the data analysis, one unanticipated finding was revealed. The word ‘craftsmanship’ was constantly reappearing in designers’ explanation of their work. While I thought that these chairs were made exclusively by machines, the

data showed me that these chairs are a result of an intensive and collaborative experimental process between designers, IT professionals and experienced craftsmen.

Figure 1: 3D printed chairs by John Briscella (<https://johnbriscellastudio.com/>)

After several consultations with shop technicians from different departments, I realized that it is impossible to print an object of that proportion at Carleton University. Although I gave up on the idea of 3D printing chairs, I did not give up on understanding the correlation between 3D printing and craftsmanship. At that time, I thought that it is a very awkward combination. I wanted to know more. My supervisors advised me to start reading literature related to craft in order to understand the essence of craftsmanship. Although I understood the authors' theories, given that I am a designer/maker, I felt that I needed to experience the theory to truly understand. I bought a 3D printer and I started experimenting. Given that I've never had any previous experience with this technology, I spent months in printing, re-printing, failing and repairing. I was trying to understand the power of the machine. After understanding how this tool makes sense in my practice, my mind was blown away with ideas. I started experimenting with techniques that I've never tried before. The tool was pushing me to go further and further. The tool was testing my capability as a maker and how I understand making.

In the end, I created something that was a representation of how I understand hybrid craft, a combination of 3D printing and traditional craftsmanship. When I showed my

experiments to my supervisors, I never thought that these experiments would become part of my thesis. While in my eyes the experimental outcomes were just understanding of the potential of 3D printing in craft production, in my supervisors' eyes the objects were a representation of meaningful making. Their experience allowed them to immediately recognize the meaning of my experiments. Throughout our conversations, I felt that I discovered a new world, a world in which the only way to understand objects and their meaning is by experiencing and living through them. By taking a step back and analyzing my experience, I started understanding what they saw in the first place. I realized that 3D printing was not just a tool for making, but a tool for thinking, through which I was making sense of the design process, the outcomes and myself, as a designer.

1. INTRODUCTION

1.1. Background

In the past decade, we have witnessed that 3D printing technology - introduced in the late 1980s as a prototyping technology - is now rapidly transforming into a mainstream manufacturing technology (Bosqué, 2015). Over the years, the promises of 3D printing have been successfully realized and presented in an enormous number of applications, from customized car and aircraft parts to complex medical applications such as implants and dental crowns (Bosqué, 2015). While most of the companies and research institutions were pushing the boundaries of this technology and its potential, several companies were working on the development of affordable and accessible 3D printing machines for home use. In less than 30 years, the technology known as high-end industrial prototyping technology has become an entry-level desktop technology (Bosqué, 2015) and allowed a wide range of people to call themselves makers.

Since 3D printing has a great potential for personalization, many of these makers used the opportunity of personal digital fabrication and entered the market of customized and handmade goods. The demand for handmade objects is a new revolution in which consumers are purposefully buying handcrafted objects to reinforce their self-identity and connection with the real world (Beverland & Farrelly, 2010). Today, in a market where there is a lack of product differentiation, consumers are hunting for unique and individual products, as well as things designed to last (Murray 2017). Looking from the outside it seems that we are witnessing a reincarnation of the Arts and Crafts movement. However, a detailed look into the real practice reveals that we are not still there. In most cases, the objects developed by 3D printing machines are the result of pure amateurism, while the

process of making is fetishized. Instead of understanding the 3D printing machine as a tool for action, as a catalyst that can lead to innovation, designers and makers are underestimating it as a machine for automatic fabrication. Since design students train to become design experts that will drive design innovations, they need to understand what is meaningful making and what will make them different from all other amateur makers.

1.2. Rationale

Most research on 3D printing has focused exclusively on the opportunities afforded by the technology in the medical, automotive and aerospace industries (Bosqué, 2015). While in these sectors the interest in 3D printing is increasing, as a result of proven numerous innovations, it seems that there is not much interest in investigating 3D printing at the consumer's entry level. While there are many studies about the importance of the 'maker movement' and the opportunities of 3D printing technology in design education, it is surprising that there is very limited literature about what makers and design students print. There are only a few authors (Bosqué, 2015; Blikstein, 2013) in academia who have reported on the quality and amateurism of these objects. Given that the same 3D-printed objects are slowly entering the market of handmade goods, in which there is a dominant traditional production, no study has been found that investigates how 3D printing fits into this market. If you visit a Maker Faire today, you will see 3D printed objects next to ceramic pottery. If you type '3D printing' in the Etsy (an online marketplace for handmade and vintage goods) search bar, there are more than 62 000 results of 3D printed objects, declared as handmade. The question is: Are we going to accept that 3D printed objects are handmade? It is important to note that the intent of this study is not to prove that 3D printed

objects are handmade but investigate the capacity of 3D printing technology for making objects that make sense to stand next to handmade objects.

Given that Bosqué (2015) reported that students today value attractive, low-quality 3D-printed outcomes, instead of the process of experimentation and production, the aim of conducting this study is to provide design practitioners (students and makers) with an opportunity to learn about meaningful making. This is a process of making in which not only the outcomes, but also the process of making evoke new meaning for the practitioner. Through understanding the handmade objects and their process of making, this study will present how design practitioners can invent 3D printed objects that make sense to stand alongside handmade objects. Given that handmade objects are known as one-of-a-kind objects, the researcher will present how design practitioners through the implementation of traditional techniques can provide uniqueness, even if the object is 3D printed. The experimental studies will demonstrate how design practitioners can develop unexpected innovations by understanding the essence of traditional making, the importance of tools and their agency. Since Holmquist, Magnusson, & Livholts (2018) reported that there is a need for research investigating innovation through tradition at the designer's level, this is a great opportunity for exploration of the interplay between tradition and digital fabrication in the creation of innovation. In addition, given that innovation can be driven by the creation of new meaning (Norman & Verganti, 2014), this study will explore how the outcomes of the experimental studies can evoke interpretations other than their own literal meaning.

1.3. Research questions

Through a mix of qualitative and quantitative methods, this study seeks empirical evidence to answer the following question:

How can the implementation of craft-based design into digital fabrication help designers explore meaningful making?

In support of this question, the research seeks to answer the following:

- 1. How can designers investigate the creation of meaningful objects through engagement with a 3D Printing machine?*
- 2. Is 3D printing capable of driving a design process that is meaningful to the designer?*
- 3. How can the reinvention of traditional techniques help designers make sense of 3D printing as a tool for craft production?*

1.4. Approach

The research begins with a literature review divided into five sections. The literature review explores different aspects of the study, seeking to find gaps and connections between the subject matter. Since the scholarly literature provides information about objects made by traditional production and 3D printing amateurism, the researcher felt that he needed to observe these objects in their own natural surroundings. The first primary research method employed in this study is an ethnographic observation. The analysis of the literature in combination with the results of the ethnographic observation defined the framework of research problems presented above. The research methods employed to address the research questions are practice based experiments and an online survey. By analyzing the

handmade object and its process of making, the researcher tried to implement his understanding into a combination of digital fabrication and traditional production and through his own hands explore 3D printing as a tool for meaningful making. While both experimental studies resulted in insights regarding the importance of the tool and the process of making, further investigation was needed regarding the meaning of the experimental outcomes. An online survey was designed and employed as a research method to investigate peoples' interpretation of the experimental outcomes and understand how the objects make sense to the participants. The insights from the survey in combination with the insights from the experimental studies are summarized in a discussion section that provides answers to the research problems.

Figure 2: Map of the research approach

1.5. Contribution

The division between the digital and material world does not only impact what we consider as design, but also how we learn design. Since many design students are born in the digital age, it seems that digital tools increasingly dominate the nature of the work done by designers. According to Renda and Kuys (2014), the best solution for avoiding digital fabrication to become the only method of fabrication is by an exploration of the combination of traditional craft-based techniques and advanced technologies. Since many authors are focused on the digital side of this hybrid process, this study makes a contribution to the design field by providing designers with an opportunity to explore the material side of the hybrid craft process. This research presents how designers, through engagement with the material world, can understand the importance of the tool and its capacity to drive design decisions. The explorative nature of the study provides designers with an understanding of the 3D printing machine beyond the ‘Print’ or ‘Start’ button; as a tool for meaningful making if treated as a tool for action. By understanding the potential of the tool, designers can propose innovations that will redefine customers’ understanding and meaning of the objects.

2. LITERATURE REVIEW

2.1. Innovation

From the first definition in the late 1920s to the present day, many different definitions related to innovation have appeared (Crossan & Apaydin, 2010). Since each definition emphasizes a different aspect of the term, for the purpose of this study, the focus will be on product innovation, defined by De Massis et al. (2016) as a representation of “knowledge search and recombination process” (p.5).

In recent studies, one of the most common criticisms regarding product innovation is the emphasis on value and novelty (Crossan & Apaydin, 2010) and its unbreakable relationship with technology (Holmquist, Magnusson, & Livholts, 2018). It is a fact that technology is a foundation of many new innovations, but the prevailing focus on it overshadows its other potentials (Holmquist, Magnusson, & Livholts, 2018). For example, the novelty in design innovation for decades has been demonstrated in different materials, forms and productions. De Massis et al., (2016) conducted a research study on Italian family-owned businesses and found out that the role of tradition is not actually an obstacle, but a new key driver for innovation. In addition, recent practices have revealed that design-driven innovation is directly related to the meaning of the object (Norman & Verganti, 2014).

2.1.1. Innovation and tradition

The concept of tradition in this study is defined as a “stock of knowledge, competencies, materials, manufacturing processes, signs, values and beliefs pertaining to the past” (De Massis et al., 2016, p.8). Given that the concept of tradition in any form is always associated with the past, it is not surprising that there is a general perception that innovation

and tradition are each other's opposites (Holmquist, Magnusson, & Livholts, 2018). Innovative design companies are very often reluctant to look back in the past because they believe that the only way to meet the customer's needs and expectations is by opening the doors to the newest technologies (De Massis et al., 2016). Such attention on the advancement in technology expressly or implicitly may lead designers, executives and industry to fail to recognize important innovation opportunities (Holmquist, Magnusson, & Livholts, 2018).

One of the most prominent recent research studies in this area is by De Massis and his colleagues (2016) in which they do not only explore the potential value of introducing tradition into innovation, but they also develop a product innovation strategy entitled "Innovation Through Tradition" (ITT). According to their strategy, one of the key elements for successful implementation of tradition is the concept of reinterpretation in which traditional knowledge is mixed with current technologies (De Massis et al., 2016). Given that many innovations already exist as a result of a process of recombination of well-understood components and new structures, the concept of reinterpretation is not new to the field of innovation (De Massis et al., 2016). This is especially evident in design-driven innovation, where a mixture of old and new materials, forms and manufacturing processes are at the heart of the design practise (Holmquist, Magnusson, & Livholts, 2018).

In terms of novelty, craftsman's tacit knowledge and expertise of materials, production techniques and symbols, can offer design companies unexpected opportunities in the development of innovative products (De Massis et al., 2016). Regarding value creation, the implementation of tradition can also help companies to develop a stronger relationship with

their consumers because their identities are based in part on the past and nostalgia (De Massis et al., 2016).

The current studies about innovation and tradition provide information about the importance of tradition, but there is very limited knowledge regarding the process of implementation. In addition, the ITT study is based on the organizational level and according to the authors, future research should/needs to explore practice-based innovation at designer's level (Holmquist, Magnusson, & Livholts, 2018).

2.1.2. Innovation and new meaning

Verganti (2008) proposed a new theory about design-driven innovation in which innovation is driven by the creation of a new meaning. According to him, worldwide leaders such as Alessi and Apple are not successful because they have user-centred innovation, but because they have “developed superior capability to propose innovations that radically redefine what a product means for a customer” (Verganti, 2008, p.4). For example, Alessi developed radical innovation of products' meaning by translating the kitchenware from a functional object into a symbolic object that reflects owners' personalities. According to Verganti and Norman (2014), Human-Centred Design (HCD) is suitable only to incremental innovation which leads to improvements on already existing products and innovations. In HCD practice, insights are created “by asking users about their needs or, more effectively, by observing them as they use existing products and by tracking their behaviour in consumption processes” (Verganti, 2008, p.4). It would be inappropriate to say that users and their behaviour are not insightful in leading designers to innovation, but what is more important for designers today is to focus on understanding

the patterns of meanings (Norman & Verganti, 2014). This understanding can be developed by analyzing the socio-cultural changes in the past and observing how changes are developing the society in which we are living (Verganti, 2008).

Verganti's work about design-driven innovation through the creation of new meaning does not emphasize the importance of the tradition in the process. Given that the meaning is driven by tradition, it is necessary to analyze the role played by traditional elements such as hand-powered machinery, craft techniques and raw materials in the development of new meaning (Holmquist, Magnusson, & Livholts, 2018). In addition, Verganti and Norman investigated the creation of new meaning by analyzing innovations developed by large corporations that are changing the world. It is important to note that in this study, the product innovation driven by the creation of new meaning is investigated on a personal and designer's level.

2.1.3. Innovation and craft-based design

According to Rossi (2013), craft-based design is characterized as a “multidisciplinary production-led approach” (p.72) to industrial design in which the designers are appropriating the handmade by using craft-based strategies. This approach is very applicable to the ITT strategy because nowadays many designers have become aware of the importance of craft and traditional techniques as a source of inspiration (Holmquist, Magnusson, & Livholts, 2018). Through experimentation with old manufacturing techniques and materials with rich histories, designers have been known to make unexpected innovations (De Massis et al., 2016).

Figure 3: Bone Armchair by Joris Laarman. Downloaded by <https://www.jorislaarman.com/work/arm-chair/>

An example that can demonstrate this is the Bone Armchair designed by Joris Laarman. Through investigating the traditional mould making and experimenting with casting resins, he found a way to use 3D printing for production of complex shapes. As De Massis et al. (2016) pointed out, using tradition as an investigative tool during the design process can improve the validity, uniqueness, and the authenticity of the innovation. Given that craft is part of the tradition, it is evident that craft-based design remains a “distinct niche within meaning-creating innovation in need of further exploration” (Holmquist, Magnusson, & Livholts, 2018, p.2).

2.2. Digital fabrication

The division between the digital and material world has been very clear, until the moment when digital fabrication tools started transforming binary digits into atoms (Lau, Mitani, & Igarashi, 2012). Since Gershenfeld (2012) declared a new revolution with his words “A new digital revolution is coming, this time in fabrication” (p.43), we have been witnessing the advent of digital fabrication, a movement that changes the means of design and making.

These two terms have historically been considered as two different stages in the design process. In general, the term digital fabrication is relevant to every process that is using computer-controlled tools in which the tool represents the digital side of the process, while the material symbolizes the analog side of the process (Gershenfeld, 2012). This study will adopt the definition of digital fabrication provided by Zoran and Buechley (2013) as a “process whereby an object design is created on a computer, and the object is then automatically produced by a machine” (p.6).

2.2.1. Categorization of digital fabrication

The categorization of these computer-controlled machines is in two basic categories: subtractive and additive. The former date back to 1952 when the first numerical controlled machine tool was created at MIT University and was commonly used in different types of factories until the late 80s (Gershenfeld, 2012). In this group are all CNC (computationally numerically controlled) machines that are shaping and reshaping the three-dimensional object by cutting extra material from a block of material, until the final shape is created (Mota, 2011). The additive category includes machines that, during the process of production, deposit and bind layers of material rather than removing matter (Mota, 2011). Additive manufacturing technologies, known as 3D printing, have evolved into seven different manufacturing processes since the mid-1980s. The most popular is Fused Filament Fabrication (FFF), previously known as Fused Deposition Modelling (FDM) (Redwood, Schoffer & Garet, 2017). This popularity is due to the process inherent simplicity and open source approach.

While at the beginning of the 21st century the price of the 3D printing machines was at \$45000 (Mota, 2011), today personal 3D FFF printers can cost less than \$500. For example, the researcher of this study bought his first 3D printing machine for only \$280. The inexpensive cost of these machines is making them accessible not only to professionals but also to average people who want to explore their creative skills. Right now, this type of machine is present in universities, research centres, small businesses and local community production shops. While many people believe that 3D printing will replace established subtractive manufacturing technologies, Gershenfeld (2012) believes that “the revolution is not additive versus subtractive manufacturing; it is the ability to turn data into things and things into data” (p.44).

Figure 4: Researcher's first entry-level FFF 3D printer.

2.2.2. 3D printing amateurism

Bearing in mind that scientists and technologists are nowadays 3D printing food, medical implants, prosthetics and aircraft parts, 3D printing is defined by many authors as a world-changing innovation (Bosqué, 2015). While in these sectors the interest in 3D printing is increasing due to the improved quality, for the wider audience there is a general confusion about the quality of 3D printing technology (Bosqué, 2015). This confusion comes from the public's limited access to Fablabs and Maker's events, where there is a dominant representation of toys, phone covers and fashion accessories made with entry-level 3D printers. As Bosqué (2015) pointed out, we are still in a stage where the public is fascinated and impressed by the seemingly magical functionality of 3D printing, but not by the 3D-printed object itself. Makers are still in the learning process in which they are printing downloaded ready-to-make samples from the Internet, demonstrating a lack of inspiration (Bosqué, 2015). Unskilled designers are printing objects in very poor surface resolution and without any individualistic or artistic touch. In the literature, these useless and disposable samples are called by many different names, such as 'phatic objects' (Bosqué, 2015) and 'crapjects'. The term 'crapjects' is defined by Scott Smith (2012) as a contraction of 'crappy' and 'objects'.

Figure 5: Example of crapjects (Maker Faire, September 30, 2018)

2.2.3. 3D printing in Industrial Design education

Thanks to the dramatic increase in affordable low-cost digital technologies, since 2011 there is a widespread building of digital fabrication facilities in schools, libraries and community centres (Blikstein, 2013). The advances in digital fabrication and the implementation of 3D printing in industrial design education has enormous potential to impact the design process and create a disorder in the discipline (Loy, Canning & Little, 2015).

From a positive educational perspective, access to 3D printing machines offers students a chance to re-engage with making. Accessibility to machines such as Makerbot, RepRap and Cube provide design students with the opportunity to transform a digital model into an accurate physical prototype (Hallgrimsson, Dewar & Laliberte, 2014). From a prototyping perspective, one-off objects with complex shapes are easier and more cost-effective for students to make with these new digital technologies compared to traditional making techniques (Lindley, 2016). As Blikstein (2013) emphasized, building functional and aesthetically appealing prototypes as contrasted with cardboard and foam low-quality prototypes can have a strong impact on students' dignity. Lastly, the school offers a safe, clean and controlled environment in which students can manufacture without waiting for a tool to be created and extend their literacy about manufacturing (Hallgrimsson, Dewar & Laliberte, 2014).

Many authors fear that the maker spaces at schools are slowly becoming fabrication facilities, instead of spaces for developing invention (Blikstein, 2013). Design education is a platform where, through open-ended experimentation and prototyping, students should liberate their creativity and “discover opportunities that can be exploited and transformed

for unpredictable design solutions” (Vermillion, Anderson & Rowe, 2014, p. 3). Printing simple beautiful objects with little effort during teaching sessions is just proof of concept (Blikstein, 2013). As Blikstein pointed out, “educators should shy away from quick demonstration projects and push students towards more complex endeavors” (p.18). Students should take the risk and explore happy accidents through engagement and combining 3D printing with other tools and materials (Vermillion, Anderson & Rowe, 2014). Instead of valuing the process of experimentation and production, students are valuing attractive 3D-printed low-quality outcomes, which are without any value or importance (Bosqué, 2015). Hallgrimsson, Dewar & Laliberte (2014) believe that without a scientific understanding of the 3D printing process, students will not be able to manipulate the process in order to achieve valuable outcomes. The designer should have manufacturing knowledge and understanding of the machines in order to be distinguished between all makers as a design expert (Hallgrimsson, Dewar & Laliberte, 2014). Instead of being passive viewers, students should strive for involvement with machines.

In addition, this new practice creates a disconnect between the designer and the physical model. With a fully automated process, students will never touch and understand the material tactile attributes and responses, which is one of the basics in industrial design practise (Renda & Kuys, 2014). The industrial design process consists of many iterations and craft-based activities (Renda & Kuys, 2014). The final outcome can be produced by an automated machine, but “the design itself must appreciate the craft-based approach to ensure the final product is what the designer intends, and not what a machine is capable of” (Renda & Kuys, 2014, p.6). According to Renda and Kuys, the best solution for avoiding digital fabrication becoming the only method of fabrication in school is by

teaching students a combination of traditional craft-based techniques and advanced technologies.

2.3. Craftsmanship

Nowadays, there is a widespread view that craftsmanship is an approach to meaningful making, instead of an approach to a specific type of manual practice. Recently, this view gained a wider audience in academia and is especially evident in the book *The Craftsman* by sociologist Richard Sennett, which investigates craftsmanship from a phenomenological point of view. According to Sennett (2008), craftsmanship is the “enduring, basic human impulse, the desire to do a job well for its own sake” (p.9). Sennett (2008) attributed the same impulse of skilled manual labour to all makers of tangible and intangible objects, such as artists, doctors and programmers. In all these people there is an internal interplay between hand and head in which thinking, and practising evolve into a habit (Sennett, 2008). Back in 1975, John Harvey held a very similar view when in *Medieval Craftsmen* he defined craftsmanship as:

“Craftsmanship is the basis of society. From shaping the most primitive tool to the assembly of the latest computer, human activity has depended upon skill: the coordination of the brain and hands. This process takes many forms, but these do not differ in kind. Each output of skill represents exactly the same faculty, an ability to learn an existing method of doing something. Although it is nowadays fashionable to talk of technology, this is nothing more than the discussion of crafts.” (as cited in Roskill, 1977, p. 138-139)

Later, Mark Roskill (1977) criticized John Harvey for not distinguishing between craftsmanship and technology and not emphasizing the essential importance between making a single piece by hand and making a collection of pieces by a machine. Mark Roskill's criticism is inspired by David Pye's work, who was the first author to replace the word craftsmanship with workmanship. Provoked by the factory-made objects present everywhere in the middle of the twentieth century, David Pye decided to fight for the invaluable variability associated with the human hand by contrasting the craftsmanship as an opposite trend of manufacturing (Marble, 2010). According to Pye (1968), we need to distinguish two types of workmanship: workmanship of risk and workmanship of certainty. While the workmanship of certainty is identified as an industrial and repeatable process in which the risk of the creation of the artifact is minimal, as a result of the implementation of high-end manufacturing technologies (Pye, 1968), the workmanship of risk is characterized as:

“workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgment, dexterity and care which the maker exercises as he works. The essential idea is that the quality of the result is continually at risk during the process of making” (p.4).

According to Loh, Burry and Wagenfeld (2016), who analyzed Pye's work, “through risk in the material, tools and techniques, the workmanship is pushed to its limit and new knowledge can be generated” (p.189). The knowledge of the material, technique and tools, developed within the process of making is where the craftsmanship underlines. The knowledge that is gained through many years of action and experience, celebrated as

something special, in the literature is known as tacit knowledge (Loh, Burry, & Wagenfeld, 2016). Michael Polanyi introduced this term in 1966 with his statement “we can know more than we can tell” (p.4). According to him, it is the knowledge that gives craftsmen expert judgment to act instinctively, without even thinking about it. As Richard Sennett (2008) points out, “in the higher stages of skill, there is a constant interplay between tacit knowledge and self-conscious awareness, the tacit knowledge serving as an anchor, the explicit awareness serving as critique and corrective” (p.50).

2.3.1. Traditional craft production

Traditional craft production is often associated with a production process in which objects are made exclusively by hand (Campbell, 2005). According to Pye (1986), this type of production has never been seen in its pure form, “considering the ancient use of templates, jigs, machines and other shape-determining systems” (p.6). In addition, the wheel of the potter, the furnace of the blacksmith and the loom of the weavers are just more proof that we cannot associate traditional handcraft production as divorced from machines (Tsoumas, 2013). Campbell (2005) believes that control over the machine is what differentiates traditional craft production from modern production. In hand production, the machine is controlled and powered by craftsman’s hand, while in the production system the machines are in control over the worker.

David Pye differentiates modern from traditional craft production on the basis of the extent of predetermined results (Kettley, 2007). Pye believes that the variation associated with the risk during the process of making is what we instinctively read into the object as authentic (Marble, 2010). As Pye explains in his work (1968), while in industrial manufacturing the

problem with error and risk can be solved with another prototype, in traditional production the slip of the hand, the unwanted mark of the tool or the lapse of the judgment cannot be undone. The beauty and quality of the artifact can be ruined at any moment because the process of making is constantly at risk, and thus requires a close relationship between the mind and the hand to control each movement of the tool (Pye, 1968).

In order to understand the difference between craft production and mass production, Loh, Burry and Wagenfeld (2016) made a comparative study based on Pye's writings in which they evaluated the level of risk in different stages of making. By comparing the manufacturing process of the Thonet Chair No 14 and the craft process of custom-made furniture by Australian woodworker Damien Wright, the authors created a visual diagram that allows researchers to visually differentiate the process, given that is very difficult to determine the precise amount of risk in each stage.

*Figure 6: Visual presentation of the amount of risk in each stage of making.
Diagram adapted from Loh, Burry, & Wagenfeld (2016).*

According to the authors, in the mass production of the Thonet Chair, the highest level of risk is in the preparatory stage, because although Michael Thonet knew the technique, he did not know how to prepare the tooling. After many years of design and development of his tooling, he finally developed an iron moulding frame that led to a controllable level of risk and successful mass-production of the chair (Loh, Burry, & Wagenfeld, 2016). In contrast, Damien began his making process with the selection of Australian hardwood timber, which influenced his decisions about technique and tooling (Loh, Burry, & Wagenfeld, 2016). By preparing his scale models and prototypes for the client, he redefined his tooling and the level of risk was decreased (Loh, Burry, & Wagenfeld, 2016). The risk that remained high all the time during his process was the selection of the material (Loh, Burry, & Wagenfeld, 2016). As the authors point out, Australian hardwood is extremely unpredictable and difficult to work with in comparison with artificially modified hardwoods.

The authors' diagram illustrates that: 1) the relationship between material and tool is directly related to the control of the craft person; 2) the relationship between material and technique is related to the dexterity and judgment of the craft person; and, 3) the relationship between tools and techniques is directly related to appropriateness (Loh, Burry, & Wagenfeld, 2016). Furthermore, they conclude that the relationship between all three elements - material, techniques and tools - is hard to define, because the process of making is not a closed loop. If the practitioners run into a risk, they find their own way to deal with it. They invent, develop and modify their own tools that will allow them to control the risk.

The process of making is individual and can be understood only by the individual makers. The unbreakable and complex relationship between the maker and his materials, techniques and tools is what underlines the authenticity of craft production (Loh, Burry, & Wagenfeld, 2016). The authenticity of traditional production is concealed inside the deep-seated construction of the practice where the process of making is a product of the maker's knowledge and his wide-ranging use of techniques and tools (Loh, Burry, & Wagenfeld, 2016). Carroll and Wheaton (2009) also find craft authenticity in the appropriate use of techniques and skills during craft production. They believe that these authentic skills should be beyond the common reach and represent a degree of professional autonomy and high-quality mastery (Carroll & Wheaton, 2009). For the purpose of this study, it can be concluded that the authenticity of craft production does not lie in the object, but in the process of making.

2.3.2. Contemporary craft production

The developments in advanced computational software and increased accessibility of technologies that can achieve complicated cutting operations in a precise and repetitive manner has led to a new craft practice, defined in literature with terms such as 'digital craft' (McCullough, 1998), 'hybrid craft' (Zoran, 2015), 'digital making' (Kolarevic, 2008) and 'digital handmade' (Johnston, 2015). All these terms imply an intimate relationship between handcrafting skills and technologies like 2D and 3D digital modelling, 3D scanning and 3D printing (additive manufacturing), CNC machining and laser cutting.

Figure 7: Contemporary craft production by Gareth Neal (<http://garethneal.co.uk/>)

According to Kolarevic (2008), the best explanation of the technological and cultural origins of the term digital craft can be found in the book *Abstracting Craft* by Malcolm McCullough. McCullough (1998) argues that digital craft is a practice based on a continually workable digital medium, such as a computer, that encourages hand-eye coordination, albeit in an indirect way. The artifact shaped by software operations does not need to have a material substance or to be touched by the craftsmen anymore, it has its own individual appearance, history, properties and authorship (McCullough, 1998). Although it is abstract and without physical substance, in a digital realm it shows the manipulation by the software tool and the skills of the craftsman (McCullough, 1998). McCullough's (1998) main argument is that digital craft is a collaboration between human agency and the digital world in which the computer is a digital medium through which the action of the hands and eyes are mediated, same as working with any other raw material.

While the current technologies are decreasing the amount of risk and are increasing the amount of certainty, there is still a risk associated with interpreting and imagining alternative digital outcomes and variations (Marble, 2010). In Kolarevic's (2008) words,

“this notion of risk, stemming from the inherent lack of predetermined design outcomes, is how we could interpret Pye's seminal work in a contemporary context” (p.121). According to Kolarevic (2008), in parametric modelling software such as CAD, interdependencies are structured and reconfigured in shape and form as a result of the abilities of the craftsman. Given that during the whole process the craftsman is interacting with external forces, actions and manipulations, the risk lies in the unpredictable and unexpected transformative process (Kolarevic, 2008). The emergence of the form or the design opportunity is not automatic, it is a result of the craftsman's experience and dexterity, “knowing intuitively which small quantitative change could potentially produce a qualitatively different outcome” (Kolarevic, 2008, p. 122). While many authors focus on providing evidence that Pye's risk is present in the digital side of the process, there are authors such as Foote (2017) who believe that there is still a degree of uncertainty in the other stages of the process. For example, in the fabrication stage, there is still a risk which is associated with the material behaviours, that is beyond the reach of predictive capacities (Foote, 2017).

Given the attention paid to the digital side of this practice, where practitioners are interacting with digital tools and abstract artifacts (Kolarevic, 2008), it is surprising that the role played by tradition in contemporary craft production has not been examined in more detail. Besides computers and modelling software, today new digital practitioners, known as ‘digital artisans’ (Johnston, 2015), use all kinds of traditional tools and materials in combination with machines that were previously seen only as belonging in the automotive industry and mass production. Johnston (2015) believes that these new digital artisans will transform the mass production into individual expression on a mass scale and will challenge individuals to see once again the vision and the skills of the craftsman.

According to her, these new digital and industrial technologies “are applied in unconventional ways to enhance and assist its crafting of extraordinary artistic forms that would previously have been all but impossible” (p.7).

While traditional artisans are questioning the authenticity of the work that new digital artisans are creating, many contemporary practitioners look at the new automated tools, as just another tool of the craft practice, not dissimilar to a hammer or a throwing wheel (Loh, Burry, & Wagenfeld, 2016). The ability of the craftsman to hand-create a series of pieces that look the same, but are at the same time not identical, is easily achievable today through algorithmic coding (Loh, Burry, & Wagenfeld, 2016). As McCullough (1998) argues, today with CNC technology and algorithmic coding, many practitioners are creating artifacts that cannot stand as originals, but at the same time, they are not identical either. CNC technology and carefully integrated creative process can produce unique and individual artifacts to the extent where an object’s authenticity is no longer in question (Loh, Burry, & Wagenfeld, 2016). As Marble (2010) states, Pye’s slip of the hand today becomes an automated variation in form of mass customization.

2.4. New Consumer Culture

2.4.1. A quest for handmade

Although we are living in an era of development of innovative and automated advanced manufacturing that is producing smart products, we are witnessing a movement in which products are promoted as handmade (Fuchs, Schreier, & van Osselaer, 2015). Researchers have a different opinion about the reason for the occurrence of this phenomenon. Carroll (2015) looks at the demand for handmade products as the most powerful and influential

revolution, because it is changing the social and political views, but more importantly consumer behaviour. According to Beverland and Farrelly (2010), the reason for encouraging customers to buy a handcrafted product lies in the dehumanizing effect, the loss of the traditional meaning and self-identity, which are directly connected to the globalization and hyperreality. According to Lewis and Bridger's work, "living in economies where their basic needs are quickly and easily satisfied, New Consumers are far more concerned with satisfying their wants, which frequently focus on original, innovative and distinctive products and services. As a result, they tend to reject mass-produced and mass-marketed commodities in favour of products and services that can claim to be in some way authentic" (as cited in Kettley, 2007, p.22). A very similar view can be seen in Luckman's work (2015) who claims that digital media did not only change the cultural meaning of the object, but also the consumer's desire for handmade objects. According to Luckman (2015), this desire is an indication of the consumer's requirement for individuality in a market where there is a lack of product differentiation. In comparison with industrialized products, handmade products offer consumers an authentic experience or connection in an inauthentic world (Luckman, 2015). Fiona Hackney looks at the new quest for handmade as a part of a new commercial culture that can be seen "as a means of addressing the problems and anxieties surrounding the acceleration of modern life (unemployment, the strain of new work processes and their effects on physical and mental life)" (as cited in Luckman, 2015, p.69).

Considering the significant shifts in consumer demands, McIntyre (2010) performed an online survey of 7000 adults in the UK to find out what are the driving forces behind this movement. The result of their research shows that the three key trends that influence

consumer demand and drive the evolution of craft market are: personalization, authenticity and ethical consumption (McIntyre, 2010). According to their report, authenticity is the most important long-term identified consumer trend, because it's closely associated with the terms 'handmade', 'workmanship' and 'genuine' (McIntyre, 2010). In addition, 22% of the participants were motivated to consume a craft only because it reflects their own identity or image of themselves (McIntyre, 2010).

Many authors believe that consumers are purposefully linking the object and the meaning of the object to their life stories (Beverland & Farrelly, 2010). Consumers today are self-conscious manipulators who are purchasing crafts with the specific intention to build their identity or lifestyle by controlling the soul and the symbolic meaning of the product (Campbell, 2005). According to Beverland and Farrelly (2010) who investigated the motivation behind the consumption of handmade object, control, connection and virtue are the three benefits that consumers are extracting from the craft purchase in order to reinforce their desired identity. Given that consumer's engagement through handmade purchase provide essential insights about human identity, it can be concluded that "if this trend is set to continue into the near future, then the prospect exists of a postmodern society in which craft consumption is not merely the dominant form of consumption, but also the principal mode of individual self-expression" (Campbell, 2005, p. 40).

2.4.2. Mass customization

Before industrialization, only groups of people with the highest levels of wealth had access to one-of-a-kind, made-to-order, high-quality handcrafted products (Harzer, 2013). With the advent of powered machinery and factories, a new generation of mass consumers grew

up with “aesthetically uninspiring standardized products, many of which they did not actually need and few of which were capable of bringing any real or lasting satisfaction” (Campbell, 2005, p.26). In the last few decades, we have witnessed a new type of hybrid manufacturing, known as mass customization, which in principle is a combination of one-of-a-kind craft production and mass production (Blecker & Friedrich, 2006). The key driver for the appearance of this type of production is the customer itself. Given that the level of competence and standardization in mass production has become enormous, it was logical for the customers to raise their voice and ask for individualization (Blecker & Friedrich, 2006). According to Babiarz et al. (2007), mass customization can be identified as a “complex business strategy, which goal is to produce goods and provide services on a large scale, customized to the individual needs of every customer with the efficiency of mass production” (p.1).

The question is, is it really customized to the individual needs of every customer? Crawford (2009) describes this practice as an “experience of remote control” (p.68). According to him, this is a passive consumption among predetermined alternatives in which the consumer is disburdened from its own individualism and agency. In addition, according to Norman (2004), “things do not become personal because we have selected some alternatives from a catalogue of choices. To make something personal means expressing some sense of ownership, of pride. It means to have some individualistic touch” (p.220). Products such as original goods, vintage or handcrafted items are especially valued in this context, because they offer individualistic touch and a sense of difference (Harzer, 2013). One of the best places for this type of product is the online marketplace Etsy, which will be discussed in the next section.

2.4.3. Etsy

The commercial opportunities offered by the Internet have made it possible for companies to directly reach thousands of customers on a daily basis (Church & Richelle, 2018). The Internet has become a key driver for small businesses to provide a level of diversification and uniqueness that is impossible in the world of retail (Aryafar, Lynch, & Attenberg, 2014). The appearance of this cyberspace gave an opportunity to the audience to become aware of the concept of consolidation between design, craft, technology and digital fabrication (Aitchison, 2014). One of the greatest enterprises that represent this concept in relation to handcrafted goods is the online marketplace Etsy, which was founded in 2005 (Aitchison, 2014).

Etsy is a marketplace where more than 2.1 million microenterprises set up a shop, and market their own handcrafted goods to an unlimited group of customers in over 180 countries (Aryafar, Lynch, & Attenberg, 2014). In the last decade, Etsy together with other marketplaces of this kind, changed customer desires and brought about an explosion of interest in customized, handmade and made-to-order products (Church & Richelle, 2018). The growth in Etsy's annual revenue clearly shows that the customers' interest in their market philosophy is growing from year to year.

Figure 8: Etsy's annual revenue. Downloaded from <https://www.statista.com/statistics/409371/etsy-annual-revenue/>

2.4.4. Etsy and 3D printing

Considering that cutting-edge technologies have become more available and affordable to the public, many practitioners started imitating hobby-level handcrafts (Aitchison, 2014). The appearance of machine-made products on Etsy has resulted in tensions between the modern form of computer-mediated craftsmanship and old-fashioned handcrafted practices (Aitchison, 2014). Since these tensions became very noticeable and caused intense debates on Etsy's forum, the CEO Chad Dickerson decided in 2013 to change the policy on 'handmade'. 3D printed parts are now considered handmade in spirit (Aitchison, 2014). Since 2013, no study has examined how this new policy affected the Etsy market and what consumers consider as handmade as a result of this change. Today, if you type '3D printing' or '3D printed' in the Etsy search bar, there are more than 62 000 results worldwide. While in 2013 only eight Etsy stores in Canada offered 3D printed items and services, today there are more than 96 that provide 3D printed handmade items. Given that 19 new stores opened only in the first quarter of 2019 it can be freely stated that this trend will grow in the following years.

Figure 9: Example of 3D printed objects available on Etsy

2.5. Meaning of the objects

2.5.1. Product semantics

Objects communicate through visual signs. These signs are clear, understandable and meaningful only when they are in opposition to other signs within a system (Parsons, 2009). The field that investigates the concept of these signs, what they resemble and the relationships within the systems is called semiotics (Parsons, 2009). The field that investigates the message of these signs and their meaning is called semantics.

Inspired by semantics, Butter and Krippendorff in the 1980s presented a new theory in the field of industrial design, entitled product semantics. According to their first definition, “product semantics is the study of the symbolic qualities of man-made forms in the context of their use and the application of this knowledge to industrial design” (Krippendorff & Butter, 1984, p.4). Product semantics is not a design style or movement, but a “reaction to the missing sense modern industrial products make” (Krippendorff, 1989, p.10). According to Krippendorff, designers should avoid the modernist design rule “form follows function” because users did not interact with a product only physically, but cognitively and behaviourally (Parsons, 2009). Instead of focusing on function, designers should focus on form, because the form is “the designer’s way of objectifying and, hence, disowning their own meaning in the process of making sense for others” (Krippendorff, 1989, p.14).

In 1989, Krippendorff updated his definition of product semantics to include “a concern for the sense artifacts make to users” (p.10). In his view, people live and surround themselves with objects that make sense to them. In other words, people surround themselves with objects that can be identified when, where, and how they can be used. Importantly, an object is perceived and interpreted differently by each viewer. The viewer

formulates an idea about the object, based on previous context or experience that allows him to formulate an understanding of it (Krippendorff, 1989). For instance, if the viewer sees a chair in a store, he/she might consider how a chair could look in his/her living room or office or might think about previous experience with an uncomfortable chair. Based on an imaginary context, the viewer constructs the meaning of the object, the chair. According to Krippendorff (1989):

“Making sense is a circular cognitive process that may start with some initially incomprehensible sensation, which then proceeds to imagining hypothetical contexts for it and goes around a hermeneutic circle during which features are distinguished - in both contexts and what is to be made sense of - and meanings are constructed until this process has converged to a sufficiently coherent understanding” (p.13).

Figure 10: The process of sense-making (Retrieved from Krippendorff, 1989)

As mentioned before, when a group of people look at the same object, none of them has the same interpretation of the object. While some people take less time to make a clear understanding of the fuzzy image, the fact that the fuzzy image may cause different responses presents the significance of individual cognitive contributions (Krippendorff,

1989). The context in which the meaning is created is based on the observer's personality and memories of previous individual experiences.

2.5.2. Interpretation and memory

Interpretation of the world as a system of signs is an intelligent activity (Semetsky, 2006). In semantic view, the term intelligence “is determined by three functions: the transmission of textual information, the creation of new information, and memory as a capacity to preserve and reproduce information” (Semetsky, 2006, p.25). Regarding the interpretation of signs and construction of meaning, memory serves the most important function, because it is a social process based on individual and collective interpretations of the past (Cipolla, 2008). As Cipolla (2008) emphasized in his research, these interpretations are constantly changing during the course of peoples’ lives, because people are introduced to new people and environments and begin to forget as time goes by. In addition, people are not the only actors in the creation of memory. We create memories together with our material surroundings. Objects are present all around us, impacting our everyday lifestyle. While at the beginning we absorb and relate to their shape and colour, with time we realize that they capture moments and share memories with us (Norman, 2004). Objects are signs of the past. As Jones (2007) point out, objects assist us to remember by acting as “physical traces of past events which are amenable to the process of reading” (p.19).

2.5.3. Agency

As mentioned before, objects index past events. If we take the handmade object as an example, we can say handmade objects are physical traces of the maker’s past actions.

Once they are made, they physically embody memory as a reference to previous objects made by the same maker (Jones, 2007). In other words, they become signs that evoke meanings related to the myth of their creation. However, albeit important, production is not the only process through which memory is embodied into the object. Consumption and usage over time enrich the object's memories to the point of overshadowing the initial memory imbued in the production stage. When the objects are in the hands of the consumer they communicate meaning through memories from both the consumer and their original maker (Kouhia, 2012).

If we analyze handmade objects through Alfred Gell's concept of art objects, we can see that objects are "positioned in time as a series of events embodied in material form" (Jones, 2007, p.20). In addition, by materializing the object in physical form, the maker projects his or her intentions in advance in the form of a physical record (Jones, 2007). By looking at the object's physical form, the meaning of the material object is manifested through every single trace that reminds the maker of past actions. Each mark, or what Pye called 'slip on the hand', is a record of an interplay between the maker and the material in the studio. Each mark is a consequence of the maker's decision, creative action or intention. Each mark on its surface acts as a separate sign. The power of these signs to subsequently affect the maker's action or response illuminates the role of agency.

According to Ahern (2001) agency is "the socioculturally mediated capacity to act" (p.112), and this is not restricted to humans but includes non-humans such as machines, technologies, spirits and signs. If objects did not have the agentive capacity to take action upon the world and affect social change, they would never be created in the first place (Ahern, 2001). Gell's most famous study *Art and Agency* (1998) proposed a theory about

the agentic capacity of the art object to cause an action or emotional response, and many authors now accept this as a theory about all material objects (Hoskins, 2005). According to Gell (1998), “agency is attributable to those persons (and things) who/which are seen as initiating causal sequences of a particular type, that is, events caused by acts of mind or will or intention, rather than the mere concatenation of physical events” (p.16). Things exert agency because they act on viewer perception as living beings that affect the viewer’s behaviour, emotions and beliefs (Gell, 1998).

2.5.4. Object Agency

The terms ‘object’ and ‘agency’ are very familiar in the field of social science. According to Russel (2017):

“the phrase ‘object agency’ attempts to unite what is a constructed separation between the role of humans as agents and objects as instruments wielded in the pursuit of a human-defined ‘end’. At the core of this union of terms is the assertion that material culture is not simply a tabula rasa constructed to reflect human ideas or to complete human tasks. The objects of material culture are active agents in the negotiation of spatial, environmental, social and cultural contexts, structuring and affecting proceedings of events through the gestalt of their changing materialities”
(p.72).

The concept of ‘object agency’ investigates the relationship between humans and non-humans (objects) (Russel, 2017). Regarding this relation, Gell in his study (1989) provided a concept of dispersed agency in which he located the primary agency in the human act,

while the secondary agency is owned by objects, as an index of human agency. While this balanced relationship between human and non-humans is well accepted in the fields of archaeology and anthropology, according to Russel it “does not move beyond the fundamental issue of human existential exceptionalism” (Russel, 2017, p.75). Generally, in human society, the objects and their agentic capacity will always be perceived as unimportant, because they are the result of the first and the most important one, the human agency (Russel, 2017).

This egotism in humans as a primary agent is evident even in Gell’s observation about mechanics, in which he concluded that objects are fetishized and taken for granted (Russel, 2017). Martin Heidegger expressed the same view back in 1927 in his work *Being and Time*. According to him, humans rely on objects as taken for granted until the moment when they stop functioning (Russel, 2017). Based on his most famous example, we cannot know a hammer just by looking at it as an object without context. A hammer is a tool for action, that requires holding and using. In his words, “the less we just stare at the hammer-thing, and the more we seize hold of it and use it, the more primordial does our relationship to it become, and the more unveiledly is it encountered as that which it is—as equipment” (Heidegger, 1962, p. 98). In phenomenological tradition, the only way to understand objects and their meaning to us is by experiencing and living through them (Smith, 2013). As a conclusion, humans will stop making blind assumptions about the world “only when human consciousness has been made aware and deems it necessary to take action in relation to an object or phenomenon that the object or phenomenon is given status as a part of a lifeworld” (Russel, 2017, p.75).

2.6. Literature Summary

The literature review demonstrated that besides the unbreakable relationship between product innovation and technology, there are authors who believe that product innovation can be driven by other elements, such as tradition (De Massis et al., 2016) and creation of new meaning (Verganti, 2008). Given that the creation of new meaning is driven by tradition, Verganti has been criticized by Holmquist, Magnusson, & Livholts (2018) that he did not explain the importance of tradition in the creation of new meaning. In addition, his work and De Massis's work are based on an organizational level, which opens a question: How we can investigate product innovation driven by tradition and new meaning at a designer's level?

Regarding technology and product innovation, the literature review presented that the digital revolution created a disorder in the design discipline. Through the example of 3D printing technology, we witness that besides providing a quick, precise and accurate process for testing innovations, this technology is capable of negatively impacting design students' creativity and understanding of the process of making. According to Renda & Kuys (2014), the only way to avoid this negative impact is by implementing a hybrid approach in the process of making, and teaching students a combination of traditional craft-based techniques and advanced technologies. To understand what students can learn from traditional craft-based techniques, the next section of the literature provided information about craftsmanship and traditional craft production. Traditional craft production showed that the machine was always part of the process and that the only difference from mass production is the control over the machine and the risk during the process of making. The literature about hybrid craft production showed that even in a

digital world there is still a risk of making. The emergence of the form is not automatic, it is a result of the craftsman's experience and dexterity (Kolarevic, 2008). While some people have doubts about this type of production, the literature showed that both types of productions are based on practical knowledge that is gained through many years of experience. The practical knowledge is celebrated again, but in a different form. Given that this hybrid practice was suggested by Renda & Kuys as most applicable to students, the literature demonstrated that most of the authors are focused on the digital stage of the process. This gap in literature opens a great opportunity for this study to investigate the material stage of this practice and answer how students can create practical knowledge through engagement with digital fabrication tools and other craft-based techniques.

In addition, it was mentioned that digital craftsmen are trying to imitate handmade qualities such as uniqueness through algorithmic coding of the machines. This new trend of designing unique objects is a result of new consumer culture, driven by a customer and its need for individuality. This movement is so powerful that it even affected amateur makers, leading them to advertise 3D printed objects as handmade. Given that there is a gap in the literature regarding the presence of 3D printed objects on Etsy, the researcher performed market research to obtain information related to the literature. The relationship between 3D printing and handmade opens an opportunity for the researcher through a handmade object to investigate the material stage of the process in hybrid production. Through engagement and understanding of the material phase of the hybrid craft production, the researcher will explore in which other stages of the production there is still a risk of making.

Lastly, given that innovation is not related only to the implementation of the tradition, but also to the meaning of the object, the last section on the literature presented that the

meaning of the object is what makes sense to the designer as the original user, and to the intended users. In Krippendorff's view, making sense is a cognitive process through which an individual travels through his own past and experience to develop an understanding and meaning of the object. In other words, we interpret meaning based on memories of past actions that can occur only through engagement with the world. As Smith (2013) states the only way to understand objects and their meaning to us is by experiencing and living through them. Since the researcher will investigate how 3D printing can be considered a meaningful tool, this is a great opportunity for the researcher to explore the meaning of the outcomes of the process. By analyzing the interpretations of the objects, the researcher can test this theory and provide information about how the objects make sense to the participants.

3. METHODS

Since the literature has raised questions regarding the creation of new meaning and the capacity of 3D printing as a tool for meaningful making, the researcher determined that a mixed research approach with both quantitative and qualitative research methods will be the most suitable for this type of research. Ethnographic observation was implemented as a formative primary research, through which the researcher became more familiar with the actors in the marketplace and their practice. This method helped the researcher to have a better understanding of the literature and in combination with the literature's findings to create a framework of research questions that need to be addressed. The main research question "How can implementation of craft-based design into digital fabrication help designers explore meaningful making?" was addressed by two other methods, experiments and an online survey. The exploratory studies provided an opportunity to the researcher to test the potential of 3D printing in meaningful making, while the survey offered an opportunity to investigate peoples' interpretation of the experimental outcomes and understand how they create meaning.

3.1. Philosophical approach

A researcher's worldview combined with knowledge and expertise influence the choice of research methods and the direction of the research study (Creswell, 2014). In this study, the philosophical approaches that can be easily identified are pragmatism and constructivism. In broad terms, pragmatism intends to reveal the creation of practical knowledge evaluated and verified by its capability to solve a problem related to everyday activities (Coghlan & Brydon-Miller, 2014). Verification through experience is the main

reason why pragmatism is perceived by many authors as an interpretation of truth and meaning. As Creswell (2014) pointed out, pragmatists are free to use all kind of methods and techniques that provide the best understanding of what and how the situation can be improved. Since this is a study that needs to reveal a creation of practical knowledge, verified through experience, the practice-based nature of this approach is the main rationale for using it. In addition, the researcher needed the freedom to use a mix of research methods that will enable him to solve a problem and create practical knowledge.

According to Creswell (2014), constructivism is a worldview that emphasizes the role of the individual and its ability to develop “meanings directed toward certain objects or things” (p.37). Although each person perceives and interprets his/her experiences and beliefs differently, on a large scale “there is substantial overlap in individual meaning-making, which is the essence of socially constructed knowledge” (Mathison, 2015, p.81). The researcher’s objective is to rely on the participants’ view of a given situation, to understand the complexity of different perceptions and based on participants’ interpretation to create a pattern of meanings (Creswell, 2014). For the following research, a constructivist approach will be used to understand participants’ interpretations of the experimental outcomes. Through open-ended questions in the last research method (survey) the researcher will provide participants with an opportunity to express their opinions and beliefs regarding the appearance of the objects. Based on the responses, the researcher will analyze the data and try to understand where the overlap of individual interpretation is, and if this overlap can lead to a new meaning.

3.2. Research through Design

Research through Design (RtD) was introduced by Frayling (1993) when he established three different forms of interactions between design and research (research for design, research into design and research through design). Given that since 1993, many authors investigated the legitimacy of the RtD approach or compared it with similar approaches, RtD can also be found in the literature by names such as: constructive design research, project-grounded research or practice-led research (Pieter & Giaccardi, 2016). While the authors have different points of view, all of them share the same goal: establishing research through design process in which designed artifacts should provide insights for a better understanding of a complex design issue (Pieter & Giaccardi, 2016). In comparison with research for design, where the artifact is the end result, in RtD the artifact is a key component for data collection. In this study, we have artifacts derived from two different study experiments that were used as instruments for collecting information in the last research method, survey.

3.3. Research methods

The study takes an exploratory mixed methods approach, which according to Creswell (2014) is an approach in which the researcher first investigates the qualitative research methods, whose findings and insights should inform about the structure of a new quantitative method. In general, qualitative research is an approach that attempts to explore and understand the meaning of the data, while the quantitative research attempt to test the data through manipulation of variables (Creswell, 2014). The combination of both methods, known as “mixed methods”, has emerged in response to the theory that all

methods have their own weaknesses (Creswell, 2014). The frequent occurrence of this mix of research methods is as a result of the common understanding that when they are together, they neutralize their weaknesses and provide a complete picture of the research problem than either approach alone (Creswell, 2014). The researcher used this as an opportunity to apply different research methods and tools to obtain the data, including: ethnographic observation, experimental studies and an online survey.

3.3.1. Ethnographic observation

3.3.1.1. Objective

Observation as a research method provides the researcher with a window of opportunity through which the researcher observes situations, behaviours and objects in their own natural surroundings (Given, 2008). Since the scholarly literature provided information about objects made by traditional production and 3D printing amateurism, the researcher's reason for using this approach was to observe these objects in their own natural surroundings. Since most of these objects are available in online marketplaces, the researcher felt that he needed to become more familiar with the real material manifestation of these objects and investigate the opportunities for further research and innovation. By understanding the materiality of the digital objects, and the practice in general, the researcher believed that he will be able to gain more precise insights of the literature, that will guide the next steps of the research study.

In addition, in order to answer the question of how 3D printing as a medium makes sense in craft production, the researcher decided to visit two different events, one related to traditional production (Etsy: Made in Canada) and one related to digital fabrication (Maker

Faire). Although the literature presented that there is a presence of 3D printed objects on the Etsy marketplace, in general, Etsy events are recognizable as events where there is a dominant traditional production. Given that there is a distinction between the techniques and technologies presented online and in real life, this observation will help the researcher to understand why this is happening. In addition, by visiting an event related to traditional craft production, the researcher felt that he could develop a better understanding of Pye's workmanship of risk and what makes handmade so valuable. By understanding the process of meaningful making, the researcher hoped to implement this knowledge through experimental studies in which the main tool will be a 3D printing machine.

3.3.1.2. Data Collection and Data Analysis

The ethnographic observation was conducted during two events that took place in Ottawa in September 2018. The first event "Maker Faire" was held in the Canada Science and Technology Museum from September 29, 2018, to September 30, 2018, while the second event "Etsy Made in Canada" took place in the Fieldhouse of Carleton University from September 28, 2018, to September 30, 2018.

Observations of both events were performed in the same way: walking from vendor stand to vendor stand, listening, looking, and occasionally feeling objects on display. The primary method of data collection was taking pictures from a personal cell phone. In some cases, some of the objects were supposed to be touched in order to provide sensorial information about their texture and quality. As a second method, field notes with careful descriptions were used in situations in which information was not able to be captured visually. Regarding the data analysis, affinity diagrams were used to visually present the

data and quantify which types of craft techniques or technologies were presented more frequently during the event. This frequency was based on general contextual image groupings. The images established a framework of artifacts made by the same craft technique or technology and identified insights about their visual appearance and message. The field notes with descriptions were implemented into an excel document and were analyzed and categorized by topics.

3.3.2. Experimental studies

The analysis of scholarly literature in combination with the analysis of ethnographic observation, provided insights about traditional production and handmade qualities. By observing and comparing the objects from both events, the researcher developed an understanding of how handmade objects make sense to consumers. Since objects did not make sense only to consumers, but also to their creators, the overarching objective of the experimental studies was exploring from a designer's perspective the potential of 3D printing in meaningful making. Given that the designer, through interactive engagement with the machine, can understand the importance of the tool and its capacity to drive design decisions, this was a great opportunity for the researcher to understand the potential of 3D printing in craft production. By analyzing the handmade object and its process of making, the researcher tried to implement the insights into a combination of digital fabrication and traditional production and through his hands to understand how 3D printing makes sense as a tool for meaningful making. While in the first experimental study the explorative approach was more decorative, in the second experimental study the explorative approach was reconstructive, in a material sense.

Regarding the first experimental study, as presented in the observation results, uniqueness in colours and patterns was one of the main characteristics that made handmade objects so different in comparison with 3D printed objects. Handmade objects reflected what Pye meant by ‘the slip of the hand’ or ‘unwanted mark of the tool’. Taking into account that the same 3D printed object can be reprinted again and again, the main objective in the first experimental study was to investigate how craft-based techniques can help designers to create one-of-a-kind 3D printed object. By exploring a combination of traditional and digital fabrication, this experiment was not only testing Pye’s risk of making and criteria for uniqueness, but also a designer’s understanding of developing innovation through the creation of new meaning. By exploring the vase as a rich cultural object associated with numerous traditions, from materiality to methods of production, the researcher provided a new innovation, a new tradition, but this time made by a 3D printing machine.

Regarding the second experimental study, the main objective was to investigate how through a reproduction of broken objects designers can understand the process of making as a sense-making. Through understanding the materiality of broken objects and their capacity to act, the researcher’s main objective was to investigate the capacity of 3D printing as a tool for driving meaningful decisions.

Lastly, as presented in the literature review, a handmade object is generally perceived as a meaningful object that embodies memories of past actions. From a semantic perspective, besides their obvious meaning, these objects evoke meanings related to the myth of the creation. The question that remains is: can the outcomes of these experimental studies evoke new interpretation other than their own literal meaning? Can these objects make sense to the users?

3.3.2.1. Experimental study 1

Before diving into experimentation, the researcher performed an investigation into the current portfolio of works available on the internet. An exploration into the 3D printing market and the online universe of 3D printed things, brought the researcher to Thingiverse. Thingiverse (<https://thingiverse.com>) is an online website created by Makerbot, a manufacturer of 3D printers, that allows users to share and provide royalty-free 3D models that can be downloaded and printed for free. Filtering through Thingiverse's database of available ready-to-print vases, the results showed that the most downloaded vases are those with a design inspired by nature. By observing the shapes of the vases, it was evident that the designers behind these models are not using just CAD modelling software, but a combination of CAD and algorithms.

Figure 11: Vases available for download on <https://thingiverse.com>

Considering that in design education parametric and generative design software are still in their early stage of adoption, it was necessary for the researcher to find another way in which these forms would be achieved. “Julia” one of the most downloaded vases on Thingiverse (the middle vase in figure 11) was downloaded as a subject for further analysis. Julia is developed by software for fractals, called ChaosPro (<http://www.chaospro.de/>). This is software that creates computer-generated art, based on mathematical formulas.

Compared to the traditional 3D CAD modelling software, where the designer can see the desired shape immediately in 3D, in ChaosPro the designer only creates cross-sections by providing parameters in a mathematical formula. The designer's input is limited to providing a number of main cross-sections, while the overall form of the sections is derived by automation.

The output of the process are images of unique 2D sections, that should be implemented in software for 3D view. The software used for this study was Fiji (<https://fiji.sc/>), one of the most popular software used by life scientists for visualizing a 2D data obtained through microscopy. The same method was implemented here. Fiji was used for visualizing the 3D model through the data of intersections. Given that the quality of the 3D model (the mesh file) was still not appropriate for 3D printing, it was necessary for the model to be implemented in software for additional processing. Fusion 360 was used for improving the quality of the smoothness and defining the details of the form. Lastly, the model was implemented in 3D printing slicer software where were defined all variables and parameters related to the printing process and the quality of the model. All models were 3D printed in PLA material on a small desktop 3D printer with a bed dimension of 12 x 12 x 12 cm. Most of the 3D printed vases were not subject of any additional post-processing such as sanding, given that the quality of the model was not the main focus of the experiment. The process of the experiment can be visually seen in figure 12.

Figure 12: Visualization of the experimental process of experimental case study 1

The first 3D printed vase, which can be seen in figure 12, showed the preliminary results of the experiment. The shape of the first 3D printed vase was unique in the sense that it was one-of-a-kind at that moment. It was impossible to be copied by someone else, just like it was impossible to copy Julia. Given that by having the STL file, the model can be printed again, the question that remained was: how to make each vase one-of-a-kind? Although this could be accomplished through coding the machine and an algorithm that will produce a new vase each time, a more manual and hands-on post-process approach was used. The researcher tested the approach of marbling also known as hydro-dipping; an old Japanese craft technique that is also used in DIY projects.

Figure 13: Visualization of the marbling process in experimental study 1

What makes this technique stand out is the richness of the colour and the inimitable flow of patterns. While the paint is laying on the water, the designer has all the freedom to create patterns that it will be impossible to be repeated. By dipping the 3D printed model in the paint, the flow of the paint with the disturbances in the water created a visual one-of-a-kind object. The first model that was tested in this process was Julia itself. The result of before and after the implementation of the marbling technique can be seen in figure 14. The more detailed examination of the results is explained below in the results section.

Figure 14: Julia before and after marbling technique

3.3.2.2. Experimental study 2

Unlike the first experiment, where the artifact was created at the very end of the design process, in the second experiment the procedure began with the artifacts themselves. This practice is also known as reverse engineering. The first step of this experimental study was a selection of objects, objects that look handmade and have their own history, objects that represent traditional making. This type of objects was the easiest to find in second-hand stores like Value Village. After careful selection of the objects, the objects become the researcher's subject of interpretations. Who made them? How they were used? Why there

are in the second-hand shop? As the questions were arising, the researcher realized that objects and their memories are evoking different interpretations in his head. Instead of analyzing the memories, he decided that he would create his own memory by breaking the object. The researcher spent a week breaking objects in order to understand how they broke and what could be done with the broken pieces. Each object broke in its own unique way, depending on the force input. Viewed from a design perspective, this is a very important part of the process, because each broken piece informed about object's materiality. Through analyzing the broken objects, the researcher did not understand only the quality of the material, but most importantly, that each broken piece speaks both to the past and to the lived present and that is still a material thing from which he can be made something. While at the beginning the objects broke into many irregular pieces (figure 15), the researcher, through interaction with the hammer, found the appropriate force needed, so that the objects would break into a few pieces.

Figure 15: Breaking an object with a hammer

The next phase of the procedure was 3D scanning. Given that the researcher did not have any previous experience with 3D scanning and did not possess a professional 3D scanner, he decided to experiment with his own mobile phone, through a method called

photogrammetry. For this purpose, he used a software called Colmap, in which the researcher's input were photos from different angles of the object, while the software output was a 3D model.

Figure 16: Process of photogrammetry with Colmap

As can be seen from figure 16, the result of the 3D model (the last photo) did not provide satisfactory results. As a result of the number of photos and their quality, the software had difficulties in identification of patterns through which create a visual presentation of the model. Given that photogrammetry as a method worked, the researcher decided to try the same procedure with new software from Autodesk, called ReCap Photo.

Figure 17: Real object (left side) vs scanned object via ReCap Photo (right side)

As illustrated in figure 17, the new software provided a more realistic visual presentation of the 3D object. Although the 3D model had imperfections as a result of the reflections and the shininess of the object, it was still good enough to undergo further analysis and 3D printing. The results of the 3D printing, as demonstrated in figure 18, showed that the researcher would never find the perfect fit. One thing that he did not consider during this

whole process was that through photos he would never be able to find all dimensions of the object.

Figure 18: Results of unsuccessful fitting of a broken object with 3D printed object

After many trials and errors, the researcher decided to 3D scan the objects at Carleton University with a professional 3D scanner, called Go!Scan scanner. Given that this scanner is scanning in real dimension, the digital files created with such precision were ready to use immediately. Digital files from the scanned pieces were transferred to the Fusion 360 software, where the researcher started the process of restoration. Given that the idea of the experiment was to create a new interpretation, the researcher decided that during the restoration he would not restore the same shape, but would try to translate his own vision of how the fusion of past and future could look. Upon completion of the design, each piece was 3D printed in the studio of the researcher and each piece was subject to additional final post-processing modifications. In the end, the pieces were glued all together and the 3D printed parts were not painted in any colour.

3.3.3. Survey

3.3.3.1. Objective

The main objective of the survey method was to investigate peoples' interpretation of the experimental outcomes and understand how the objects make sense to the participants. Given that the study investigates 3D printing as a tool for meaningful making, it is important to be validated if the outcomes of the process are meaningful or not. By applying the constructivist approach, the researcher's objective was to rely on the participants' interpretation and based on participants' interpretation to create a pattern of meanings. In addition, given that the literature presented information about the new consumer culture and the appearance of machine-made objects on Etsy, the researcher needed to test these theories in order to understand if there is any potential for 3D printed objects to be considered as part of the craft market.

3.3.3.2. Survey design

The survey was comprised of sixteen (16) questions in total (Appendix E). As presented in table 1, the first two questions were related to participants background. In Q3 the researcher asked participants to define handmade with only one word. The researcher wanted to understand the first association that comes to the participants' mind when they think about a handmade object. Given that the literature about consumer culture provided information that participants are purchasing handmade to build their self-identity, questions Q4 and Q5 were related to participants' emotional connection to handmade objects. The next two questions, Q6 and Q7, asked participants about the reason for purchasing handmade objects and which objects' features are most important to them while buying. Given that the

questions were in multiple-choice format, the keywords used for provided answers were based on McIntyre's report (2010), which investigated the driving forces behind the evolution of the craft consumption today. Since the literature presented that the appearance of machine-made objects on Etsy resulted in tensions between the makers, the next questions were designed to provide insights about participants' perception about machine-made objects. In addition, the literature presented that there is an appearance on 3D printed objects on Etsy, so participants were additionally asked about their familiarity with 3D printing technology and if they believed that a 3D printed object could embody handmade qualities. The next five questions were related directly to the outcomes of the experimental studies. In Q12, the researcher took a constructivist approach and through an open-ended question asked participants to explain the objects from the second experimental study. Given that the Semantic Differential Scale is known as a technique for measuring the meaning of product or concept (Salkind, 2007), Q14 was designed based on this technique. Participants rated the object's attributes using a 5-point bipolar rating scale. The choice of attributes such as handmade, innovative, high quality, unique etc. was designed based on keywords, provided in the literature about traditional production. The last two questions were created in Side by Side format. The participants were provided with two pictures (regular 3D printed vase and 3D printed marbled vase) in which they were asked to provide a description for each of them. Lastly, the participants were provided with the same adjectives from Q14 and were asked to indicate which adjective better describe the vases on the pictures.

Q1 to Q2	Participant's background
Q3 to Q5	Definition of handmade and emotional connection with handmade objects
Q6 to Q7	Reasons for purchasing handmade and most important features
Q8 to Q11	Understanding of 3D printing technology and beliefs about 3D printed objects
Q12 to Q14	Participants' interpretation of the outcomes from experimental study 2
Q15 to Q16	Participants' interpretation of the outcomes from experimental study 1

Table 1: Categorization of survey questions by topic

3.3.3.3. Data Collection and Data Analysis

For the development of the survey, a licence for the software Qualtrics Survey was requested and obtained through ITS Service Desk at Carleton University. The survey was launched on May 22, 2019, and closed on June 3, 2019. The survey was distributed online in two ways. The first method of distribution was by sending a letter of invitation (Appendix C) via email, which contained an introduction that briefly explained the purpose of the survey and a clickable link to the online survey. The second method was performed through social media, by posting a written invitation (Appendix D) to Master of Design Facebook group and other Facebook groups related to craft such as: Handmade in Canada and Etsy Sellers and Buyers. In addition, participants were encouraged to forward the invitation to acquaintances whom they believe might also be willing to contribute to this study.

A total of eighty-one (81) participants submitted responses to the anonymous online survey. The eligibility criteria for participants was based on their background and personal interest. The survey was open to people who are design students/professionals, craftsmen (makers, artisans) and people interested in purchasing handmade/custom-made items. All participants were adults (over the age of 18) and comfortable with reading and answering

English. Before accessing the survey, participants required access to the Internet. By accessing the survey, prior to the beginning of the questions, participants were asked to download and read the Implied Consent, regarding ethical implications (Appendix B). During the data collection, there were no records of any personal information or contact association with the participants. Incomplete survey responses were deleted and not included in the results.

The collected data was firstly analyzed through the Qualtrics' tools for filtering. While the statistic results were exported in a form of graphs and charts, the text responses were exported in a list format. The long text responses in which the participants provided an interpretation of the objects were analyzed with content analysis. This type of analysis established a coding frame designed to generate meanings from participants text interpretations. In addition, the text responses with only one word were generated by World Cloud Generator, integrated into the software, for a visual representation of the text in different sizes and a better understanding of the frequency of most used words.

4. RESULTS

4.1. Ethnographic observation results

Affinity diagrams were used to visually present which types of craft techniques and technologies were presented more frequently during both events. According to the first affinity diagram, it can be clearly seen that during the Maker Faire event there was a distinction in the presented types of workmanship. A dominant number of objects were made exclusively by machines such as 3D printers and CNC cutters, while a small number of craft objects were made by hand. During the second event, Etsy: Made in Canada, almost all objects were made exclusively by hand.

Figure 19: Affinity diagrams of photos taken during both events

According to the field notes, the audience that was present during the first event-Maker Faire, was much younger than the audience at the second event. While the first event was dominated by the younger male population, the second event was dominated by the older female population. A distinction was evident even in the visual representation of the vendor

stands. While in the first event the tables were preoccupied with working 3D printing machines, in the second event there was no representation of tools and techniques at the vendor stands, except for some weaving needles. Given that Etsy people are known as craft makers who invest a lot in their branding and image representation, they proved that even in real events they think about every detail about their representation. The objects were carefully placed on the tables, waking up the imagination of the customers about the story behind the object.

Figure 20: Visual representation of Etsy's vendor stand

While the researcher was visiting the vendor stands, he used the opportunity to listen to the conversation between the makers and the consumers. He was interested to know how the makers are presenting the objects, their story and the process of making. During the first event, the researcher realized that most of the makers, especially the people behind 3D printing machines, were interested in discussing about the capabilities of the machines and their process of working. Instead of presenting themselves as creative individuals, they presented themselves as scientists of unprecedented technology. In the second event, the craft makers were focused on consumers and building a relationship with the consumers.

By discussing their story and the process of making they were helping consumers to understand how the object came into life and what make the object so valuable. In addition, they were using every chance of the dialogue to point out that their objects are exclusively made by hand and with high-quality materials.

Regarding the quality of the objects, the 3D printed objects that were presented during the first event, from spare parts to decorations and toys, were made in very low quality. While most of them were printed with high precision in details, the surface quality was still rough. The finish of the models clearly showed that these makers are still in the experimental stage where they are playing with their machines and software settings. Given that the researcher has experience in 3D printing and is very familiar with the website Thingiverse, it was easy to recognize that most of the presented designs were not designed by the makers but downloaded from open-source data. Only one vendor promoted a design that was never seen before and that was a functional violin, 3D printed in real size. In addition, most of the presented models, including the violin, were printed exclusively in one colour (mainly white). There was only one vendor, where the models were in multicolour, painted with acrylic colour.

In the second event, judging by the visual appearance, it was clear that almost all objects were made by hand and high-quality craftsmanship. Smoothness and uniqueness in colours and patterns were the characteristics that made these objects so different in comparison with the craft objects from the first event. As can be seen from figure 21, although all mugs look the same, each mug stands on its own. In some of the mugs, it can be clearly seen that there are marks that were not supposed to be there. Instead of removing them, the craft

maker behind these objects left them with purpose, presenting Pye's 'slip of the hand' or 'unwanted mark of the tool'.

Figure 21: Handmade mugs that illustrate Pye's slip of the hand

The questions that arose during the second observation were: How can we use traditional techniques to create one-of-a-kind 3D printed object? How can 3D printing practitioners create unique 3D printed objects that can stand next to handmade objects? How can 3D printing as a tool make sense in craft production?

4.2. Experimental study 1 - results

During the first experimental procedure, more than 50 different virtual prototypes were created. Since the 3D objects were created by automation, only those that met the researcher's appearance criteria were additionally 3D printed. Although the software provided abstract shapes that were never seen before in vase production, the researcher had the last word about which shapes make sense to him and consumers. The researcher was looking for forms that represent movement. Forms that were inviting the viewer to move into a space of speculation regarding the meaning of the object.

Figure 22: Results from the first experimental study

One of the vases from figure 22 was selected for additional analysis. Given that this experiment was supposed to provide uniqueness, the selected vase was reprinted five times. The purpose of this re-printing step was to find out how different these five models are after applying the marbling technique. All five models were dipped one after another in the same coloured water and, as seen in figure 23, all five vases are slightly different and each of them can stand as a one-of-a-kind.

Figure 23: Five vases before and after marbling technique

Since there is no software that could calculate the uniqueness of the vases or how different they are between each other, software for image comparison was used. In order to obtain correct and relevant results, there was a need for two series of identical photos of all five models. For that purpose, the models were placed in an identical position, while the camera was statically set on a tripod in one position. In the first series were taking photos from the first half of the model (front), while in the second series pictures were taken from the same model, rotated for 180 degrees and placed on the same identical position. Given that the software captures all pixels (including those in the background), the background was additionally removed in Photoshop. During the software analysis, one vase was chosen to be main, and all other vases were compared to that one. According to the results shown in figure 25, the five models differentiate between them by an average of 8%.

Figure 24: Visual presentation of the process of taking photos

Figure 25: Visual diagram for the results from the software for image comparison

4.3. Experimental study 2 - results

During the second experimental study, while many objects remained unfinished and broken, a few objects went through the entire design process and provided satisfactory results.

Figure 26: Artifacts from experimental study 2

For the purpose of the study, the researcher decided that only the collection of three cups would be subject for further analysis. He believed that this was the best example of providing understanding how a simple object such as cup, can be designed and interpreted differently.

Figure 27: A collection of three cups from experimental study 2

As can be clearly seen from the figure 27, the three cups together created a composition of visual elements representing the tradition and the future. The breaking of the mugs created a unique appearance that cannot be repeated by any manufacturing process. If they are observed separately, each cup can stand as its own and tell its own story. The clear separation between the old and the new is made with a purpose. Inspired by Kintsugi, Japanese craft technique for repairing broken pottery with gold lacquer, the author wanted to emphasize and celebrate the moment of breaking as a new beginning. While the Japanese pottery vessels are still functional after their restoration, the unusual design of these cups made them non-functional.

Given that Krippendorff recommended that designers should avoid the design rule “form follows function” and that the meaning is related only to the form of the object, the researcher decided to focus exclusively on the form and what makes sense to him. If the researcher had decided to print the 3D printed part without holes and post-finish with a protective coat, the mugs would still be functional to some extent. The reason why the researcher opted not to give the cups their functionality, or force the viewer to focus on it, was to understand what people see and how they interpret the object without the socially constructed meaning normally associated with that object. The results from their interpretation are presented in the next section.

4.4. Survey results

Findings from the survey results reflected a difference in the attitudes, beliefs, and values that are held by participants with regards to handmade objects. While a detailed list of the survey findings can be seen in Appendix F, here in this section will be elaborated only the most important findings.

From 81 participants, 73 participants (90%) identified themselves as female, while 8 participants (10%) identified themselves as male. While in Q2, participants were asked to identify themselves in one of seven proposed categories, for better understanding of the findings, these seven categories of participants were filtered into four main groups: G1_Craft, G2_Design, G3_Customer and G4_Other. According to the results, 21% of participants identified themselves as part of G1_Design group, 66% as part of G2_Craft, 7% as part of G3_Customer and 6% as part of G4_Other group.

G1 DESIGN	Design students + Design professionals
G2 CRAFT	Maker/Craftsman/Artisan + Etsy Seller
G3 CUSTOMER	Potential buyers + Etsy buyer
G4 OTHER	Other

Table 2: Categorization of participants based on their background

The findings from question Q3 (*How would you define HANDMADE with only one word?*) showed that most of the participants define handmade as ‘Unique’. While at first glance it looks like participants are relating uniqueness of the object to the authenticity of the object, the findings from questions Q4 and Q6 clearly showed that participants relate the uniqueness to self-identity. More than a half of the participants (57%) responded ‘yes’ to the question “*Do you believe that the desire to buy a handmade reflects your identity/self-expression?*”, while 30% answered ‘maybe’. In addition, “Unique objects reflect my identity” is the second most dominant reason (from eight provided reasons) that affect the

participant's decision to buy or consider buying a handmade object. Furthermore, the finding from Q7 reveals that the second most important feature to participants after “quality of the object” is “to be one-of-a-kind”.

In question Q8 (*How much do you agree that an object made by machine can be considered as handmade?*), on average scale designers were more agreeable than craft makers. On a scale of 1 to 5 (1=Strongly disagree / 5=Strongly agree), designers' average score was 3.12, while craft makers' score was 2.75. On the other side, in question Q11 (*How much do you agree that 3D printed object can own handmade qualities?*), the average agreement of designers is 2.94, which is lower than the average agreement score of craft makers (3.49). It is important to note that in the previous question (*How familiar are you with 3D Printing technology?*), designers identified themselves as the most familiar group with 3D printing. The fact that designers were the group that is most familiar with 3D printing technology (with an average score of 3.82) and is the group that did not believe that 3D-printed objects can have handmade qualities opens a discussion about designers' understanding of handmade and 3D printing as a tool for making.

Table 3: Results from questions Q8, Q9, Q10 and Q11

Regarding the meaning of the object, in question Q12, participants were asked to describe what they see in the picture with broken mugs (Figure 27). According to the content analysis, ten different categories of interpretations emerged from the data. The top three categories of interpretations were related to: the function of the object (44%), the process of making (14%) and the form of the object (12%).

In relation to the functional meanings, there were participants that gave a new function to the object. For example:

P.2: “Unique oil burners”

P.8: “Handcrafted vases”

P.18: “Ornament. We can place them as part of the living room furniture”

P.33: “Candleholders made by broken pieces”

P.81: “In my opinion, these objects look like clay candlesticks in the form of cups or mugs”

In addition, there were participants who were trying to make sense of the object through a functional perspective. For example:

P10: “They first appear as drinking mugs but with the 3D printed cut-outs, they appear more as a display piece”

P12: “Piece of decor since the design is not functional.”

P46: “They look like drinking mugs but obviously not for drinking, I'm not sure what they would be used for other than a vase”

P76: “Wabi-sabi inspired artifacts. The function is clearly not intended for liquids. Perhaps decorative.”

In the next two questions, participants were asked to describe the objects again. While in Q13 they were supposed to describe the objects with only one word, in Q14 they were supposed to rank the object's attributes in semantic differential scale format. Survey analysis showed that in both questions, the most dominant response was 'Unique'.

Table 4: Results from questions Q13 and Q14

In addition, filtered by groups, the analysis of Q14 showed that there is a slight difference in the participant's responses. The division of the results pointed out that the craft community (G2_Craft) believe more than the design community (G1_Design) that the objects on the picture are 'handmade' and 'innovative'.

Figure 28: Visual representation of Q14 results, divided by groups

Regarding the uniqueness of the objects, a very similar situation can be observed also in the results of the last question Q16, in which participants were comparing a 3D-printed white vase versus 3D-printed marble vase. Although both vases have the same shape, the results showed that the 3D-printed vase finished by marbling is described by 70 participants as Unique, while the other 3D-printed vase was described by 67 participants as Simple. These results just demonstrated that the objects in both studies awaken interpretation as something that stands as unique.

Figure 29: Visual representation of Q16 results

Lastly, in the previous question (Q15), participants were provided with two text fields where they were supposed to describe the vases in the pictures. Regarding the size of the answers, there was no limitation about the text entry, but the results showed that half of the participants chose to describe the vases with only one word. While the vase on the left side was described with words such as: White, Modern, Pure, Simple, Minimalistic and Unfinished, the vase on the right side was described with words such as: Abstract, Artistic, Chaotic, Unique, Colorful and Painted.

5. DISCUSSION

5.1. Insights

The insights from the observation are based on a correlation between the researcher's perception and the findings from the literature review. Regarding the experimental studies, given that both studies were performed by the researcher himself, the insights are documented as a reflection on his experimental knowledge gained through the process of making. According to Schön (1991), this interpretation of knowledge is known as reflection-on-action: the researcher reflects on actions, limitations and feelings during the process of making and their impact on its practice and design thinking. In addition, the insights from the online survey are based on detailed analysis and comparison of different findings related to the same topic.

5.1.1. Ethnographic observation insights

The ethnographic observation of Etsy and Maker Faire demonstrated that these two events did not only present different kinds of production, but also different cultures. While Etsy was mostly visited by people interested in purchasing handmade objects, the Maker Faire was dominated by young nerds interested in the advances of digital fabrication. Although the literature presented that there is a presence of 3D printed objects on the Etsy marketplace, the observation of the Etsy event showed that it is still a marketplace with a dominant traditional production. In contrast, the observation of the Maker Faire event only confirmed the literature's findings that Maker Faire is dominated by amateur makers who fetishize machines as taken for granted. Instead of presenting new ideas or experiments, they still present simple outcomes as evidence of the functionality of 3D printing machines.

As Bosqué (2015) pointed out, amateur makers are still in a stage where they are printing downloaded ready-to-make samples from the Internet, demonstrating a lack of inspiration. The lack of inspiration was not recognized only in their samples, but also in the colours of the samples. Most of the models presented were in their natural filament colour. It is true that machines with two extruders are more expensive than regular 3D printing machines, but the researcher, by exploring the marbling technique, found his own way to present diversity in colours. Since the Maker Faire has lost its momentum, the experiments of this study provide a great opportunity for amateur makers to investigate the potential of the combination between tradition and digital fabrication and present a new understanding of 3D printing technology. In addition, regarding amateur makers who started entering the Etsy market, by engagement with the real material world and presentation of more appealing products, they have the opportunity to start embracing 3D printing as a more sophisticated tool that can lead to innovation. By understanding the importance of the tool and the experience that can be gained through engagement, they can learn about meaningful making, through which they can create objects that make sense to consumers.

5.1.2. Experimental studies insights

By analyzing the experimental processes, the researcher found that the true insights are not in the experimental outcomes, but in the process of their making. By taking a step back and investigating the meaning of the experimental processes in relation to the literature review, the researcher found that both experiments presented meaningful making. Both experiments demonstrated that:

- 1) 3D printing has a potential not only to develop meaningful outcomes, but also to drive

design processes that make sense to designers

2) Designers can develop practical know-how knowledge through engagement and understanding of 3D printing machine

3) 3D printing can be implemented in a process that meets Pye's workmanship of risk

Regarding the first insight, by investigating the visual presentation of Krippendorff's graph for sense-making (figure 10 in section 2.5.1), the researcher demonstrated that both experimental processes met Krippendorff's criteria for sense-making.

Figure 30: The experimental processes as sense-making processes

As can be clearly seen from figure 30, in both experimental studies the researcher started at the very beginning with unknown and confusing design situations. Instead of escaping from the unknown, by thinking through the notion of handmade, the researcher imagined hypothetical contexts that defined the features of the objects. Through experimentation with computer software and 3D printing he developed his imagination into reality, he developed an object with its own meaning: an object based on individual discretion and judgment. Given that the objects were supposed to provide meanings other than their own literal meaning, the researcher explored other contexts through which he created objects with complex meaning. For example, in the second experiment, the researcher, instead of stopping with the restoration of the cup, decided to take a step further and investigate the context of generative design. By exploring the forms of generative design, he implemented shapes that not only changed the object, but also its own meaning. The restored cup was no longer just restored cup, but a representation of past and future, a representation of hybrid craft, a representation of new production and something that made sense for the designer.

Regarding the second insight - the potential of 3D printing as a tool for developing practical knowledge - the researcher showed what Heidegger meant by “equipment for action”. Instead of staring at the machine and using it as a fabrication machine, the researcher used the machine as a tool that can inspire a new process. By printing and re-printing again and again, he was trying to understand the opportunities and obstacles of the tool. Instead of being a passive viewer, the researcher was trying to understand the agentic capacity of the 3D printing machine and how it affects his decisions about his next design. As Crawford (2009) pointed out, “bodily involvement with the machines we use entails a kind of

agency” (p.63). Without active engagement and human agency, 3D-printers will stay just devices that invite consumerism, but never things that “convey meaning through their own inherent qualities” (Crawford, 2009, p.65). By understanding the power of 3D printing machine and engagement with other techniques the researcher discovered opportunities that led him to unpredictable design solutions. This practical experience cannot be downloaded on thingiverse.com, it can only be lived. From a phenomenological point of view, this is the experience that leads to skill and tacit knowledge.

This practical knowledge was especially evident while the researcher was trying to break the objects with a hammer. While from the outside it looks very easy to break an object, the experience showed that this is extremely difficult when you have a design vision in your head. Depending on the force used, the object exerted his own agency that constrained the researcher’s ideas and changed his design thinking. Through demonstration of their agency, the objects showed that working with them involves a negotiation of sorts between the human and non-human. The researcher was supposed to negotiate between himself and the power of the hammer in order to understand the response of the object. After many breakings, he developed the required knowledge to control the process of breaking. While he learned which force is needed to break the object in two or three pieces, one thing remained uncontrollable. He will never know how exactly the object will break and act at that particular moment.

This example leads to the third insight, which is that 3D printing can be implemented in a hybrid process that meets Pye’s workmanship of risk. By taking a step back and analyzing the visual diagram by Loh, Burry and Wagenfeld (2016) in which they evaluated the level of risk in different stages of making, the researcher realized that both experiments

evidenced workmanship of risk. If both experiments are tried a hundred more times or the processes become automated, each time there will be a different outcome. While during the prototyping stage the risk of tools and techniques will be reduced to a minimum, in the production stage the risk of the material will still remain high. The breakage of the object will always be unpredictable, and thus similar to the Australian hardwood with which Wright deals on a daily basis in his craft production.

Mass Production

Craft Production

Experimental Study 1

Experimental Study 2

Figure 31: Analysis of the experimental processes according to the visual diagram for workmanship of risk by Loh, Burry and Wagenfeld (2016)

In addition, as presented in the first experimental study, during the process of dipping, the paint in combination with water exerted agency that affected the design of the object. While the researcher was trying to achieve a particular pattern (where the dominant colour would be white) he realized that he would be never able to control how the pattern will hang on the object. As presented in the literature, this is the risk associated with the material behaviours, that is beyond the reach of predictive capacities (Foote, 2017).

5.1.3. Survey Insights

While in the literature review the word handmade is very often associated and defined with terms such as ‘workmanship’ and ‘genuine’ (McIntyre, 2010), the findings from question Q3 showed that most of the participants define handmade as ‘Unique’. As the findings from questions Q4 and Q6 clearly showed, participants relate the uniqueness to self-identity. While in McIntyre’s survey (2010), 22% of the participants were motivated to consume handmade only because it reflects their own identity or the image of themselves, in this study 57% of the participants believe that the desire to buy a handmade reflects their own identity. These results just confirmed the findings from the literature review that consumers’ desire for handmade objects is based on their requirement for individuality. In addition, these results confirmed why it is important today for designers today to focus on creating objects that make sense for consumers. As Campbell (2005) points out, consumers today are self-conscious manipulators who are purchasing crafts with the specific intention to build their identity or lifestyle by controlling the soul and the symbolic meaning of the product. We are living in a society where people are purchasing handmade objects to prove to themselves that they are unique, that they are different than others.

Another unanticipated finding that was revealed from the survey results was participants' familiarity with 3D printing technology and their belief that 3D printed objects can embody handmade qualities. Given that more than half of the craftsmen identified themselves as familiar with 3D printing technology, this result can be looked from two perspectives. From the first perspective, the familiarity can be based on their understanding of the essence of the making and 3D printing as a tool for making, while from the second perspective this familiarity can be understood as a result of the increased presence of 3D printed objects on the handmade market. Regardless, the fact that craftsmen believe that 3D printed objects can possess handmade qualities more than designers, who are the most familiar group with 3D printing technology, talks about the designers' insufficient understanding of 3D printing as a tool for making. As indicated in the literature review, designers look at a 3D printer as an automatic fabrication machine in which their only responsibility is to press the button PRINT. As Blikstein (2013) stated, printing simple beautiful objects with little effort is just proof of concept. With this behaviour and not understanding that the 3D printing machine is just another tool of the making process, designers will never explore innovation through 3D printing.

Regarding the meaning of the object, the researcher's objective was to rely on the participants' view of a given picture and based on participants' interpretation to create a pattern of meanings. A detailed look in the associative interpretations of respondents showed that there is a pattern of functional meanings. Most of the participants interpreted the objects based on function. They looked at the object and compared it to a vase, oil burner, plant holder and candle holder. During the analysis, while the researcher was reading the responses he was surprised by the respondents' imagination. For example, he

never thought that the object can function as a plant holder or oil burner. In addition, the most striking result related to the function of the object emerged from the data of question Q7. “Function of the object” is the least important feature (2%) to participants when they are considering buying a handmade object. According to these findings, participants are not concerned with the function of the object, but they are interpreting the meaning of the object based on functional context. This is directly related to the theory of Krippendorff about sense-making. As he said, people formulate an idea about the object based on previous context or experience that allows them an understanding of the object. In his work *Product Semantics: A Triangulation and Four Design Theories* (1989), he stated that the meaning of an object “emerges in use, with practice, the practice of living with our environment and in particular contexts whenever we cognitively connect our actions and perceptions in an experiential circle of use” (p.4).

As indicated in the literature review, the objects of the picture act as physical traces of past events. The shape of the object reminded participants of experience in which they used a similar object. The shape of the objects reminded participants of practical knowledge. As Heidegger stated in his work *Being and Time*, “the nearest kind of association is not mere perceptual cognition, but, rather, handling, using and taking care of things which has its own kind of knowledge” (p.63). If the participants who defined the object in the picture as an oil burner, never used or interacted with oil burner before, they would never have developed knowledge or memory that would then act on their interpretation.

Regarding the questions related to 3D printed vases, the results showed that although both vases have the same shape, they evoke different interpretations. While the regular 3D printed vase was described by most participants as ‘simple’, the 3D printed vase with

marbling was described by most participants as ‘unique’. Given that in Q3, participants defined handmade as unique, it can be concluded that the researcher’s intention to translate handmade quality into 3D printed object provided satisfactory results. By investigating a simple traditional technique, such as marbling, the researcher provided an example of how a 3D printed object can stand on its own with its uniqueness.

5.1.4. Insights summary

By interpreting the experimental outcomes as ‘handmade’ and ‘innovative’ and believing that 3D printed objects can embody handmade qualities, craftsmen signaled that the 3D printing machine as a tool is mature enough to enter the craft market. While the doors remain open, during the observation, the amateur makers showed that they still rely on the machine as taken for granted. In addition, by identifying themselves as familiar with 3D printing technology, by not believing that 3D printed objects can reflect handmade qualities, they showed their inability to recognize 3D printing machine as a tool for making meaningful objects. As shown through the researcher’s experimental studies, a 3D printing machine can become a tool for meaningful making when there is an interplay between the maker and the machine. Without engagement and understanding the material world, 3D printing practitioners will most likely remain stuck making ‘crapjects’.

Participants’ responses clearly demonstrated that the uniqueness of handmade object is a very important feature when buying handmade objects, because it reflects participants’ identity and self-expression. Given that the objects in both studies by most of the participants were defined or rated as unique, it can be concluded that the researcher, through experimentation and implementation of traditional techniques, successfully

translated the uniqueness of handmade object into 3D printed objects. In addition, participants' interpretations of the broken objects showed that when 3D printing is carefully implemented in the process of making, even if the objects are not functional they still have potential to evoke meanings that make sense to consumers. As handmade objects, the experimental outcomes acted as physical traces of past events that awaken participants' imaginations and memories.

Regarding the process of making, both experimental studies showed that the processes of making met the criteria for meaningful making. By interactive engagement with the machine, the researcher understood the importance of the tool and its capacity to drive design decisions. By learning how to control the tool, he developed practical knowledge and skills that lead him to unpredictable design solutions, such as uniqueness and new meaning. Through experimentation, the researcher did not change only the meaning of the objects, but also the meaning of the tool. While 3D printing is recognized as a tool for making, the researcher showed how can be used as a tool for thinking. The researcher used the tool to think through design conceptually and literally and create a design process that makes sense to him.

5.2. Limitations

Although a mixed research approach with both quantitative and qualitative research methods was utilized in this study, there are a couple of limitations in this study that needs to be clarified. The first limitation that needs to be addressed is the ethnographic observation. The researcher believes that if he had in-depth interviews with the participants, he would have had a better understanding of the process of making and the

meaning of the objects. The fact that observation was performed through his own perception may affect the adequacy and legitimacy of data collection.

The second limitation is the researcher's interpretation of his experimental studies. Given that insights are documented as a reflection on his experimental knowledge and memories, some details may be omitted during the reflective interpretation.

The third limitation is the choice of the survey as a research method. The researcher believes that a workshop in combination with a questionnaire would provide more accurate and insightful results. Interacting with design students and observing their process of making will provide more insightful results regarding the student's understanding of 3D printing. Introducing 3D printing in workshops has its own limitation, primarily due to time constraints and the depth of knowledge which students need to develop to complete the design process. Another disadvantage of the survey as a method is tactility. Given that tactility is a very important factor in materiality and that can evoke memories, the researcher believes that participants may have different interpretations of the objects if the objects were allowed to be touched. In addition, the researcher believes he would gather different data of interpretations if Julia vases in questions 15 and 16 were presented without flowers. The participants would be focused on the form of the vases and would provide meaning based on their understanding of the form. Regarding the survey data, it is important to mention that the researcher's main motivation behind using a survey as a research method was not to obtain scientific data, but to seek feedback on his experiments. Although during the creation of the experiments the researcher understood that he changed the meaning of the objects he felt that he needed an external validation of what other people see and how they interpret the new objects. Due to time constraints, the researcher was not

able to perform in-depth interviews and decided to use a survey as a faster and easier way for collecting a large sample of qualitative data over a short period of time. While the researcher tried to implement more open-ended questions through which he would collect more qualitative data, during the creation of the survey, the Qualtrics software warned him that people prefer not having to provide long responses in a survey. This warning proved to be true. In one of the questions where the participants were asked to describe the vases with long text entry, most of the participants chose to use only one word.

5.3. Future research

Considering the results, analyses and findings from the mixed research approach, the research questions in this study have been addressed and answered. However, this study has thrown up new questions in need of further investigation. Firstly, there is a need for a detailed study that would investigate the reason behind 3D printing practitioners' inability to recognize a 3D printing machine as a tool for meaningful making. Further study should examine how this group of people perceive the tool and whether their lack of knowledge and inspiration is related to their educational background.

Secondly, the performed experimental studies in this research are just one example of how the implementation of tradition into digital fabrication can lead designers to unexpected discoveries. Design educators should reconsider the purpose of maker space at school and push students to take a risk and explore more happy accidents through engagement and combining 3D printing with other techniques. If the studio course outline constrains implementation of this type of investigation, design workshops are a great opportunity for design educators to test the potential of this method and its capacity to act on students'

design thinking and developing practical knowledge.

Lastly, the results from the survey method reveal a question that is not a concern in the design field but may open a discussion for future research in the field of material studies and consumer culture. In question Q3, where participants were supposed to define handmade with only one word, 32 out of 81 participants defined it as 'Unique'. Instead of using words that are associative with handmade such as craft, workmanship, love, quality, authenticity and genuine, the most dominant participant response was unique. Since in the preceding two questions there was no indication that would lead to this response, the question that opens is: What is handmade today? In addition, there is a need for future research that would investigate the presence of 3D printed objects on the handmade market and explore its impact on the definition of handmade.

6. CONCLUSION

The purpose of this research study was to investigate the potential of 3D printing for meaningful making. Through investigation of handmade objects and their process of making, this study set out to determine how design practitioners can invent 3D printed objects that make sense to stand alongside handmade objects. Since most of the current studies are focused exclusively on the opportunities in the medical, automotive and aerospace industries (Bosqué, 2015), this study provides an understanding of the opportunities of 3D printing in the craft industry.

The study was driven by one main research question: how can the implementation of craft-based design into digital fabrication help designers explore meaningful making? To provide an answer to this question, the study firstly presented a large and growing body of literature regarding the subject matter. By revealing insights about the new consumer culture, the importance of the meaningful objects and the new phenomenon in which amateur makers are advertising 3D printed objects as handmade, the literature demonstrated why this study should be investigated. Since handmade objects are associated with traditional craft production, the literature additionally revealed insights about traditional making and digital fabrication. Since hybrid craft, a combination of both methods, was proposed by Renda & Kuys (2014), as a most suitable type of fabrication for new designers, the literature demonstrated that most of the authors are focused on the digital stage of the process. This gap in literature opened a great opportunity for this study not only to investigate the material stage of this practice, but also to demonstrate how traditional craft production can help designers understand meaningful making. In order to understand how traditional making can be implemented into digital fabrication, the

researcher decided to perform an ethnographic observation and visit two different events. The ethnographic observation helped the researcher to familiarize himself with both methods of production and to gain insights about handmade objects and their qualities by observing them.

The researcher believed that the best way to answer the research question was through a conceptual and material exploration. Through two experimental studies, the researcher implemented and translated his insights about handmade qualities into a new combination of digital fabrication and traditional production. By experimenting with different techniques and understanding the importance of engagement with the tool, the researcher provided insights that went beyond the material outcomes. The two explorative studies demonstrated what Verganti and Norman (2014) meant by innovation driven by the creation of a new meaning. In both studies, the imagination of hypothetical contexts allowed the researcher to explore new forms and redefine what an object may mean for a customer. The two experimental studies presented that the researcher created not only objects with new meaning, but also a process of making that has a new meaning to him. By taking a step back and reflecting on his practice he realized that he was not using the tool for making, but for thinking. By understanding the potential of the tool and its capacity to act and drive design decisions, the researcher revealed a new practice, unknown to him. He revealed an innovation in which the deconstruction of the materials of the objects and recombination of techniques, made sense both to him and the surveyed participants. The survey results showed that both experimental outcomes were interpreted differently from their literal meaning and that 3D printed objects can be considered as other than ‘crapjects’. In addition, both experiments demonstrated Foote’s argument that even in hybrid craft

there is still a risk associated with the material behaviors, that is beyond the reach of predictive capacities. If both experiments were repeated a hundred more times, each repetition would yield a different outcome. From here it can be concluded that the researcher's intention to translate handmade uniqueness into a 3D printed object provided satisfactory results. In other words, through careful implementation of 3D printing into combination with traditional techniques the researcher demonstrated De Massis's concept of Innovation Through Tradition. Since Holmquist, Magnusson, & Livholts (2018) argued that there is a need for research investigating ITT at the designer's level, this study not only fulfilled that need, but also demonstrated how ITT can affect the designer's understanding of meaningful making.

6.1. Contribution to the field

Innovation is one of the main foundations on which the design field is built. Designers, by implementing the newest technologies for improving the speed and accuracy of the process and testing low-quality outcomes, are slowly breaking the traditional bond between a designer and a maker. Besides the fact that technologies can negatively affect the design process and outcomes, additionally, there are implications for designers in terms of how they learn and develop practical knowledge.

While many researchers state that designers are still developing practical knowledge through digital modelling, this study demonstrates how designers can develop practical knowledge of these technologies through material experimentation. This study provides an opportunity for designers to understand that a 3D printing machine is not just a machine, but a medium such as clay and foam, through which they can experiment and develop innovation. By understanding the importance of the medium and the experience that can

be learned through engagement, designers can rebuild the traditional bond between the maker and the designer. They can understand what makes them experts and what is the meaning of their making.

BIBLIOGRAPHY

- Ahearn, L. M. (2001). Language and Agency. *Annual Review of Anthropology*, 30, 109-137. Retrieved from <https://www.jstor.org/stable/3069211>
- Aitchison, M. (2014). *The Architecture of Industry: Changing Paradigms in Industrial Building and Planning*. Ashgate Publishing Limited.
- Aryafar , K., Lynch, C., & Attenberg, J. (2014). Exploring User Behaviour on Etsy through Dominant Colors. *22nd International Conference on Pattern Recognition* (pp. 1437-1442). Stockholm: IEEE.
- Babiarz, P., Piotrowski, M., Pomianek, B., Wawrzynkiewicz, M., & Freund, R. (2007). *Prerequisites for successful introduction of mass customization strategy in central Europe*. Retrieved from <https://www.robertfreund.de/blog/wp-content/uploads/2008/12/freund-piotrowski-2004-ohrid.pdf>
- Beverland, M. B., & Farrelly, F. J. (2009). The Quest for Authenticity in Consumption: Consumers' Purposive Choice of Authentic Cues to Shape Experienced Outcomes. *Journal of Consumer Research*, 36(5), 838-856. doi:10.1086/615047
- Blecker, T., & Friedrich, G. (2006). *Mass Customization: Challenges and Solutions*. Springer.
- Blikstein, P. (2013). Digital Fabrication and 'Making' in Education: The Democratization of Invention. In J. Walter-Herrmann, & C. Büching, *FabLabs: Of Machines, Makers and Inventors*. Transcript Verlag.

- Bosqué, C. (2015). What are you printing? Ambivalent emancipation by 3D printing. *Rapid Prototyping Journal*, 21(5), 572-581. doi:10.1108/RPJ-09-2014-0128
- Campbell, C. (2005). The Craft Consumer: Culture, craft and consumption in a postmodern society. *Journal of Consumer Culture*, 5(1), 23-42. doi:10.1177/1469540505049843
- Carroll, G. R. (2015). Authenticity: Attribution, Value, and Meaning. *Emerging Trends in the Social and Behavioral Sciences*, 1-14. doi:10.1002/9781118900772.etrds0020
- Carroll, G. R., & Wheaton, D. R. (2009). The Organizational Construction of Authenticity: An Examination of Contemporary Food and Dining in the U.S. *Research in Organizational Behavior*, 29, 255–282.
- Church, E. M., & Oakley, R. L. (2018). Etsy and the long-tail: how microenterprises use hyper-differentiation in online handicraft marketplaces. *Electronic Commerce Research*, 18(4), 883–898. doi:10.1007/s10660-018-9300-4
- Cipolla, C. N. (2008). Signs of identity, signs of memory. *Archaeological Dialogues*, 15(2), 196-215. doi:10.1017/S1380203808002675
- Coghlan, D., & Miller, M. B. (2014). *The SAGE Encyclopedia of Action Research*. SAGE.
- Crawford, M. B. (2009). *Shop Class as Soulcraft: An Inquiry into the Value of Work*. New York: The Penguin Press.
- Creswell, J. W. (2014). *Research design : qualitative, quantitative, and mixed methods approaches* (4 ed.). Thousand Oaks, SAGE.

- Crossan, M. M., & Apaydin, M. (2010). A Multi-Dimensional Framework of Organizational Innovation: A Systematic Review of the Literature. *Journal of Management Studies*, 47(6), 1154-1191. doi:10.1111/j.1467-6486.2009.00880.x
- De Massis, A., Frattini, F., Kotlar, J., Petruzzelli, A. M., & Wright, M. (2016). Innovation Through Tradition: Lessons From Innovative Family Businesses and Directions for Future Research. *Academy of Management Perspectives*, 30(1), 1-58. doi:10.5465/amp.2015.0017
- Foote, J. (2017). Redoing is the new undoing: Workmanship of risk and certainty in digital craft. *Il Quaderno: The ISI Florence journal of architecture*, 2, 12-19.
- Frayling, C. (1993). Research in Art and Design. *Royal College of Art Research Papers*, 1(1), 1-5.
- Fuchs, C., Schreier, M., & van Osselaer, S. M. (2015). The Handmade Effect: What's Love Got to Do with It? *Journal of Marketing*, 79(2), 98-110. doi:10.1509/jm.14.0018
- Gell, A. (1998). *Art and Agency: An Anthropological Theory*. Clarendon Press.
- Gershenfeld, N. (2012). How to make almost anything: The Digital Fabrication Revolution. *Foreign Affairs*, 91(6), 43-57.
- Given, L. M. (2008). *The SAGE Encyclopedia of Qualitative Research Methods*. SAGE.
- Hallgrimsson, B., Dewar, A., & Laliberte, J. (2014). Taking 3D printing from art to science: Designing for a transformative technology. *Education Symposium*.

Austin: IDSA. Retrieved from <https://www.idsa.org/content/taking-3d-printing-art-science>

Harzer, T. S. (2013). *Value Creation Through Mass Customization: An Empirical Analysis of the Requisite Strategic Capabilities*. Retrieved from <http://publications.rwth-aachen.de/record/229868?ln=de>

Heidegger, M. (1962). *Being and Time*. Blackwell Publishers Ltd .

Holmquist, A., Magnusson, M., & Livholts, M. (2018). Reinventing tradition: Exploring the creation of new meaning through innovations involving craft-based design. *Creativity and Innovation Management*, 124-137. doi:10.1111/caim.12297

Hoskins, J. (2006). Agency, Biography and Objects. In C. Tilley, W. Keane, S. Küchler, M. Rowlands, & P. Spyer, *Handbook of Material Culture* (pp. 74-84). SAGE.

Johnston, L. (2015). *Digital Handmade: Craftsmanship and the New Industrial Revolution*. London: Thames & Hudson.

Jones, A. (2007). *Memory and Material Culture*. Cambridge University Press. Retrieved from <https://ebookcentral-proquest-com.proxy.library.carleton.ca>

Kettley, S. (2007). *Crafting the wearable computer: Design process and user experience*. Retrieved from <https://pdfs.semanticscholar.org/f1b1/717a237bff51c80ee0bc75ab42f8882a702e.pdf>

- Kolarevic, B. (2008). The (risky) craft of digital making. In B. Kolarevic, & K. Klinger, *Manufacturing Material Effects: Rethinking Design and Making in Architecture* (pp. 119-128). London: Routledge.
- Kouhia, A. (2012). Categorizing the meanings of craft: A multi-perspectival framework for eight interrelated meaning categories. *Techne Series*, 19(1), 25-40.
- Krippendorff, K. (1989). On the Essential Contexts of Artifacts or on the Proposition That "Design Is Making Sense (Of Things)". *Design Issues*, 5(2), 9-39. Retrieved from <https://www.jstor.org/stable/1511512>
- Krippendorff, K., & Butter, R (1984). Product semantics: Exploring the symbolic qualities of form. *Innovation*, 3(2), 4-9. Retrieved from http://repository.upenn.edu/asc_papers/40
- Lau, M., Mitani, J., & Igarashi, T. (2012, December 24). Digital Fabrication. *Computer*, 45(12), 76-79. doi:10.1109/MC.2012.407
- Lindley, J. (2016). Creativity, 3D printing & Design Education. *International Conference on Engineering & Product Design Education*. Aalborg: Design Society. Retrieved from <https://www.designsociety.org/download-publication/39140/CREATIVITY%2C+3D+PRINTING+AND+DESIGN+EDUCATION>
- Loh, P., Burry, J., & Wagenfeld, M. (2016). Reconsidering Pye's theory of making through digital craft practice: A theoretical framework towards continuous designing. *Craft Research*, 7(2), 187-206. doi:10.1386/crre.7.2.187_1

- Loy, J., Canning, S., & Little, C. (2015). Industrial Design Digital Technology. *Procedia Technology*, 20, 32 - 38. doi:10.1016/j.protcy.2015.07.007
- Luckman, S. (2015). Material Authenticity and the Renaissance of the Handmade: The Aura of the Analogue (or ‘The Enchantment of Making’). In S. Luckman, *Craft and the Creative Economy* (pp. 68-86). London: Palgrave Macmillan.
- Marble, S. (2010). Imagining Risk. In P. Bernstein, & P. Deamer, *Building (in) the Future: Recasting Labor in Architecture* (pp. 38-43). Princeton Architectural Press.
- Mathison, S. (2005). *Encyclopedia of evaluation* . Thousand Oaks: SAGE .
- McCullough, M. (1998). *Abstracting craft: The practiced digital hand*. Massachusetts: MIT Press.
- McIntyre, M. H. (2010). *Consuming Craft: the contemporary craft market in a changing economy*. London: Crafts Council. Retrieved from https://www.craftscouncil.org.uk/content/files/consuming_craft_full_report.pdf
- Mota, C. (2011). The rise of personal fabrication. *8th ACM conference on Creativity and Cognition* (pp. 279-288). Atlanta: ACM.
- Norman, D. A. (2004). *Emotional Design: Why We Love or Hate Everyday Things*. New York: Basic Books.
- Norman, D. A., & Verganti, R. (2014). Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change. *Design Issues*, 30(1), 78-96. doi:10.1162/DESI_a_00250

Parsons, T. (2009). *Thinking: Objects: Contemporary Approaches to Product Design*. Singapore: AVA Publishing.

Pieter, S., & Giaccardi, E. (2016). Research through Design. In J. Lowgren, J. M. Carroll, M. Hassenzahl, & T. Erickson, *The Encyclopedia of Human-Computer Interaction, 2nd Ed.* Interaction Design Foundation.

Polanyi, M. (1966). *The Tacit Dimension*. Garden City.

Pye, D. (1968). *The Nature and Art of Workmanship*. Cambridge University Press.

Redwood, B., Schöffner, F., & Garret, B. (2017). *The 3D Printing Handbook: Technologies, design and applications*. 3D Hubs.

Renda, G., & Kuys, B. (2014). The Craftsman Versus The Maker: Tensions in Design Education. *ACUADS CONFERENCE 2014: THE FUTURE OF THE DISCIPLINE*. Melbourne: Victorian College of the Arts and RMIT University.
Retrieved from
https://www.researchgate.net/publication/272295312_The_Craftsman_Versus_The_Maker_Tensions_in_Design_Education

Roskill, M. (1977). The Aesthetic Concept of Craftsmanship. *The British Journal of Aesthetics*, 17(2), 138–148. doi:10.1093/bjaesthetics/17.2.138

Rossi, C. (2013). Bricolage, Hybridity, Circularity: Crafting Production Strategies in Critical and Conceptual Design. *Design and Culture*, 1, 69-87.
doi:10.2752/175470813X13491105785622

- Russel, I. (2007). Objects and Agency: Some Obstacles and Opportunities of Modernity. *Journal of Iberian Archaeology*, 9(10), 71-87. Retrieved from <http://hdl.handle.net/2262/8698>
- Salkind, N. J. (2007). *Encyclopedia of measurement and statistics*. Thousand Oaks, CA: Sage Publications, Inc. doi: 10.4135/9781412952644
- Schön, D. A. (1991). *The reflective practitioner: How professionals think in action*. Aldershot: Ashgate Publishing Ltd.
- Semetsky, I. (2006). The Language of Signs: Semiosis and the Memories of the Future. *Sophia: International Journal for philosophy of religion, metaphysical theology and ethics*, 45(1), 95-116. Retrieved from https://www.academia.edu/442950/The_Language_of_Signs_Semiosis_and_the_Memories_of_the_Future
- Sennett, R. (2008). *The Craftsman*. Yale University Press.
- Smith, D. W. (2013, December 16). *Phenomenology*. Retrieved from Stanford Encyclopedia of Philosophy: <https://plato.stanford.edu/entries/phenomenology/>
- Smith, S. (2012, November 2). *Plastic Overdrive*. Retrieved from Changeist: <http://www.changeist.com/changelog/2012/10/30/plastic-overdrive>
- Tsoumas, J. (2013). The ideal of handicrafts and the modern design formation: coincidences and failures. *METU: Journal of the Faculty of Architecture*, 30(2), 55-63. doi:10.4305/METU.JFA.2013.2.4

- Verganti, R. (2008). Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda. *Journal of Product Innovation Management*, 28(5), 436-456.
doi:10.1111/j.1540-5885.2008.00313.x
- Vermillion, J., Anderson, J., & Rowe, D. (2014). Craft-based Education: A Model That Supports Play and Innovation. *National Conference on the Beginning Design Student Proceedings*. Chicago: NCBDS.
- Zoran, A. (2015). Hybrid Craft: Showcase of Physical and Digital Integration of Design and Craft Skills. *Leonardo*, 48(4), 384-398. doi:10.1162/LEON_a_01093
- Zoran, A., & Buechley, L. (2013). Hybrid Reassemblage: An Exploration of Craft, Digital Fabrication and Artifact Uniqueness. *Leonardo*, 46(1), 4-10.
doi:10.1162/LEON_a_00477

APPENDICES

APPENDIX A: Ethics Approval Certificate

Office of Research Ethics
503 Robertson Hall | 1125 Colonel By Drive
Ottawa, Ontario K1S 5B6
613-520-2600 Ext: 4085
ethics@carleton.ca

CERTIFICATION OF INSTITUTIONAL ETHICS CLEARANCE

The Carleton University Research Ethics Board-B (CUREB-B) has granted ethics clearance for the research project described below and research may now proceed. CUREB-B is constituted and operates in compliance with the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (TCPS2).

Ethics Protocol Clearance ID: Project # 110775

Research Team: Mr. Spase Janevski (Primary Investigator)
Bjarki Hallgrímsson (Research Supervisor)

Project Title: How the implementation of craft-based design into digital fabrication can help designers to explore the creation of innovation

Funding Source (If applicable):

Effective: **May 22, 2019**

Expires: **May 30, 2020.**

Please ensure the study clearance number is prominently placed in all recruitment and consent materials: CUREB-B Clearance # 110775.

Restrictions:

This certification is subject to the following conditions:

1. Clearance is granted only for the research and purposes described in the application.
2. Any modification to the approved research must be submitted to CUREB-B via a Change to Protocol Form. All changes must be cleared prior to the continuance of the research.
3. An Annual Status Report for the renewal of ethics clearance must be submitted and cleared by the renewal date listed above. Failure to submit the Annual Status Report will result in the closure of the file. If funding is associated, funds will be frozen.
4. A closure request must be sent to CUREB-B when the research is complete or terminated.
5. During the course of the study, if you encounter an adverse event, material incidental finding, protocol deviation or other unanticipated problem, you must complete and submit a Report of Adverse Events and Unanticipated Problems Form, found here:
<https://carleton.ca/researchethics/forms-and-templates/>

Failure to conduct the research in accordance with the principles of the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans 2nd edition* and the *Carleton University Policies and Procedures for the Ethical Conduct of Research* may result in the suspension or termination of the research project.

Upon reasonable request, it is the policy of CUREB, for cleared protocols, to release the name of the PI, the title of the project, and the date of clearance and any renewal(s).

Please contact the Research Compliance Coordinators, at ethics@carleton.ca, if you have any questions.

CLEARED BY:

Date: May 22, 2019

Bernadette Campbell, PhD, Chair, CUREB-B

Natasha Artemeva, PhD, Vice-Chair, CUREB-B

APPENDIX B: Consent form

Research Consent for Online Survey

Project Title

How the implementation of craft-based design into digital fabrication can help designers to explore the creation of innovation

Carleton University Project Clearance

CUREB-B Clearance #: 110775 Date of Clearance: May 22, 2019

Invitation

We are asking you to complete this survey because you are a design student/professional or a person interested in purchasing handmade/custom-made items. This survey is being conducted by Spase Janevski of the Carleton University School of Industrial Design (id@carleton.ca, 613-520-5672) working under the supervision of Prof. Bjarki Hallgrímsson.

Objectives and Summary:

The aim of this study is to better understand how designers can implement craft-based techniques as part of their digital fabrication practice in order to change the meaning of a 3D printed object.

We estimate that the survey will take between 5 and 10 minutes to complete. Your participation in this survey is voluntary, and you may choose not to take part, or not to submit the completed survey. Once survey responses are submitted, they cannot be withdrawn. We expect to survey a total of 100 people.

Risks and Benefits:

We do not anticipate any risks from taking the survey, nor do we anticipate that you will derive any direct benefit.

Confidentiality and Data Storage:

We will treat your personal information as confidential, although absolute privacy cannot be guaranteed. No information that discloses your identity will be released or published without your specific consent. Research records may be accessed by the Carleton University Research Ethics Board in order to ensure continuing ethics compliance.

The results of this study may be published, but the data will be presented so that it will not be possible to identify you, unless you give consent. All research data will be password-protected, and any hard copies of data will be kept in a locked cabinet at Carleton University.

Your data will be stored and protected by Qualtrics Survey Management, on servers located in Toronto, ON, but may be disclosed via a court order or data breach.

Your data will be retained for a period of 3 years and then securely destroyed.

REB Review and Contact Information:

This project was reviewed and cleared by the Carleton University Research Ethics Board. If you have any ethical concerns with the study, please contact Dr. Bernadette Campbell, Chair by phone at 613-520-2600 ext. 4085 or by email at ethics@carleton.ca.

Implied consent:

By completing the online survey and pressing 'SUBMIT', you are agreeing to participate in the study.

Researchers Contact Information:

Name: Spase Janevski
Department: Carleton University,
School of Industrial Design
Tel.: [REDACTED]
Email: spase.janevski@carleton.ca

Supervisor Contact Information:

Name: Bjarki Hallgrimsson,
Department: Carleton University,
School of Industrial Design
Tel.: 613-520-2600 x 5677
Email: bjarki.hallgrimsson@carleton.ca

APPENDIX C: Letter of invitation (email)

Letter of Invitation

Title: Invitation to participate in a research project on "How the implementation of craft-based design into digital fabrication can help designers to explore the creation of innovation"

Carleton University Ethics Clearance:

CUREB-B Clearance#: 110775

Date of clearance: May 22, 2019

Ethics Clearance for the Collection of Data Expires:

May 23, 2019

Dear Sir or Madam,

My name is Spase Janevski and I am a Master of Design student in the School of Industrial Design, Faculty of Engineering and Design at Carleton University. I am working on a research project under the supervision of Prof. Bjarki Hallgrímsson.

I am writing to you today to invite you to participate in an online survey which is part of my research project entitled "How the implementation of craft-based design into digital fabrication can help designers to explore the creation of innovation". The aim of this study is through experimental designs to inform future designers how with a hybrid combination of old-fashioned craft techniques and 3D printing they can create one-of-a-kind 3D printed artifact.

You can access the online survey through this link [\[link to survey\]](#) or through the same link provided at the end of this email. The survey should take between 5 and 10 minutes to complete and can be terminated at any time with the option to save for later or delete.

I am conducting an online survey of design students and professionals, and people interested in purchasing handcrafted or custom-made objects on craft events or websites such as Etsy. In the first part of the survey, I would like to collect your opinions and assumptions about what you consider as handmade, while in the second part of the survey, I would like to ask you to evaluate my designs that are part of this research study. Your participation in this survey will be of great benefit to me because your opinion will validate if my design experiments have fulfilled the goal of showing the designers how they can use tradition to create innovation.

Page 1 of 2

Your participation in this survey is **voluntary and anonymous**, and you may choose not to take part, or not to submit the completed survey. If you choose to take part in the survey, you will be asked to take a moment to read and download the consent form before you start with the questions. Once the survey responses are submitted, they cannot be withdrawn.

Please complete the survey no later than May 15th, 2019 to ensure that your responses can be included in the analysis. If you agree to participate in this survey, it can be accessed online here: [\[link to survey\]](#) or through the link provided at the end of this email.

This ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

CUREB-B:

If you have any ethical concerns with the study, please contact Dr. Bernadette Campbell, Chair, Carleton University Research Ethics Board-B (by phone at 613-520-2600 ext. 4085 or via email at ethics@carleton.ca).

Researcher:

If you have any further questions, please feel free to contact me through email at spase.janevski@carleton.ca.

Sincerely,
Spase Janevski

[\[LINK TO SURVEY\]](#)

APPENDIX D: Online Invitation (Social media)

Online Invitation

To be posted on Facebook group

Are you interested in purchasing handmade items?

I am looking for volunteers to participate in an online survey which is part of my research project entitled "How the implementation of craft-based design into digital fabrication can help designers to explore the creation of innovation". The aim of this study is to inform future designers how with a hybrid combination of old-fashioned craft techniques and 3D printing they can create one-of-a-kind 3D printed artifact.

During the survey, you will be asked to provide your opinion about what you consider as handmade object, while in the second part of the survey, you will be asked to evaluate designs that are part of this research study.

To be eligible, you must be English-speaking, comfortable using computers to access the internet and at least 18 years of age.

The survey should take between 5 and 10 minutes to complete and can be terminated at any time with the option to save for later or delete.

If you are interested, you can access the online survey through this link [\[link to survey\]](#).

This ethics protocol for this project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

CUREB-B:

If you have any ethical concerns with the study, please contact Dr. Bernadette Campbell, Chair, Carleton University Research Ethics Board-B (by phone at 613-520-2600 ext. 4085 or via email at ethics@carleton.ca).

Appendix E: Survey Questions

How the implementation of craft-based design into digital fabrication can help designers to explore the creation of innovation

Spase Janevski

Please take a moment to download and read the consent form.

[Consent form](#)

What gender do you identify with?

☐ Male

☐ Female

☐ Other

☐ Prefer not to say

Which of the following options best describes you?

☐ Maker / Craftsman / Artisan

☐ Potential buyer of handmade/custom-made items

☐ Design student

☐ Design professional

☐ Etsy seller

☐ Etsy buyer

☐ Other

How would you define HANDMADE with only ONE word?

Do you believe that the desire to buy a handmade reflects your identity/self-expression?

☐ Yes

☐ Maybe

☐ No

Do you believe that you can develop a stronger emotional connection with a handmade object, rather than with a mass-produced object?

☐ Yes

☐ Maybe

☐ No

Which of the following reasons affect your decision to buy or consider buying a handmade object?

☐ To support craft people / makers

☐ I prefer not to buy mass-produced items

☐ I like to have beautiful objects in my home

☐ I am fascinated by the creative process

☐ Unique objects reflect my identity

☐ Handmade is perfect for a gift

☐ It means I own something that nobody else does

☐ I admire the human skill involved

☐ Other (please specify)

When buying a handmade object, which of the following features are important to you?

- ☐ To be made by natural materials
- ☐ To be one-of-a-kind
- ☐ The function of the object
- ☐ To look beautiful
- ☐ The story behind the object
- ☐ The quality of the object
- ☐ To be able to be customized
- ☐ Other (please specify)

How much do you agree that an object made by machine can be considered as handmade?

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
☐	☐	☐	☐	☐

How much do you agree that an object made by machine and finished by hand can be considered as handmade?

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
☐	☐	☐	☐	☐

How familiar are you with 3D Printing technology?

☐ Extremely familiar

☐ Very familiar

☐ Moderately familiar

☐ Slightly familiar

☐ Not familiar at all

How much do you agree that 3D printed object can own handmade qualities?

Strongly agree

Somewhat agree

Neither agree nor disagree

Somewhat disagree

Strongly disagree

What do you see in this picture? How you will describe the objects? Please explain

How would you describe the objects from the picture with only ONE word.

For each pair of adjectives, please indicate the extent to which you believe the adjective on the left side OR the right side describes the objects on the picture.

Machine-made	☐	☐	☐	☐	Handmade
Old-fashioned	☐	☐	☐	☐	Innovative
Ugly	☐	☐	☐	☐	Beautiful
Low quality	☐	☐	☐	☐	High quality
Ordinary	☐	☐	☐	☐	Unique
Inauthentic	☐	☐	☐	☐	Authentic
General	☐	☐	☐	☐	Customized
Impractical	☐	☐	☐	☐	Practical
Boring	☐	☐	☐	☐	Exciting

Please describe the vases on the picture in the text fields below.

Vase on the left side	Vase on the right side
<input type="text"/>	<input type="text"/>

←
→

For each adjective, please indicate which adjective better describe the vase on the left side OR the vase on the right side.

	Vase on the left side	Vase on the right side
Handmade	☐	☐
Innovative	☐	☐
Beautiful	☐	☐
Unique	☐	☐
Simple	☐	☐
Customized	☐	☐
Practical	☐	☐
Emotional	☐	☐

←
→

APPENDIX F: Survey findings

The following part is the analysis of participants' responses to all sixteen (16) questions of the survey.

Q1: What gender do you identify with?

- 90% (n=73) of participants identified themselves as female, while 10% (n=8) identified themselves as male.

Q2: Which of the following options best describes you?

- 21% (n=17) of participants identified themselves as part of G1_Design
- 66% (n=53) of participants identified themselves as part of G2_Craft
- 7% (n=6) of participants identified themselves as part of G3_Customer
- 6% (n=5) of participants identified themselves as part of G4_Other

Q3: How would you define HANDMADE with only ONE word?

- According to the analysis, the words that are most repeating in participants' responses are: Unique (n=32), Craft (n=7), Creative (n=5), Special (n=4) and Original (n=4).
- The 30 most used words according to the Word Cloud generator integrated into Qualtrics software, are presented in the figure below.

Q4: Do you believe that the desire to buy a handmade reflects your identity/self-expression?

Q5: Do you believe that you can develop a stronger emotional connection with a handmade object, rather than with a mass-produced object?

Divided by groups, the results showed that there is a significant difference in “Yes” responses. In comparison with G2_Craft (58%), the majority of respondents (94%) in G1_Design believed that they can develop a stronger emotional connection with a handmade object, rather than with a mass-produced object.

Q6: Which of the following reasons affect your decision to buy or consider buying a handmade object?

According to the general results, the top two reasons for purchasing handmade objects are:

- 28% (n=23) – “To support craft people/makers”
- 22% (n=18) - “Unique objects reflect my identity”

Divided by groups, the results showed that:

- In G1_DESIGN (n=17) the most dominant reason for purchasing handmade is “Unique objects reflect my identity” with 47% (n=8), while in G2_Craft (n=53) the most dominant reason is “To support craft people” with 32% (n=17)
- In G3_Buyer (n=6) the most dominant reason is “To support craft people” with 32% (n=2)

Q7: When buying a handmade object, which of the following features are important to you?

- According to the general results, the top two features that are most important to the participants are “The quality of the object” with 33% (n=27) and “To be one-of-a-kind” with 28% (n=23), while the feature that is the least important to participants is “The function of the object” with 2% (n=2).

Divided by groups, the results showed that:

- In G1_DESIGN (n=17) the most important features to participants are: “To be one-of-a-kind” with 35% (n=6), followed by “The quality of the object” with 23% (n=4), while in G2_CRAFT (n=53) the most important feature is “The quality of the object” with 40% (n=21), followed by “To be one-of-a-kind” with 26% (n=14).

Q8: How much do you agree that an object made by machine can be considered as handmade?

According to the general results from all participants (n=81):

- 19% (n=15) strongly disagree, while 27% (n=22) somewhat disagree that an object made by a machine can be considered as handmade
- 20% (n=16) neither agree or disagree that an object made by machine is handmade
- 25% (n=20) somewhat agree and 10% (n=8) strongly agree that an object made by a machine can be considered as handmade

- On a scale of 1 to 5 (1=Strongly disagree / 5=Strongly agree), the average agreement per group is:

Q9: How much do you agree that an object made by machine and finished by hand can be considered as handmade?

According to the general results from all participants (n=81):

- 5% (n=6) strongly disagree, while 15% (n=12) somewhat disagree that an object made by machine and finished by hand can be considered as handmade
- 16% (n=13) neither agree or disagree that an object made by machine and finished by hand can be considered as handmade
- 41% (n=33) somewhat agree and 22% (n=18) strongly agree that an object made by machine and finished by hand can be considered as handmade

- On a scale of 1 to 5 (1=Strongly disagree / 5=Strongly agree), the average agreement per group is:

Q10: How familiar are you with 3D Printing technology?

According to the general results from all participants (n=81):

- 14% (n=11) of participants were not familiar at all, 21% (n=17) of participants were slightly familiar, 35% (n=28) of participants were moderately familiar, 20% (n=16) of participants were very familiar and 11% (n=9) of participants were extremely familiar

- On a scale of 1 to 5 (1=Not familiar / 5=Extremely familiar), the average familiarity per group is:

Q11: How much do you agree that 3D printed object can own handmade qualities?

- 12% (n=10) strongly disagree that 3D printed object can be considered as handmade
- 14% (n=11) somewhat disagree that 3D printed object can be considered as handmade
- 22% (n=18) neither agree or disagree that 3D printed object can be considered as handmade
- 38% (n=31) somewhat agree that 3D printed object can be considered as handmade
- 14% (n=11) strongly agree that 3D printed object can be considered as handmade

- On a scale of 1 to 5 (1=Strongly disagree / 5=Strongly agree), the average agreement per group is:

12: What do you see in this picture? How you will describe the objects? Please explain.

The text responses were analyzed with content analysis.

Number	Responses	THEMES	CODES
1	Restoration of broken cups	Making	M
2	unique oil burners	Function	Uniqueness
3	eccentric style and decorative function	Style	Function
4	Candle holders made from mugs	Function	Making
5	The maker tried to create a visual story. It is clear that the function was not in first plan.	Story	Function
6	beautiful	Expression	Aesthetic
7	3D objects that can be used for different occasions. It's an interesting combination of colours and	Function	Form
8	Hand crafted vases	Function	Making
9	Pottery	Form	PM
10	They first appear as drinking mugs but with the 3D printed cutouts, they appear more as a display piece	Function	Form
11	Jug due to the shape but I would expect it to hold liquid so it doesn't seem of any use other than as a decorative item so Decorative Jug.	Function	Form
12	Piece of decor since the design is not functional.	Function	Form
13	Pottery	Form	PM
14	Nice	Expression	E
15	ceramic and 3d printed display pieces	Material	Function
16	Vintage vases	Style	Function
17	Creative, original, unique	Uniqueness	Aesthetic
18	Ornament. We can place them as part of the living room furniture.	Function	Home
19	White, blue, and grey ceramic plaster blended to make a unique statement piece	Making	Function
20	Very deep and emotional products	Expression	Emotion
21	Beautiful vases	Aesthetic	Function
22	Innovative pots	Function	F
23	New function and form	Function	Form
24	Unique, useful, interesting	Uniqueness	Function
25	Cups you can't easily use	Function	F
26	Unique pottery jars	Uniqueness	Function
27	I see intricate mug-shaped vessels. Due to their filigree hole structure, I would guess they were vessels for holding solid objects rather than liquids. The glazed are beautiful and I love how the colors work together. The white filigree reminds me of bone structure, which I think is awesome.	Form	Function
28	Cups, made of plastic and ceramic	Material	Function
29	decorative vases	Function	Making
30	Three mixed-media mugs, conceptualised as art pieces	Making	Function
31	handmade mugs for decorative purposes only	Making	Function
32	A mixed ceramic and 3D printed object	Material	Making
33	Candle holders made by broken pieces	Function	Making
34	A picture is thousand words as they say. I sense a philosophical story behind the development of objects. I feel if these are sold, there should a small card or note that should go with it which indicates the story behind the making of such object.	Story	Making
35	A candle holder shaped like a mug, the functionality of a mug doesn't exist as much because of the holes present, however it still as a handle.	Form	Function
36	Coffee mugs	Function	Association
37	Decorative mugs. Mugs with gradient colours with blocks of white holes	Function	Form
38	3D printed mugs, experimenting with form and function, combined techniques.	Form	Function
39	A different perspective on mugs and a freedom in expression.	Story	Making
40	Decorative cups	Function	F
41	Beautiful designed mugs	Aesthetic	Function
42	Art piece mixed up with a 3D printer and handcrafted. It seems to me more art than real product. In different words, not sure about the functional perspective or even the sustainable approach.	Story	Function
43	3d printed mugs or plant holders? Would not be functional as they have holes in them, so maybe decorative mugs.	Form	Function
44	First I see that they are mugs. Second, I see a combination of pottery and precise manufacturing which is probably 3d printing. Third, I see that all three mugs are unique in their own way and have their own identity.	Making	Function
45	vases, jugs, pitchers, mugs	Function	F
46	They look like drinking mugs but obviously not for drinking, I'm not sure what they would be used for other than a vase	Function	Form
47	Pottery cups with cut out areas	Making	M
48	Decorative mugs. They don't seem functional	Function	F
49	Ceramic mugs. Looks like they have been painted	Material	Making
50	I see three cups or planters	Function	F
51	Candle decorations	Function	F
52	Pottery mugs	Form	Function
53	Coffee mugs but not for use, just display	Function	F
54	Candle holder	Function	F
55	Decorative pottery	Form	PM
56	Creative made not for function but for artistic value	Function	Story
57	Decorative mugs	Form	Function
58	Use vase	Form	F
59	Oil burners	Function	F
60	Art	Function	F
61	Decorative pitchers	Function	F
62	Beautiful, handmade mugs	Aesthetic	Making
63	Very unique coffee mugs for display purposes only	Uniqueness	Function
64	Jugs made with ceramic and 3D printing. They're beautiful	Making	Material
65	Beautiful artisan vase/decors. These hand crafted designs are beautiful and unique	Style	Uniqueness
66	Mugs	Function	Uniqueness
67	3 mixed medium containers.	Function	F
68	Candle holders. Cute, creative	Expression	Function
69	Unique mugs. Obviously 3-D printed. Stoneware and printed mugs?	Aesthetic	Making
70	One of a kind	Aesthetic	F
71	One of kind plant holder	Aesthetic	Function
72	Its a type of craft. 3d print mixed with pottery	Making	Material
73	Unique	Uniqueness	U
74	Hand made mixed with plastic 3D which is cute for decoration.	Making	Material
75	A handmade craft/pottery combined with like a plastic material which is a machine made. So it's interesting.	Making	Material
76	Wabi sabi inspired artifacts. The function is clearly not intended for liquids. Perhaps decorative.	Style	Function
77	Combination of pottery and futurism	Style	Story
78	I see decorative products that can be placed as an artistic piece	Function	Story
79	Unique and exotic craftery, combination of modern vs old	Story	Uniqueness
80	Pottery coffee cups that don't hold liquid	Function	F
81	In my opinion, these objects look like clay candlesticks in the form of cups or mugs	Form	Function

According to the content analysis, ten different categories of interpretations emerged from the data. The top three categories of interpretations were related to: the function of the object (44%), the process of making (14%) and the form of the object (12%).

In relation to the functional meanings, there were participants that gave new function to the object. For example:

P.2: “Unique oil burners”

P.8: “Hand crafted vases”

P.18: “Ornament. We can place them as part of the living room furniture”

P.33: “Candle holders made by broken pieces”

P.81: “In my opinion, these objects look like clay candlesticks in the form of cups or mugs”

In addition, there were participants who were trying to make sense of the object through functional perspective. For example:

P10: “They first appear as drinking mugs but with the 3D printed cut-outs, they appear more as a display piece”

P46: “They look like drinking mugs but obviously not for drinking, I'm not sure what they would be used for other than a vase”

Q13: How would you describe the objects from the picture with only ONE word?

- According to the analysis, the words that were most repeating in the description of the objects were: Unique (n=15), Décor/Decorative (n=6), Art (n=5) and Interesting (n=4)
- The 30 most used words according to the Word Cloud generator integrated into Qualtrics software, are presented in the picture below.

Q14: For each pair of adjectives, please indicate the extent to which you believe the adjective on the left side or the right side describes the objects on the picture.

Respondents were rating object's attributes, using a 5-point bipolar rating scale. According to the results, eight out of nine attributes finished on the positive side of the scale, leading by "Unique" with an average of 1.53, while on the other side "Impractical" finished with an average of -0.35.

Filtered by groups, the analysis showed that there is a very similar pattern in the participant's responses. The division of the results pointed out that the craft community (G2_CRAFT) believe more than the design community (G1_DESIGN) that the objects on the picture are "handmade" and "innovative". On the other side, G1_DESIGN gave a better score to "beautiful" and "customized" in comparison with G2_CRAFT.

Q15: Please describe the vases on the picture in the text fields below.

Participants were provided with two text fields where they were supposed to describe the vases on the pictures. Regarding the size of the answers, there was no limitation about the text entry, but the results showed that half of the participants chose to describe the vases with only one word. For example:

- The vase on the left side was described with words such as: White, Modern, Pure, Simple, Minimalistic and Unfinished.
- The vase on the right side was described with words such as: Abstract, Artistic, Chaotic, Unique, Colorful and Painted.

16: For each adjective, please indicate which adjective better describe the vase on the left side or the vase on the right side.

- According to participants' responses, five out of eight adjectives better describe the right vase in comparison with the left one.
- The adjectives that describe the right vase are the following: Unique (n=70), Handmade (n=63), Customized (n=62), Innovative (n=60) and Emotional (n=56).
- On the other side, the adjectives that fit better the left vase are: Simple (n=67), Practical (n=55) and Beautiful (n=51).