Digital Craftsmanship: practitioners' principles and their significance for defining a community of practice

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Digital Craftsmanship: practitioners' principles and their significance for defining a community of practice

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Si attraversa un deserto per ogni mare

Abstract

Through the last two decades the spectrum of artefacts produced at the intersection of digital and hand-making processes has increased, seeing novel artefacts emerging under the umbrella of *digital crafts*. However, the challenge remains to specify a distinct set of shared characterising *principles* able to describe digital craft practitioners' ethos as a community. Through the identification of shared *principles* practitioners could start more easily defining their community, developing an affinity among each other, and possibly interacting with other experts in the field – which is argued to be fundamental to ensure future acquisition, transfer, and preservation of *tacit knowledge*.

This work explores the landscape of digital craftsmanship within Design Research and practice-based communities, highlighting the disparate backgrounds of digital craft practitioners. A combination of *ethnographic*, *auto-ethnographic*, and *para-ethnographic* approaches were adopted to articulate underlying *principles* by which digital craft practitioners can be addressed as a community of practice with shared motivations and ethos. Central to this study is the use of *Kelly's Repertory Grid* framework, through which the researcher supported and facilitated a set of diverse expert practitioners to reflect on a range of examples of digital crafts and making processes. Through the insights obtained using these methods, and supported by theoretical debates unpacked through a critical contextual review, three principles currently shared among digital craft practitioners are tentatively proposed as a key contribution from this research: (1) digital craft practitioner's nurture creative complex imitative learning through craft material knowledge, (2) they strongly believe aspects of the making-process need to include mostly "polymorphic" actions as opposed to "mimeomorphic" sequences, and (3) their main motivation is bound to

the making process as it expresses the practitioners' material *contributory expertise* –rather than the reaction or experience their outputs could elicit in viewers/users. These *principles* offer a definition of the community considering digital craft practitioners' perspectives, providing the opportunity for practitioners and several stakeholder groups to engage with a provisional description of the community. Moreover, they set the basis for future research in the field and reflections on digital craftsmanship as a form of both explicit *and* tacit knowledge.

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Acknowledgments

Many of my former colleagues, whom I can now successfully call Doctors, have been metaphorically describing the journey of a PhD as climbing a mountain of which you are unable to see the tip until the very end. I believe that climbing is a metaphor suggesting that a sense of direction and progression is never lost throughout the journey. No matter the height you might be looking from, when climbing you can always get some perspective by comparing your current position to the starting point. Personally, I would rather describe the journey of a PhD as being offshore, in the middle of the Ocean, and with very few but sturdy technologies supporting the navigation process. While navigating in the open, you look out and you see only water: it might truly feel that you are getting nowhere until you hit the coast. While sailing, you don't know where about in the journey you are standing at, you get a couple of storms and a few sunny and pleasant days, but you are stuck on the boat until you ultimately get back on land, and the only way to get there is to keep going and to trust the navigation process. While this might sometimes not be easy, the captain is never alone throughout the journey. Therefore, it is unequivocally thanks to others if the shore is ever reached by the end. As I am now sighting on the horizon what could effectively be the coast, I would like to thank all the persons who were there throughout these years and who truly and undoubtedly helped me reaching this milestone.

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Da Livorno a Roma, passando per Sofia, GRAZIE.
Un grazie speciale va a Mamma, Nicolò e Nonna Germana: siete stati i miei più grandi sostenitori. Grazie anche al piccolo Lucky per il supporto emotivo: quest'estate eravamo spesso io e lui in casa a scrivere, mentre tutti andavano al mare.

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I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions of the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the University Ethics Committee on the 11th of February 2019 .

I declare that the Word Count of this thesis is 75454 .

Name: Erica Vannucci

Signature:

Date: 31 August 2021

CHAPTER 1. Introduction

The interest in digital fabrication and as a consequence in computational tools, has been producing a diverse range of innovative methods and form-finding techniques (e.g., generative design, parametric design and algorithmic design) that have been revolutionizing many fields in design and manufacturing. Hand skills have had to re-negotiate their presence and significance for the second time since the Industrial Revolution, both in relation to technology and the engagement with materials.

The philosophical effort devoted to the analysis of the relation between the body, cognition, materials, and tools / machinery, have been –and still are– revisited, discussed and expanded throughout the last decades (McCullough, 1998; Sennett, 2008; Pallasmaa, 2009). Along with this, our notion of what it means *to make* or *craft* and, even more significantly, what it means to be a *maker* or a *craft practitioner,* continues to be disputed (e.g., Ingold, 2010; Shiner, 2012; Shorter, 2015).
Although these debates are still ongoing, there is a broad recognition that our sensory-motor functions play a fundamental role in understanding the world around us and, ultimately, in actively engaging with it (i.e., ecological views on perception). It is argued that complex actions cannot be solely articulated but should be directly experienced through practice and the direct engagement of the body with the material world (Dewey, 1986; Schön, 1938; Ryle, 1945). Moreover, it has been argued that sometimes actions simply cannot be articulated but can only be transmitted through practice. Michael Polanyi's (1945) famous *bicycle example* has become one of the most used examples to describe the importance of the body in human knowledge acquisition and transmission. Once we learn how to ride a bicycle, and we must do it through practice through attempts and failures, we just

know how to do it for the rest of our lives without being able to fully explain how it works and all the rules involved in the action in an explicit way.

Polanyi's statement on the *Tacit* dimension of knowledge "*we know more than we can tell*" (Polanyi, 1966, p.4; *italics in original*), has also become one of the most used examples to describe *Tacit Knowledge*. The link tacit knowledge has with craftsmanship is that a significant portion of the knowledge embodied in craftsmanship is a prime example of *Tacit Knowledge.* Hence, in craftsmanship practices, *Tacit Knowledge* has often been used as a way to explain how embodied action relies on making expertise and, experiential / non-propositional knowledge and its variations (Williams, 2001; Grayling, 2003; Niedderer, 2007; Niedderer & Roworth-Stokes, 2007).

Niedderer and Townsend (2014), while acknowledging the limits of knowledge transmission that craft practices inevitably have, due to the nature of its tacit dimension, encouraged practitioners to describe, share and discuss their experienced knowledge. They write:

> "Recognizing experiential and emotional knowledge as agents for intrinsic understanding, interpretation and judgement is key (...) because of craft's affinity with human values. Therefore, it is essential to make these values and judgements explicit as part of any research" (Niedderer & Townsend, 2014, p.641).

The hope being that through better and improved articulation, practitioner's judgement criterias, unconsciously used while making, would clarify and advance craft-based research and overcome the perceived dichotomy between the needs of the crafts sector and the traditional requirements of conducting research.

More recent studies have argued that *Tacit Knowledge* can be broken down into three main degrees of resistance to being made explicit, namely: *Relational,*

Somatic and *Collective tacit knowledge* (Collins, 2010). This clarification is significant as it underlines that even if the core of craftsmanship practices often rely on the concept of *Tacit Knowledge* to imbue value to those tacit aspects that lie in creativity and skills of the practitioners, there are ways to uncover aspects of knowledge that we thought being inherently and immutably non-explicable *(Tacit)* thus are simply not explicitated yet (i.e., while possibly explicable they are not yet made explicit). In other words, activities that are claimed to be entirely *Tacit* can in fact be explicitated to some degree if the makers wish to do so, or the right environment/conditions are fostered, which is the reason why Niedderer and Towsend's suggestion is of important relevance to this thesis.
Further studies on the tacit dimension of knowledge have shed light on the fact that, while the possibility of better explicitating knowledge is valid under certain circumstances (e.g., if the degree of resistance falls under *Relational* or *Somatic tacit knowledge* it allows further explication), certain types of actions relying on *Tacit Knowledge* will always remain *Tacit*.

While craftsmanship is being redefined and revalued in the digital age (Bernabei & Power, 2018), many scholars from various disciplines (e.g., Design, Human Computer Interaction) have been engaging with the topic of Digital Fabrication over the last 20 years. Contrasting this relatively new concept with hand-making, digital fabrication has been compared to industrial/automatized processes that work with almost no human involvement in the making, where the shifting role of hands and technologies in the active engagement with materials is devaluing the latter, engendering a sense of loss in our heritage (Pallasmaa, 1996, 2009). Several researchers working in the design research field have been promoting craft sensitivities demonstrating the worth of traditional craftsmanship knowledge transmission, and addressing how craft values could result as valuable assets in the field of digital making/fabrication (e.g Wallace & Press, 2004; Niedderer & Townsend, 2014; Bardzell et. al, 2012; Nimkulrat, 2012; Bernabei & Power, 2018).

Indeed, through the last two decades the richness of the spectrum of artefacts produced with the aid of digital technologies within craft practices has been growing, emerging under the umbrella concept of *Digital Crafts*. However, Frankjær and Dalsgaard (2018) in their recent study of craft-based approaches in the Human Computer Interaction (HCI) community, underline how *Digital Crafts* have become a "fuzzy area", where terms used to describe different approaches are often used interchangeably, reinforcing ambiguity and "discrepancies of the definition of craft itself" and making it harder "to establish a common frame of reference" (Frankjær & Dalsgaard, 2018, p.474). Also, researchers such as Nitsche and Weisling (2019), underline how differentiating the traditions of craft and personal fabrication/digital media from each other, focusing on "distinct materials and divergent practices, histories, and communities", has on one hand fueled emerging interesting interdisciplinary approaches, while on the other hand it has endangered the fields "to diffuse into an unspecific amalgamation of neither" (Nitsche & Weisling, 2019, p.684). Consequently, the difficulties in sharing and discussing craft-based approaches among different communities associated to this area of practice (i.e technologists working with craft-processes, craftspeople who have adopted digital production tools, craftspeople who have adopted digital interaction tools, digital natives who have only ever used digital tools), has grown, making it more difficult to clearly understand the nuances of the standards valued in *Digital Crafts* by such a diverse community.

In traditional crafts practices, mastery of specific processes and techniques applied to a specific medium provide the foundation for a practitioner to be recognised as an expert in the field (Sennett, 2008). As a consequence, the Master becomes a social authority within the community as their commitment to achieve high, ideal standards, is regarded as the ethos and social value that a new beginner in the field should be striving for.

These standards have also been referred to as “guiding principles or criterias of success, or satisfactorily appropriate results” (Landry, 2011, p.115). They do not refer to specific technical details, rather they refer to “high crafting standards and social responsibility . . . The master can assess when to depart from convention or tradition, what to alter and why” (Ibid., p.115).

In 1996, scholars Keller and Keller produced a study where they aimed at describing the situated learning behind the practice of blacksmithing. Through the articulation of the virtues lying in the creativity of blacksmiths, they attempt to define the identity of a whole community. These virtues are addressed as *principles* by the authors and have been collected from an attentive analysis of the smith’s conversations about their artefacts, and additionally, from their own observations of the practitioner’s qualities that “are expressed implicitly in their products, performances and literature” (Keller & Keller, 1996, p.52).

The *principles* identified by Keller and Keller “represent ideals of the community members and direct a smith’s initial approach to the project [the project of the craft]” (Ibid., p.52). The *principles* are fundamentals for the community and even if partially rooted in the historical/ political background of the discipline, they refer to implicit rules or guidelines needed while smithing. Keller and Keller categorised them into three main principles: *transformation, thinking hot, and working freehand* (Ibid., pp.52-58). Through understanding these overarching approaches, Keller and Keller could describe the complex capabilities of blacksmithing and their community ethos.

The examples mentioned bring in focus the key problem posed by the evidence of several distinct emerging perspectives on the constitutive features of *Digital Crafts*.

Indeed, the perspectives which have been advanced by researchers studying the field of *Digital Crafts* still lack homogeneity and delineation of a distinct area of research or a distinct community of practice (Frankjær & Dalsgaard, 2018; Nitsche & Weisling, 2019) if compared to more traditional craft communities that have been studied for longer by researchers with the aim of understating their ethos (i.e., *principles*). These discrepancies on the definition of *Digital Craft* and its community will be extensively articulated in the research to underline the repercussions on the way practitioners acquire and transmit deeper layers of *Tacit Knowledge*. This research focuses on these concerns.

1.1 Research Question

Through the contextual review and the gaps evidenced, two significant research tasks have been identified:

a) Identifying and defining (i.e., clarifying) some distinct and shared emerging perspectives and *principles* that are considered significant by digital craft practitioners.

b) Articulating as clearly as possible both shared features and key differences among those perspectives, with a view to foster a wider understanding across the breadth of digital making practices, and so provide an evidenced set of *principles* that will help inform and frame future work.

Therefore, the guiding research question of this thesis is:

- ***What are the underlying principles that characterise a digital craft practitioner's ethos?***

This overarching question evolved into two sub-questions, namely:

- *What is their significance in relation to understanding forms of knowledge acquisition and transmission in the field of digital craftsmanship?*
- *What are the implications of this new understanding for the field of digital craftsmanship?*

1.2 Research Aims and Objectives

This extensive work on digital craft-oriented practices aims at getting hold of a set of guiding *principles* characterising digital craft practitioner's ethos and, therefore, aims at providing a clearer understanding of *digital craftsmanship* as a practice and how it differentiates from other forms of making. In other words, this research will not touch upon technological innovation or speculations of possible future technological innovations, nor the craft sector development (e.g., what digital fabrication and its acquisition brings to the current economic model etc.). Whilst the nature of this project is epistemic, and it will study and try to articulate the contemporary craft practitioners' *status quo*[1].

Hence, the aims of this research can be listed as it follows:

- To identify and articulate the underlying *principles* that characterise a digital craft practitioner's ethos.
- To identify those aspects of their making process that, while being *Tacit*, might have a lower degree of resistance to being made explicit, in order to develop effective strategies for the further development and establishment of *digital craftsmanship*.

[1] 'status quo' (from latin literally in eng: "the state in which"), meaning: *the current state of things*. In its sociological sense it refers to existing social structures and/or values of a specific community.

- To propose a set of actions and strategies that would help scaffold the field and activity of digital craftsmanship in the future.

The objectives to achieve these aims were:

- To undertake an overarching review of digital craftsmanship and how its theoretical debates have evolved in the last two decades.
- To critically examine the types of knowing within craft practices, with a focus on the ways in which *Tacit Knowledge* is acquired and transmitted.
- To develop *interactional knowledge* in the field of *digital craftsmanship.*
- To gain first-hand experience using digital tools within the context of a crafts practice through undertaking a series of making projects.
- To explore the nature craft practices through extended observation and discussion with a range of craft practitioners.
- To facilitate a series of structured activities and interviews with expert digital craft practitioners to inform a theoretical and contextual understanding of *digital craftsmanship*.

1.3 Thesis Structure

To help the reader better navigate and understand the reasoning and research process that developed and evolved during the project, the researcher divided the thesis into two main parts. Overall, the thesis consists of 7 chapters, the first two of which are the Introduction of the thesis, (including its scope, its intent, the background of the researcher and the aims and objectives of the research project) and the Methodological Chapter (Ch.2).

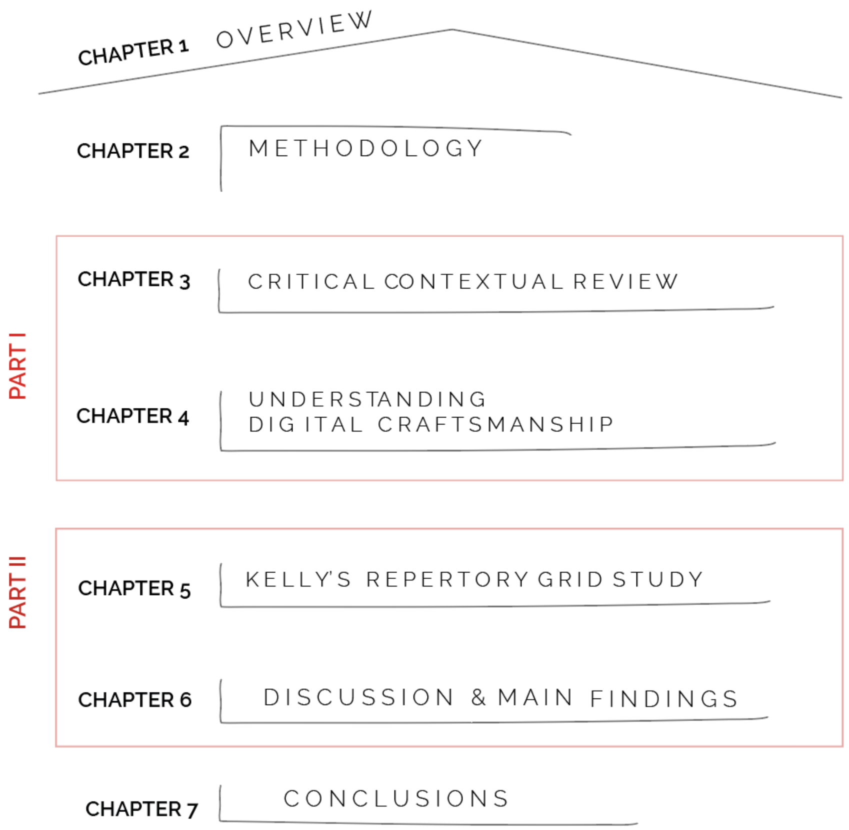
The remaining Chapters are divided into two parts.

As illustrated in Figure 1, Chapters 3 & 4 are pillars of PART I: here are developed the Critical Contextual Review (Chapter 3) and the *auto-ethnographic* and *ethnographic* research activities (Chapter 4).

Chapter 5 is the core of the thesis' PART II. This chapter is marked by a change of the methodological choice, and it describes in detail the study conducted and gathered data. Chapter 6 discusses the findings deriving from the data and Chapter 7 concludes the thesis. In the following, the researcher provides a more detailed description of the chapters of the present dissertation.

Figure 1.

Thesis structure



Chapter 2 describes the Methodology undertaken; it addresses how the methodological approaches have developed throughout the evolution of the methods in the quest to find an effective way of exploring the subject needs. The Chapter is unorthodoxically placed at the very beginning of the thesis, even before the Critical Contextual Review (Chapter 3), because the contextual review is considered as part of the methodology itself as it will be described more in detail in the thesis. The methodology was divided into two main parts as the first part describes the methodological approaches used in the initial stages of the project (PART I) while in the second part the researcher uses a different methodology (PART II).

PART I

Chapter 3 is the Critical Contextual Review. The chapter is divided into two main Sections: S*tate-of-the-art of digital crafts* (Section 3.1) and *Understanding digital craftsmanship through the complexities of Tacit* and *Explicit Knowledge* (Section 3.2).

Section 3.1 is a snapshot of the artefacts produced in the field. This part of the chapter is not meant to provide an exhaustive review of the artefacts produced in the field; thus, it provides a diversified spectrum of crafted pieces selected by the researcher. The pieces were selected with the aim of addressing, through these examples, the theoretical debates undergoing through the short history of digital crafts. The researcher articulates a reviewed body of literature on digital craftsmanship organised into main themes providing a full overview of the most relevant debates concerning the topic of *digital craftsmanship*. Some paragraphs address aspects mostly related to the *digital* aspect of things, others focus on the hands-on and *crafting* qualities of the practice, materials, and processes.

Instead, Section 3.2 reviews a body of theoretical literature concerning the key area of *Tacit* and *Explicit Knowledge* in relation to traditional craftsmanship practices. The researcher provides an overview of the theoretical debates concerning *Tacit* and *Explicit Knowledge* acquisition and transmission, a topic that will be returned to in the discussion section.

Chapter 4 describes the first steps undertaken in the understanding of the context of the research topic through auto-ethnography and ethnography. The first section of the chapter describes a series of small *auto-ethnographic* reflections. While articulating the researcher's experience using digital fabrication technologies – adopting a CNC machine–, through the description of several projects that took place in this exploratory phase the researcher will articulate her role in the research project and how it developed throughout time and why.
In the second section the researcher addresses the *ethnographic* fieldwork carried out in the first part of the project. In this phase, different craft practitioners were observed in their studios and open-ended interviews were carried out. The researcher gives an overview of the material acquired during this observational phase and through the interviews, and the insights gained. The end of the chapter will focus on the key theme of "interactional expertise". Through the insights coming from the literature review, the *auto-ethnographic* and *ethnographic* activities, the researcher was able to critically reflect upon the *interactional expertise* that all the above activities provided her with. These insights prompted the researcher to change the methodological approach and to start the conclusive phase of the project which is described in the second part of the thesis.

PART II

Chapter 5 addresses the Kelly's Repertory Grid (KRG) study conducted in the research. This chapter describes in detail how the study was conceived, designed, and carried out. Moreover, the researcher in this chapter describes and analyses the gathered data.

Chapter 6 is the discussion of the thesis. The Chapter combines the outcomes deriving from Part I with those deriving from the KRG study conducted in Chapter 5. Through this process the researcher articulates a few principles tentatively describing the community of practice studied.

Chapter 7 is the conclusive chapter of the thesis. Here the researcher addresses how the aims and objectives of the thesis were met, underlines the limitations of study, and suggests some further possible lines of work.

1.4 Publications and research activities

Alongside more informal occasions, the researcher had valuable more formal opportunities to discuss the researched theme in different venues and with different communities.

In collaboration with her supervisor Dr. Justin Marshall and other two co-authors, the researcher organised a workshop at the *Designing Interactive Systems 2018* (DIS'18) conference held in Hong Kong. The workshop, *Handmaking Food Ideals: Crafting the Design of Future Food-related Technologies* (Vannucci et al., 2018) can be found in Appendix D.

Moreover, in collaboration with Dr. Justin Marshall and Dr. Jayne Wallace, the researcher organised a second workshop held at Northumbria University. The outcomes derived from the analysis of the data gathered through this workshop were later presented at *Research Through Design 2019* (RtD'19) conference held in Delft. The full paper presented is *Enticatypes: exploring how artefacts can entice conversation on craft values in digital making* (Vannucci et al., 2019) and it can be found in the Appendix E.

CHAPTER 2. Methodology

Before going into the details of the methods and approaches used in the thesis, it is crucial to give an overview of the researcher’s methodological position, as it forms the basis for the entire study.

The study is of epistemological nature, which is that area of philosophy concerned with analyzing the very notion of knowledge and the processes underlying its production, validation, and transmission.

Using a multi-method approach, the researcher uptakes a “bricolage” of the most suitable strategies in relation to the context of the study, constructing a “complex, dense, reflexive, collage-like creation that represents the researcher's images, understandings, and interpretations of the world” (Denzin & Lincoln, 1994, p.2-3).

Gray and Malins (2016) differentiate between spectacles, sieves and filters as metaphorical tools helping researchers visualise the research process. Spectacles and sieves are the means by which researchers “focus, capture and distil value and meaning” (Gray & Malins, 2004, p.131). Different lenses in the spectacles allow us to see the world in different ways; they help the researcher to focus on certain themes whilst not being distracted by others. Instead, filters help the researcher discard grounds to obtain essential distilled liquids. All these tools are metaphors for the set of criterias the researcher adopts as they result from the relationship between the inquirer and the “knowable” (Ibid., p.19). Through a multimethod inquiry, the researcher aims to question the world rather than create objective categorical answers to solve specific issues.

Based on Neuman’s (2000) view on the world, the researcher assumes that the world is not knowable objectively but *subjectively*: it is impossible for the researcher to take a completely neutral role as knowledge is always value-led and never impersonal.

Therefore, the epistemological position adopted by the researcher is that we socially construct the world around us in that we co-create our understanding of ourselves and the world in which we live, while interacting within our culture and society (Berger & Luckmann, 1966). Specifically, we tend to construct our world within our community and others (Mead, 1934). With these premises, the researcher explores the inquiry relying on *subjectivism* (Neuman, 2000), through an overarching *constructivist* approach (Willis, 1995).

A *constructivist* theoretical approach relies on the researcher's continuous revisioning and reflecting over the designed research process. *Constructivism* requires a non-linear and sometimes seemingly chaotic design process: precise objectives emerge from the developments within the design process rather than being set in stone from the start. In other words, the understanding of the research objectives and tasks emerge with time through an iterative understanding of the *context* of interest, the actors – objects of the study – and their collaboration in the research process (Knight & Cross, 2012).

Moreover, its subjective nature derives from the constant interactions between the inquirer and the inquired in their continuous effort of generating new meaning. Through these interactions, using *hermeneutic* and *dialectic* approaches, the researcher aims at finding and eliciting from the inquired subjects their individual constructions of the world. These constructions can be then refined and compared to generate constructions of the world on which there is a substantial consensus (Gray & Malins, 2004, p.20). It follows that the possibly 'objective' dimension of knowledge is better construed as 'intersubjective'.

Recognising that "multiple realities exist as a personal and social construction" (Ibid., p.19), the researcher argues for the importance of *reflexivity* (Schön,1987).

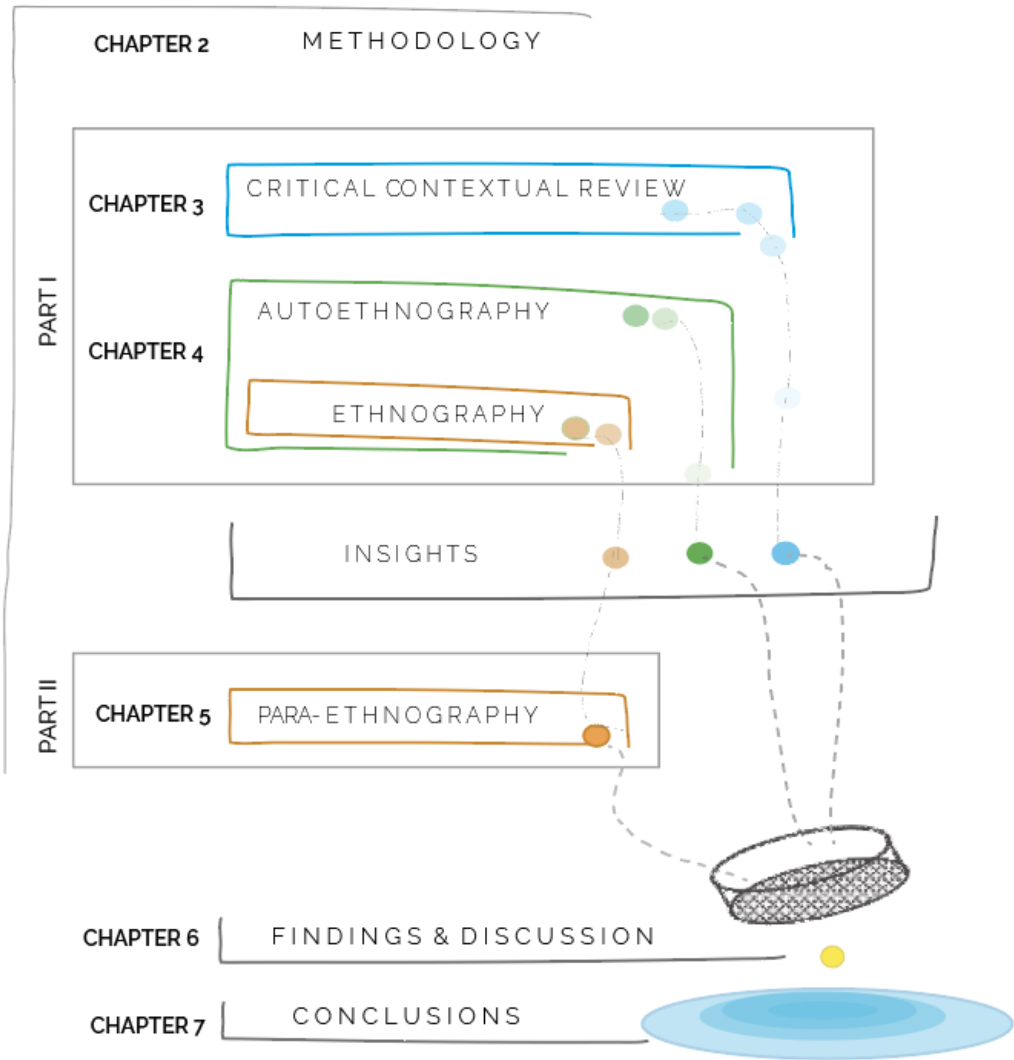
Reflecting *on-action* and *in-action* (Schön,1987) about and through the process, allows both iterative reframing of the research inquiry (Scrivener, 2000) and a deeper understanding of the researcher's thinking.

In this Chapter, the researcher will describe the various methods used throughout the research process. The division of the thesis into two main parts is to a certain extent explained by the chosen methodological approaches; for this very reason, this Chapter is also divided into two main Parts (I and II). Hence, the Methodology Chapter was unorthodoxically placed before the contextual review (Chapter 3). In this research project, the reviewing of the literature is seen as a methodological strategy and active part of knowledge generation rather than a descriptive, introductory piece of work to the inquired topic (subsection 2.1). Moreover, the Methodological chapter will address the validity and appropriateness of this approach.

As we can see in Figure 2, Chapter 1 can be seen as an overarching framing for the thesis, while Chapter 2 addresses the methodological strategies undertaken in the development of the research project in both Parts I and II.
Part I includes: (a) the Critical Contextual Review, (b) the *Auto-ethnographic* and (c) the *Ethnographic* stance. These three methods were fundamental to gather the initial understanding on the inquiry and first insights. These outcomes are described in Chapter 7. Through this first exploratory part, the researcher understood that the methods undertaken were not working for the breadth and depth of insights she was willing to uncover, therefore, the researcher decided to take a (d) Para-ethnographical approach for the second part of the thesis. The reasoning behind this decision will be thoroughly articulated in Sections 2.2 and 2.4 of this Chapter.

Figure 2.

What the Methodology entails



Note. The Methodology (Chapter 2) is divided into Part I containing the Critical Contextual Review (Chapter 3), the *auto-ethnographic* stance and the *ethnographic* approaches (Chapter 4), while Part II comprehends the (c) *para-ethnographic* stance (Chapter 5).

PART I

The first part of the research is iterative, exploratory, and descriptive (Neuman, 2000, p.38). Its purpose is to examine the research field and develop preliminary ideas about it, painting a picture of the *context* studied. To do so, the researcher adopted a diverse set of approaches that will be described in the following subsections.

2.1 Contextual Review

Digital craftsmanship is a relatively new topic of research and there has been limited previous work in the conceptualisation of digital crafts in relation to a multidisciplinary and holistic body of literature (i.e., literature coming from different fields of research). Indeed, the researcher did not find in the extant literature any reliable conceptualisation of digital crafts in relation to traditional craft practices and knowledge transmission to produce a sound summary of the evolution of craftsmanship practices in the last two decades. Therefore, an Integrative Literature Review method was used to conceptualise and synthesise the literature to date in a holistic manner (Torraco, 2005).

For relatively new emerging topics, the mission of such mode of reviewing is to:

> "Create initial or preliminary conceptualisations and theoretical models, rather than reviewing old models (..) this type of review often requires a more creative collection of data, as the purpose is usually not to cover all articles ever published on the topic but rather to combine perspectives and insights from different fields of research traditions" (Snyder, 2019, p.336).

For this reason, the literature review does not only focus on sources specifically about *digital craftsmanship* stemming from the design/craft research field, but rather seeks to cover a broad spectrum of literature of relevance to the topic. As previously stated, the overarching objective of this research is to investigate the notion of *digital craftsmanship* and how it relates to traditional forms of craftsmanship and technical hand-making practices. Hence, the researcher started reviewing sources from different research streams, crossing a diverse range of fields that have studied craftsmanship and the role of technologies and theories on knowledge acquisition and transmission

The iterative reviewing of literature within the Contextual Review broadened the author's understanding of the research area. Moreover, the various research outputs related to *digital craftsmanship* revealed the diversity of authors undertaking research around the digital – in relation to fabrication technologies – and craftsmanship. Besides the number of relevant contributions in the field of design research, many authors from material culture to sociological, anthropological, archaeological, historical and political backgrounds have made relevant contributions to this topic.

The researcher arranged the relevant sources in terms of their content, rather than the chronology of development in relation to digital craftsmanship as a practice. Furthermore, the literature was reviewed with the particular lens defined by the first objectives of the research inquiry:

- to give an overarching review of digital craftsmanship and how its theoretical debates have evolved in the last two decades.
- to examine types of knowing within traditional craft practices, with a specific focus on the ways in which knowledge is acquired and transmitted.

Establishing a relation between the theoretical and the practical world is of relevance in any inquiry. However, it is contented that this is of even higher relevance in the field of craftsmanship. Within craftsmanship, there is a strong interdependence between making and thinking; therefore, the researcher claims that there should be an even stronger interdependence between practical examples of artefacts and related theoretical debates (Dormer, 1994; Adamson, 2007; Ingold, 2013).

It is contended that synthesising the critical analysis of literature from multiple fields of study, should generate the premises to construct new knowledge about a topic (Torraco, 2005). For this reason, the researcher sees the Contextual Review as one of the pillars of the methodology used as a driving force to conduct the research, rather than an introductory, framing chapter of the topic of interest.

2.2 Auto-ethnography

The researcher, through the Contextual Review, identified a range of practitioners studying the field of inquiry, holding varied backgrounds ranging from:

- technologists working with craft- processes;
- craftspeople who have adopted digital production tools;
- craftspeople who have adopted digital interaction tools;
- digital natives who have only ever used digital tools in their making processes.

Other scholars in the design research field (Risner, 2012; Shorter, 2015) tried to define, closely relying on their own crafting practice and auto-biographical experience, characteristics that describe the way in which practitioners in their domain of practice conduct making processes. Their studies highlighted how the researcher's background positioned her into a different space; aspiring to closely study craft practitioners, yet not holding the skills of a technologist nor a craft practitioner.

This different standpoint by the end of the research project was valued as a positive asset, as it gave a unique lens on the field of inquiry. However, throughout the research process, the researcher had to re-negotiate her role within the inquiry more than once. Through this negotiation process, reflective questions around her own relation with materials and technology, embodiment and making experience, came into play. These reflective outcomes radically shaped the design process undertaken in this research.

For this very reason, in the thesis the researcher promotes reflexivity, addressing her individual research experience on the topic through two *auto-ethnographic* Chapters (Ch. 4 and 6). Autoethnography is a reflexive processing of personal experience and self-observation (Chang, 2016), and, as underlined by Blundel et al. (2019), it is a method that is often used in craft-research approaches (e.g., Groth, 2017; Shorter, 2015).

These reflections express how the researcher's own personal values and background knowledge evolved during the research process, both through practice – making – and theory – thinking. The *auto-ethnographic* Chapter will therefore be written in the first person as it describes the researcher’s subjectively lived experience, and will provide an overview of the motives behind the different strategies applied during various stages of the research process.

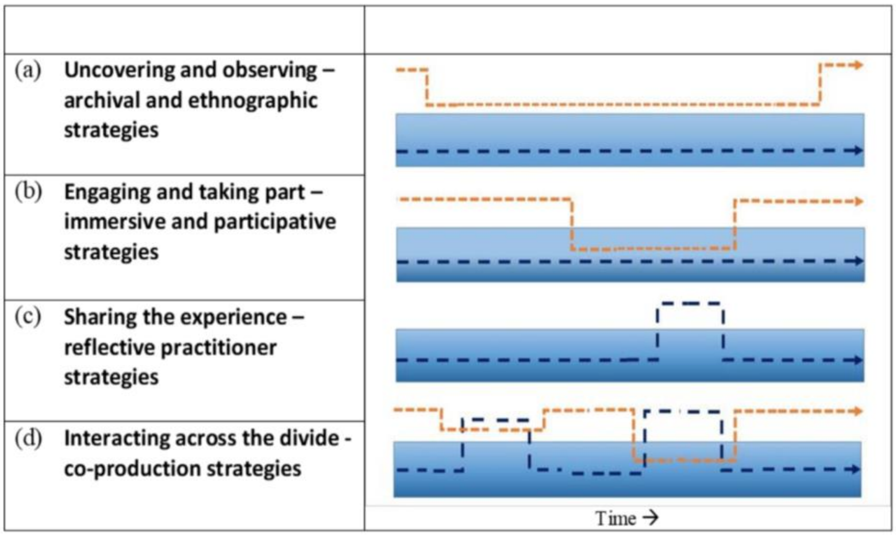
2.2.1 The Role of the Researcher

Craftsmanship is a form of knowing that is highly experiential and embodied, reliant on personal experiences and senses, in connection with materials (Sennett, 2008). Blundel et al. (2019), in their study, recognise how difficult it becomes, from the researcher perspective, to access and to articulate such forms of knowing. Through their studies, they identify four possible strategies for researchers trying to better understand craft practices and practitioners. The authors figuratively represent craft practitioners as marine creatures and academic researchers as birds, each living and progressing in separate elements (air as for the academic discourse and water as craft practice), that sometimes entangle.

Most strategies described by Blundel et al. were examined in the context of organisational research, seeking to apply “social scientific methods to study the work practices of contemporary craft practitioners” (Ibid., p.1). In their study, the authors acknowledge how the described strategies are often not executed in a linear or sequential mode but rather used by researchers in a more organic and overlapping manner.

Figure 3.

Strategies to examine craft work as organisational researcher



Note: *the dotted lines represent the roles of the researchers (orange) and practitioners (blue); the blue shaded area represents the craft practitioners’ domain and the white area the domain of academic discourse. The vertical and horizontal positioning of the lines is indicative of potential degrees of proximity and engagement with each domain.*

Note. From “Examining craft work: methodological challenges and choices”, by Blundel R., Koomen P., and Bell E., 2019, *Proceedings of the 35th EGOS Colloquium, Enlightening the Future: The Challenge for Organizations*, p.6. Copyright retained by the Authors.

The strategies individuated by Blundel et al. are represented in a schematic illustration (see Figure 3) as four separate streams:

a) *Uncovering and observing* – archival and *ethnographic* strategies

b) *Engaging and taking part* – immersive and participative strategies

c) *Sharing the experience* – reflective practitioner strategies

d) *Interacting across the divide* - co-production strategies

In the first two strategies (a,b), the researcher is seen as the primary actor, deciding when to engage with the researched participants and when to take distances from them. Both strategies rely on *ethnographic* methods, thus, in the first case, the researcher holds a higher degree of distance from the participant studied.

In the second strategy, the researcher is an active observant in the fieldwork, participating actively and engaging with the observed participant. The researcher tries to experience what the participants do and tries to re-enact their behaviours to better understand them.

Instead, the third strategy (c) sees the practitioner at the very centre of the research process. The practitioner's reflexivity skills on his/her own practice are seen as the research strategy's central outcome. Their ability to be *reflective practitioners* (Schön, 1938) producing insights over their own personal experiences, are central cues of this strategy. Thus, this strategy holds limits: the possibility of marginalising the broader academic research literature at the expense of the researcher's individual perspective (Blundel et al., 2019, p.10).

Finally, the fourth and last strategy (d) sees the researched practitioners and the researcher as collaborators, where "the practitioner is no longer simply a research subject, but has become actively involved in data collection, analysis and theorising" (Ibid. p.13).

The ongoing co-creative approach and the conversational aspect of the data extrapolated from the implementation of this strategy happens to be particularly effective in reaching depth into “technical, embodied and valued-based dimensions of craft practice, which might otherwise prove elusive” (ibid, p.13). This approach is methodologically called *para-ethnography* (further described in section 2.4) to underline the decentering of the researcher’s role in the project.

The researcher did cross the practitioner’s path with similar proximity and engagement to the ones described in Blundel et al. (2019). Throughout the research, she applied varying strategies, depending on the progress of the project. Thus, even if some methodological choices align with Blundel et al.’s examination on craftwork research strategies, the researcher recognises that the practitioner’s and academic’s ‘elements’ are not as crisply distinguished as Blundel et al. represent them in their illustration. Within the design research realm, practice and theory often intertwine much more than shown through the dashed lines illustrated by Blundel et al. (2019) in Figure 3; digital craft is a topic that has been widely explored by practitioners using craft-based approaches who may also be researchers at the same time. Hence, there are papers that discuss critical aspects of digital crafts and making that are written by makers themselves. Therefore, differently from the trajectories individuated by Blundel et al., such distinct paths become blurred and overlapping within this project.

2.3 Ethnography

While exploring the field through the Critical Contextual Review and the *auto-ethnographic* approach, the researcher undertook fieldwork activities to gather qualitative data and understand the topic of study in detail. Field Research starts

with very loosely formulated questions but with a clear target concerning who to study and in which context, as seen in Blundel et al. research strategies (2019). The *ethnographic* approach gives the researcher control as it allows the researcher to decide when to engage with the studied participants and when to distance himself/herself from them. The researcher used a mix of qualitative research methods to closely observe a varied set of craftspeople in their engagement with craft materials, techniques and technologies.
By observing, interviewing and shadowing (Silverman, 2013) the participants for one up to six months, the researcher started getting to know the participants, their studios, and their practices in accessing their daily lives. To achieve minimal intervention in the interviews, the researcher tried to assume a marginal role. It was often enough to ask the first question, letting the conversation take its shape naturally and generating possible relevant insights to the inquired topic (Crouch & Pearce, 2013).

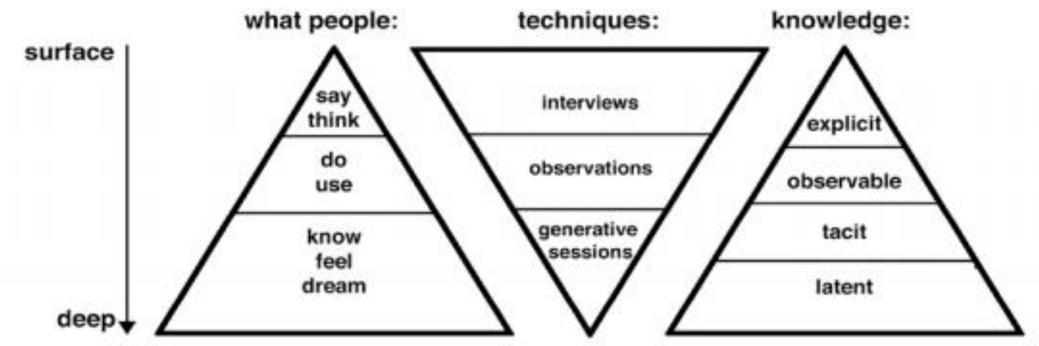
The observational period and semi-structured interview aimed to generate new data and knowledge needed by the researcher to have an in-depth picture of the researched context. This mode of interaction with the participants proved to be very relevant for the researcher’s understanding of the field of inquiry but held some limitations on the breadth and nuances of the collected data (this point will be further developed in Section 4.2). As such a change of strategy in methodology (Part II, below), was adopted in order to yield more relevant insights.

PART II

In the first phase of the research project (Part I), the researcher reached a detailed understanding of the context of *digital craftsmanship* through the Critical Contextual Review, Ethnographic research, and Auto-ethnographical reflections.
However, as illustrated in Figure 4, Visser et al. (2005) in their studies on generative techniques, researchers by using only observational and interviewing methods might incur in the risk of remaining on the surface of the topic under study. To reach deeper layers of knowledge (i.e.,, *tacit* and *latent knowledge*), Visser et al. show how researchers should move from observational techniques to generative sessions (see Figure 4). Through generative techniques, researchers can support the participants in constructing and expressing their experiences at a much deeper level (Visser et al., 2005).

Figure 4.

Design researchers' techniques to access different levels of participant's knowledge



Note. From "Contextmapping: experiences of practice", by Visser, F. S., Stappers, P. J., Van der Lugt, R., & Sanders, E. B., 2005, *CoDesign: International Journal of CoCreation in Design and the Arts, 1*(2), p.123. Copyright retained by the Authors and © Taylor & Francis Group Ltd.

To provide support to a set of participants in *generative research* (Hanington, 2007), the researcher stresses how it is fundamental that they firstly acquire a good level of *interactional expertise* (Collins, 2010). When researchers use an *ethnographic* methodological stance over an extended period to try to understand the social dynamics and meaning of a studied context, they will inevitably start absorbing the *culture* of the group observed. For this reason, having strengthened her understanding of the context and culture of interest (see Chapter 4), the researcher felt in a stronger position to adopt a different methodological strategy for the second part of the thesis.

The various methods adopted throughout the thesis provided the researcher with the basis to return to the gathered data from Part I of the research with new insights gathered in Part II. By *triangulating* the qualitative data gathered in both Parts I and II of the thesis, the researcher was able “to enhance the meaningfulness of data" (Suter, 2012, p.376) gathered. The *triangulation process* involves the cross-checking and convergence of the different data obtained, allowing the researcher to extrapolate richer findings until it reaches *corroboration* and *saturation* point (Ibid.). Hence, the second part of the research, rather than exploratory, can be considered explanatory (Neuman 2000, p.38).

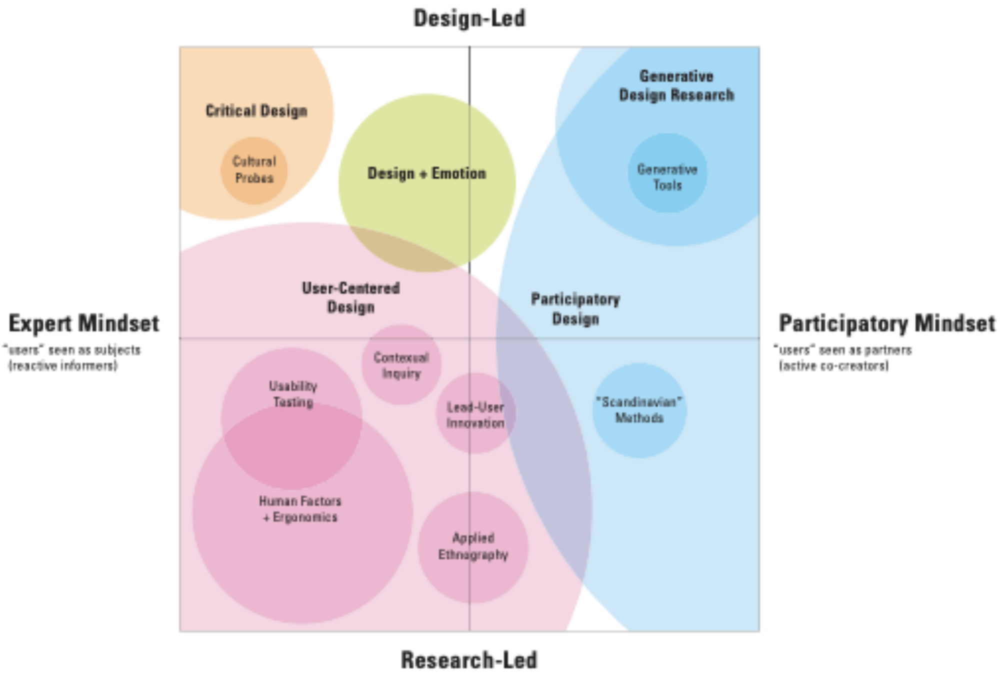
While in Part I the researcher used ethnography to approach and study the community of digital craft practitioners, within design research ethnography has been often examined in relation to participatory design methodologies (Blomberg & Karasti,2012). Through ethnography, the researcher focuses on understanding a specific community by observing selected members of the community in an everyday setting. This results in an intimate and long-term relationship that often allows for more profound *reflexivity (*Schön, 1987) of the researcher. To a certain extent in design research, ethnography is often seen as a subservient method for design rather than a tool radically integrated with design processes (Blomberg & Karasti, 2012). Conversely, in participatory design methodologies the researcher mediates between the actors involved in the project and the project goals themselves, negotiating and facilitating opportunities for mutual learning. Therefore, the researcher assumes a role that is less marginal and closer to the role of a facilitator. The individuals from diverse backgrounds bring different perspectives to the design process which the researcher considers valuable and enriching.

Considering Sanders' *Design Research Mapping* (2008) in Figure 5, the researcher points out how within the design research realm, applied *ethnographic* approaches sit between a *Participatory Mindset* (users seen as partners) and an *Expert Mindset* (users seen as subjects). Whereas, Participatory Design and related Scandinavian Participatory methods sit closer to a *Participatory Mindset*, where users are seen as active co-creators of meaning rather than reactive informers (Sanders, 2008).

Therefore, while there are synergies and alignments within the approaches of Ethnography in relation to Participatory Design, they embrace slightly different principles. On the one hand "ethnography seems to have been normalised, accepted as part of Participatory Design practice". Yet the dichotomy raised by Blomberg and Karasti underlines how on the other hand, "ethnography is being 'backgrounded', secondary to those activities that directly engage participants in design" (Blomberg & Karasti, 2012, p.108).

Figure 5.

Map of the design research field



Note. From *"An evolving map of design practice and design research"*, by Sanders L., 2008,. *Interactions, 15*(6), p.14, (https://doi.org/10.1145/1409040.1409043). Copyright retained by © 2008 ACM.

Despite this, it has been underlined more than once how it is fundamental for researchers and designers to acquire the reflexive abilities ethnographers traditionally develop through their practice. Those reflexive abilities are often lacking in Participatory Design approaches, where researchers lose the opportunity to make themselves visible*:* their backgrounds, their particular knowledge, their agency and responsibilities and how they overall influenced and enriched / limited the research process (Ibid.). Simultaneously, Participatory Design approaches "allow a multi-perspectival collaboration" (Ibid., p.19): a dynamic negotiation and a re-articulation of meaning with participants, which enriches the research process.

Because of this, within the last decade, approaches suggesting the combination of Ethnography and Participatory Design have been heavily encouraged by scholars as they promise to provide a deeper and more nuanced method to conduct a research inquiry (Ibid.).

In the first part of the thesis the researcher, as a single, tacit observer of the context and paradigm of *digital craftsmanship,* relied on the essential descriptive functions the ethnographer's role provides. Thus, the researcher soon realised how much the community she wished to explore was fully capable of excellent critical reflections regarding their practice's theoretical debates. Therefore, the researcher found it necessary to change strategy, adding a Participatory element to the Ethnographic approach to fully address the alternative perspectives, ethos, and principles that practitioners in the community have developed over years of their practice-based research experience (Neuman, 2000).

To get access to the practitioner's underlying knowledge in relation to *digital craftsmanship* (e.g., *tacit* and *latent knowledge*, unexplored feelings), the researcher started looking at possible techniques she could use to undertake Participatory sessions with the experts in the field, without losing the reflexivity and relationships acquired in Part I of the research project.
As previously seen in section 2.2, Blundel et al. (2019) suggest a research strategy that combines the elements of both Participation and of Ethnography, where researchers and practitioners are seen as collaborators within the research process. The study, referred to as a co-production strategy, revolves around the method of *Para-ethnography* (later articulated in Section 2.4).

2.4 Para-Ethnography

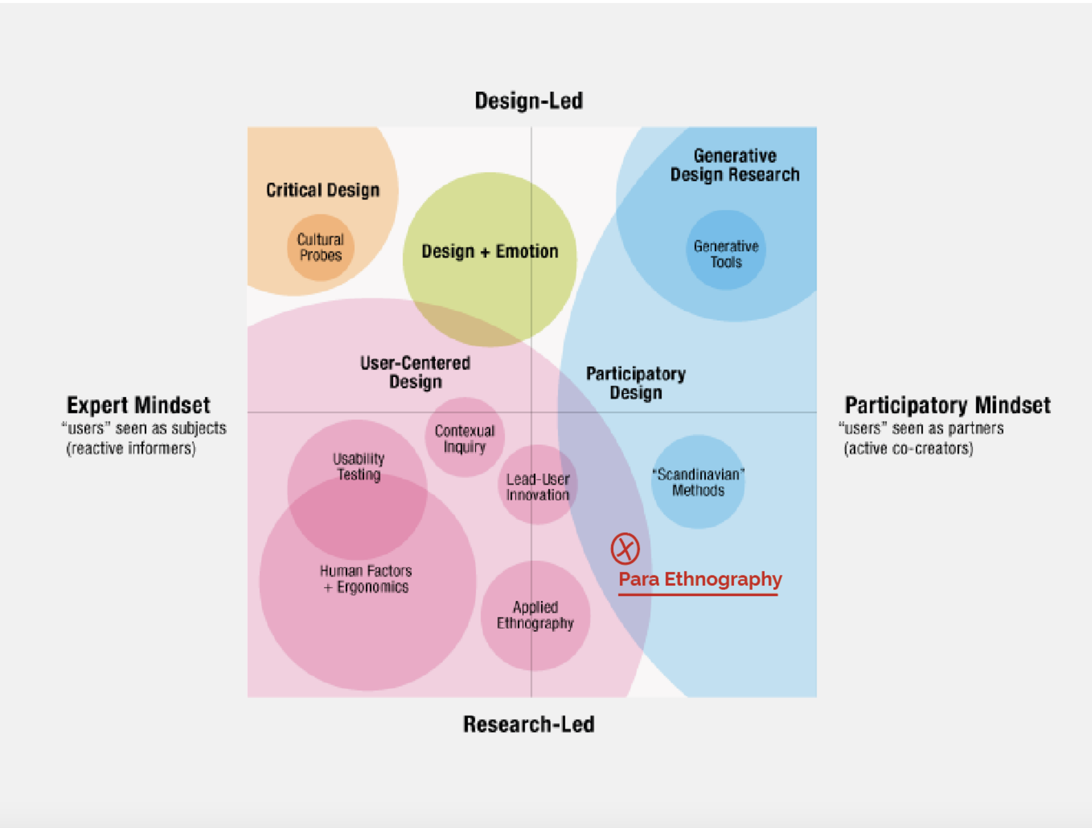
The notion of Para-ethnography was introduced by Holmes and Marcus (2006) to explicate complex organisational structures of actors (i.e., people involved in a study as participants) that “often alternate between highly formalised analyses and ‘anecdotal’ evidence” (Islam, 2015, p.234). It recognises the actors involved in a research process as theorists and experts of the culture in which they participate. Moreover, it emphasizes that even if participants are part of the same community they may be dispersed across disciplines or locations, not being able to – or interested in – assuming shared fundamental beliefs.

Para-ethnography does not assume the social group studied is homogeneously reflective (i.e., that everyone in the group under examination is reflective), or more reflective than other social groups. It is emphasized however, that although actors studied in research settings are not ethnographers, they are active producers of self-conscious analysis of cultural evidence rather than sources of raw data (Islam, 2015).

This methodology alters the dynamics between the researcher and the researched by challenging the researcher’s authorial standpoint and status. Instead, it imbues the researcher with the critical task of facilitating, promoting, and articulating as best as possible reflective stories of experts (Ibid). Far from devaluing the knowledge of the researcher, para-ethnography relies on the researcher’s contribution to the reflections of experts on a topic. Para-ethnography looks at diminishing distances between academics and actors; the researcher is an interpreter of reality, seeking to engender the conditions to produce critical knowledge. As previously seen in Blundel et al. (2019) study of the researcher’s role in craft-based research (see Section 2.2), meaning is *co-created* by scholars and practitioners through para-ethnography. If we were to position para-ethnography within the previously mentioned design research map by Sanders (2008), the researcher believes that it would take its position between *Applied Ethnography* and *Scandinavian Methods* as illustrated in Figure 6. Within para-ethnography, participants are seen simultaneously as partners and subjects to the researcher. In the following, the researcher describes the technique adopted to gather new qualitative data using this method.

Figure 6.

Para-ethnography positioned in the map of design research



Note. Adapted by the researcher from "*An evolving map of design practice and design research"*, by Sanders L., 2008, *Interactions, 15*(6), p.14, (https://doi.org/10.1145/1409040.1409043). Copyright retained by © 2008 ACM.

2.4.1 Kelly's Repertory Grid

Kelly's Repertory Grid (KRG) is a method developed by George Kelly in 1995 within the field of clinical psychology. KRG is based on the Personal Construct theory, a psychological theory that places its roots in Constructivism[2], claiming that all human beings construct their own meaning from the world around them in a subjective way, their *personal construct system* or more commonly their view of the world. KRG was developed as a structured interview technique, allowing the psychotherapist to entice and subsequently explore each client's unique *construct system*.

KRG is a technique that might appear convoluted at first sight, but it amounts in fact to a quite simple procedure. How the technique works will be described in more detail through the following paragraphs; thus, the researcher will first list and roughly describe the four main components that constitute the KRG system. The main components of the method are:

- ***The topic*** – what is being studied;
- ***Elements*** – these are examples that illustrate the topic of study;
- ***Constructs*** – these are the criteria and attributes through which the *elements* are compared with one another to produce a series of statements. The statements produced by the practitioners involved in the study will reflect what they think about the specific topic. From these statements the participant will form a diametrically opposed pole for each *element*, building up a personalised unit of analysis. In other words, the participant creates a

[2] philosophical perspective previously discussed at the beginning of Chapter 2

first *construct* describing a particular set of *elements* that can be considered the *emergent pole* and then they will need to come up with a binary opposite *construct* for the other pole (the *implicit pole).* Therefore, every statement has to be presented as opposite ends of a spectrum (e.g., small/big, heavy/light etc..).

- **Rating scale system** – once the primary *constructs* and *elements* are in place, they are entered on a Grid with the *elements* sitting on top and the *constructs* down the side. The participants at this point will need to rate each *element* against each *construct* according to a numerical rating scale. The rating scale is non-evaluative (e.g., running from 1 to 6), as indicating negative or positive poles (e.g.,, scale running from +3 to -3) may affect the responses of the participants (Fransella et al. 2004).

The technique is based on interviewing a range of selected participants over a set of *elements* using a particular structure designed as a Grid. The *elements* all together compose a *repertoire* (from here the word *repertory*) of objects, people, or things that are taken into consideration for analysis. Through these selected elements, the researcher can carry out an interview with the participant, using the interviewee's language to set up a Grid, based on their responses. These responses are defined as *constructs* (Ibid.) and are the attributes used to express their view on the world and, specifically, over the *elements* discussed. Such *constructs* are statements that describe the world (e.g., adjectives, short sentences). In other words, the participant is asked to think aloud about each *element* and to describe each one of them through a series of *constructs*. Of these identified *constructs*, the participant is asked to define an opposing *construct* for each. In order to ease this construction process, the researcher places the opposite *constructs* (i.e., diads) on the polar opposites of the Grid. Finally, the researcher will ask the participant to define and assign a numerical value on a scale to the *element* under consideration, based on the opposites defined.

Due to its merits, being a method allowing psychologists to successfully access and explore the tacit *construct* system of their clients, this technique has been widely adopted in various research fields, including the design research field (e.g., Siraj-Blatchford, 1995; Downs & Wallace, 2004; Bang & Nissen, 2009; Bang, 2013). Two examples of KRG used in previous design-related studies are described below to clarify the process.

Example 1

Siraj-Blatchford (1995) used KRG to conduct pedagogical research within the educational field. His study aimed to "discuss the potential of applying repertory Grid techniques in response to the introduction of the 'Product and Applications' and 'Quality' programmes of study" (Siraj-Blatchford, 1995, Abstract) in the national curriculum of *Design and Technology*. Siraj-Blatchford claims that there is a strong need in education "to develop childrens' technological literacy as citizens" (Ibid., p.196) as it is important that they understand how to evaluate the implications of the things they will make themselves as future designers and technologists. Moreover, he believes that through KRG, it is possible to facilitate a reflective practical exercise with young students. The author of the study claims that to evaluate existing products and the effort placed in understanding and articulating their differences (through the *constructs* and *rating system*), will teach the scholars to activate a deeper reflexive mechanism when evaluating technological products. Training them this way refines their judgement, helping them point out possible "undesirable technological side effects of products" (ibid., p.196).

Siraj-Blatchford carried out several pilot studies with students using KRG (see an example of the Grid used in his studies in Figure 7) and, through his experience, he developed a version of the method providing “a powerful means of revealing students’ personal *constructs* of technological products and artefacts” (Siraj-Blatchford, 1995, Abstract).

Groups of 3 to 4 students were asked to select a triad (i.e., three *elements*) from a more comprehensive selection of *elements* that they would have had to consequently rate, based on a scaling system from 0 to 10. Once they had chosen their triad, they were asked to identify the two somewhat similar *elements* and a third opposing one. Furthermore, students had to assign 0 to the two *elements* recognised as similar and 10 to the *element* recognised as the opposite. At this point, the students were asked to provide *constructs* that could encapsulate and articulate the *elements*’ dichotomies. In Figure 7 we can see how, in the first example, the elements of an *electric epilator* and a *pocket computer* were picked by a group of students as they were considered somewhat similar, while the same group of students identified the *home-made jumper* as the opposite *element* of the triad. Subsequently, the similar *elements* were defined by the same students as “non-ecological” while the *construct* chosen for the opposite element was “ecologically sound”. Consequently, the first two elements of the triad were assigned the rating number of 0, while the latter was rated with a 10. All the other *elements* were then rated with the remaining numbers of the scale (in the range of numbers from 1 to 9, as 0 and 10 cannot be used again once assigned to the triad) according to the *constructs* chosen.

Figure 7.

Example of the forms distributed in one of the case studies conducted by Siraj-Blatchford

	Bipolar constructs (words or phrases)	Dhava	Electric epilator	Flourescent bulb	Walking Boot	Bow and Arrow	Pocket Computer	Home-made Jumper
		Elements						
1.	Non ecological (o)- Ecologically sound (10)	7	0	9	5	6	0	10
2.	Using natural resources - Not	9	0	2	9	10	0	9
3.	Need electrical power to use - Did not	N	Y	N	N	N	Y	N
4.	Natural fibers - Not	10	0	8	8	10	0	10

Note. Groups of 3-4 students were asked to select a triad (assigning 0 to the similar *elements* and 10 to the different ones), the researcher modified the labels in the Grid to make the *constructs* more readable (in red). Adapted from “Kelly's repertory Grid: a technique for developing evaluation in design and technology” by Siraj-Blatchford, J., 1995, *IDATER 1995 Conference*, p.199. Copyright retained by © Loughborough University.

Through this technique, Siraj-Blatchford was able to prove how successful the KRG system can be as a pedagogical tool for educators. Moreover, he stressed how KRG is a powerful tool also for research purposes in the design field, as it offers the means to identify some of the fundamental categories by which a group of people evaluates and describes a range of products or artefacts (Siraj-Blatchford, 1995), providing the necessary information for the designer to reiterate adequate design propositions in response.

Example 2

Several craft-based researchers have used KRG as an exploratory approach to better investigate how a group of people perceive and articulate their feelings and beliefs within a defined research topic (e.g., Dillon et al., 2001; Downs & Wallace, 2004; Homlong, 2006; Bang, 2013).

Downs and Wallace (2004), jewelry makers themselves, used KRG to investigate how other communities of people would perceive twelve different jewelry objects. Distinct from other research fields, it is important for scholars interested in craft-related themes to allow participants to directly experience (i.e., see/touch) the selected *elements* –in this case, physical jewelry items–. In their article, the researchers provide an example of the KRG used in their study (see Figure 8).

In Figure 8, the letters displayed on top of the Grid correspond to the *elements* (i.e.,, the jewelry artefacts). The numbers on the sides correspond to the rating scaling system (here going from 1 to 5). The numbers assigned to each *element* signify the rating of that specific *element* related to the *constructs* assigned to the *value scale*. The researchers in this study decided to provide their participants with a definite set of *constructs* to choose from before prompting them to generate new ones. In the example above, the interviewee chooses the “attachable silver curl” (b), the “polystyrene & steel pin” (f) and the “marble & steel brooch” (l) as *elements* of the *triad* where (b) and (f) were rated as the most ‘delicate’ *elements* in the repertoire, opposite from (l) that was associated to the *construct* ‘brutal’. In this research, participants had the chance to personally interact with the *elements* (i.e., the jewelry objects) displayed on a board. This proximity allows a multi-sensory engagement with the *elements*’ physicality, enabling the participants to build a more profound knowledge/appreciation of the assessed *elements*.

Figure 8.

Example of a study using the KRG technique

1	a	b	c	d	e	f	g	h	i	j	k	l	5
delicate	2	1	4	3	3	1	2	3	3	4	5	5	brutal
emotional													rational
accessible													inaccessible
permanent													non permanent
controlled													uncontrolled

Note. From "Making Sense: Using an experimental tool to explore the communication of jewelry" by Downs, J. & Wallace, J., 2004. In McDonagh, D., Hekkert, P., Van Erp, J., & Gyi, D. (Eds.) *Design and Emotion: The Experience of Everyday Things*, 144-149, -. Copyright retained by the Authors and © Taylor Francis Group.

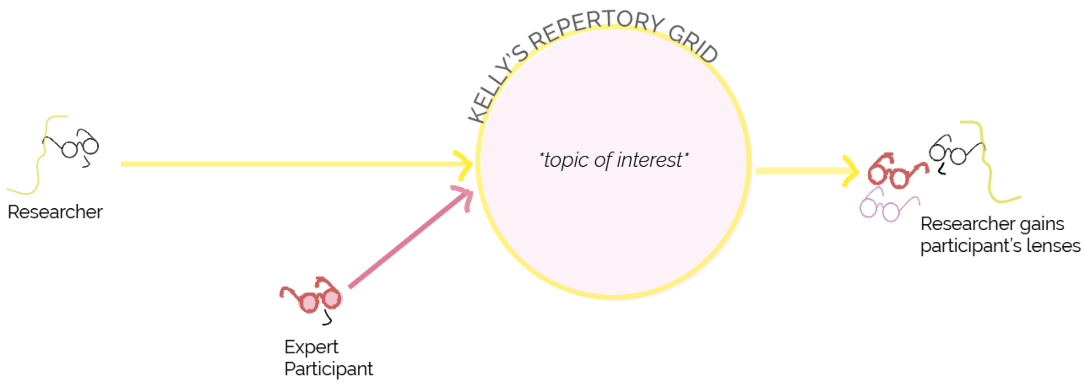
2.4.2 KRG supporting para-ethnography

KRG advantages are that it is "an adaptable method of encouraging people to externalize their understanding of the world or whatever the focus is, for example, artistic identity, collaborative relationships, design values, learning styles, and so on" (Gray & Malins, 2004, p.120).

As in the example of the sieves/filters/spectacles used by Gray and Malins (2004) explicated at the beginning of this chapter, through filtering the gathered data “essential distillations” (Gray & Malins, 2004, p.132) of information will be sought through the researchers’ final data analysis. Thus, this can happen only if the researcher gets access to new lenses (the expert practitioners’ ones), which can help shift in focus generating new visions on the topic of *digital craftsmanship:* observing a topic of interest from different viewpoints and perspectives, builds on the principle that much more is to be learnt by observing a diverse set of perspectives rather than a single one.

Figure 9.

Kelly’s Repertory Grid role in relation to the researcher and the experts involved in the study



Note. The researcher’s path (yellow) and the expert participants’ path (pink) collaborate through Kelly's Repertory Grid technique. KRG allows for a co-creative articulation and discussion on precise topics of interest. The process gives structure to what would otherwise be an anecdotal conversation. The researcher through the encounters gathers data on participants’ perspectives and opinions on the topic of interest. These in the illustration are represented by the different lenses gained by the researcher at the end of the process.

With this methodology, the researcher will attempt to define different perspectives concerning digital-craft-based approaches that have been emerging in diverse communities (e.g., HCI, RtD) and in individual practitioners with very different backgrounds. To do so, it is essential to understand the practitioners' ethos. As illustrated in Figure 9, the researcher (the yellow path) will be running KRG with multiple expert practitioners within the field of craftsmanship and digital making (the pink path). Asking them to think through the *elements* selected by the researchers' topic of interest (here *digital craftsmanship*), the researcher will be capturing precious material (their *constructs*) that will help build an understanding of how expert practitioners within the studied field perceive and see the world.

As said, this technique is applied in order to elicit the personal *constructs* of different individuals within a particular studied group of people. Hence, it is expected from the researcher to adopt an open, dialogic approach as the facilitator. In her study, Fransella (2003) explores which skills and tools should be combined to be a good *construct practitioner*, claiming that a good combination of both is what allows the generation of qualitative data to avoid the interviewers and interviewees biases as much as possible. Some of the necessary skills the facilitator should hold in Fransella's point of view are: the ability to subsume another's construing (i.e., see the world from the practitioner's point of view), the ability to suspend personal values (i.e., not interfering in the practitioner's view of the world with personal values), the ability to listen courteously (i.e., see the participant's view of the world from their eyes but at the same time retaining personal integrity over those perspectives (i.e., we do not need to accept them or agree with them), and the ability to be reflexive (Fransella, 2003). Therefore, the researcher, while acknowledging that her role is not completely neutral (Neuman, 2000) attempts at clarifying her position and role within the research inquiry through the *auto-ethnographic* stances. Moreover, taking in mind Fransella's key roles to be a good *construct practitioner* the researcher will attempt at articulating the participants' perspectives through the help of the KRG framework and thanks to the rigour it allows.

The researcher valued the KRG technique and its application as a powerful tool for this study. The reasons being:

1. While facilitating qualitative conversations over a defined topic and set of *elements,* KRG provides a structure that gives rigour to anecdotal conversation allowing the researcher to gather deeper, qualitative data, and to go back to it afterwards –through the visual aid of the grids.

2. If compared to other methods such as open-ended interviews and observations (conducted as part of the *ethnographic* research in PART I of the thesis), the KRG encourages deeper reflections on the studied field through (i) concrete and recognised examples of *digital crafts* (i.e., the *elements),* and (ii) the use of a numerical scale. While quantitative data was less relevant to this particular research, it certainly helped the researcher to enquire about the practitioners' choices in the disposition and rating of the artefacts[3];

3. KRG elicits practitioners' participation and engagement from diverse communities therefore, the researcher is not assuming the expert's role, determining fixed *constructs*; instead, she is co-creating them with the help of expert practitioners in the studied field, supporting a *para-ethnographic*

[3] The researcher did not focus on the quantitative data itself but used the rating system to try and elicit the participants' reasoning behind a particular number's choice formulating questions such as "Why did you feel like rating this *element* with the chosen number?" or again "Why did you feel like rating this *element* [number] while this other *element* [number]?

methodological approach. This strategy allows her to extract information on different perceptions on and propositions about the practitioners' beliefs (Dennett, 2003) on what *digital craftsmanship* entails;

4. In order for the researcher to analyse and understand the *constructs* used in the Grid by the practitioners and to aim for the most coherent knowledge articulation of the topic, she is forced to understand better and review the theoretical debates addressed in the Critical Contextual Review (Chapter 3).

2.5 Heterophenomenological method

The researcher used an overarching *heterophenomenological* (Dennett, 2003) method to frame the research inquiry in Part II of the thesis, especially while conducting the study with Kelly's Repertory Grid and while analysing its gathered data.

Phenomenology describes the phenomenon of subjective experience with theory-neutral presuppositions. On the other hand, *heterophenomenology* studies the "phenomenology *of another* not oneself" (Ibid., p.1) focusing on first-person phenomena from a third person point of view –which is historically more used in scientific fields.

In other words, *heterophenomenology* relies on the understanding that unlike unanimated subjects involved in a study, human subjects have their own beliefs and see the world from their own lenses (i.e., their sets of beliefs). Which in turn means that cooperating with human subjects, interacting verbally with them, and guiding a set of participants through a planned study, will naturally guide the researcher in the collection of "a catalogue of beliefs" about the participants experiences, rather than “a catalogue of experiences themselves” (Ibid., p.3). *Heterophenomenology*, similarly to para-ethnography, sees participants in a study as active collaborators of the investigators, rather than passive informants. Hence, the method was selected by the researcher as it “holds out much hope of taking human subjectivity seriously” (Ibid., p.2).

A researcher practicing *heterophenomenology* has the obligation to “reserve judgment about whether the subject’s [i.e., participant’s] beliefs, as expressed in their communication, are true, or even well-grounded” (Dennett, 2003, p.5). Since they constitute the *subject’s subjectivity* they should not be mixed with the researcher’s personal catalogue of beliefs.
A *catalogue of beliefs* also includes the *catalogue of experiences* as described under an (auto-)phenomenological approach, along with other relevant data. Hence, the researcher acknowledges that the outcomes of this research will be naturally influenced both by participants' own beliefs on the world –that might differ from how they unconsciously act in it daily or describe it–, and by the researcher's beliefs and background –despite her commitment in maintaining an overview as neutral and objective as possible.

2.5 Summary and reflections on the methods used

The researcher’s framing of the research project evolved throughout the study as the researcher was acquiring more knowledge about the inquired context of search. These changes reflected in the diversity of the methods adopted and in the overarching theoretical framing of the thesis.

In Part I of the thesis, the researcher spouses a *constructivist* (Willis, 1995) and *subjectivist* (Neuman, 2000) approach enacting a series of mixed-methods (e.g., contextual reviewing, *auto-ethnographic* and *ethnographic* approaches) aiming towards an epistemological analysis of the researched topic. Whereas, in Part II of the project, the researcher understood the value of adopting methods moving towards a *heterophenomenological* (Dennett, 2003) approach, where the participants and the researcher are seen as valuable active informers of the researched inquiry. The methodology of Para-ethnography, mentioned by Blundel et al. (2019) in their research on craft practitioners, supported the researcher in the new framing of the study.

Through the help of the KRG framework, the researcher was able to actively *construct* data from the beliefs of the participants. Reflecting over the KRG study and the researcher's role in facilitating the correct running of the Grids, the researcher believes that without having first developed her *interactional knowledge,* she would have not been able to facilitate the conversations with the expert participants in the way she did. The first *constructs* shown in the descriptions of the Grids have been articulated entirely by the participants. Only a few times did the researcher intervene in the conversation in order to support some of the participants in the re-articulation of the *constructs.* Whenever they would feel that a *construct* could have been better expressed or articulated, the researcher would try to facilitate their reflective process only by asking targeted questions with the aim of furthering the articulation or explanation of the *constructs.* The researcher put effort in always showing her interest and participation in the process, but at the same time strived to maintain her distance and to remain as neutral as possible throughout the running of the Grids. Following a *heterophenomenological* approach (Section 2.5), the researcher would pose questions such as "What were you thinking when you placed [*element* name] here?" or "What were you thinking when you articulated [*construct*]?". These are considerable *heterophenomenological* inquiries in that they are “third-person investigations of the special kind that exploit the subject’s capacity for verbal communication” (Dennett, 2007, p.6).

Understanding when to intervene in the conversation to support deeper analyses and reflection on the participant’s own believes was possible, thanks to the *interactional expertise* acquired by the researcher throughout the first part of the project (see PART I). Indeed, the researcher's *interactional expertise* provided her with the sensibility to formulate specific questions to enrich the breath of discussion in its nuances and depth[4]. Participants' perspectives on digital crafts enabled the researcher to better explore how they experience and view their practice. The qualitative conversations were supported by the rating numerical system and the *elements* positioned in KRG. Thanks to these factors, the researcher could provide a coherent data analysis showing the similarities/differences between the participants collected data in the form of grids compiled, as well as find correlations across the collected data, and the theoretical debates addressed throughout PART I of the project. While the sample of participants interviewed was contained, the KRG made it possible to start highlighting clear features of the community of practice of digital craft practitioners (see Chapter 5).

[4] Other remarks on *interactional expertise* in relation to design research methods and techniques will be addressed in the conclusions of the thesis (Chapter 7, Section 7.5)

PART I

CHAPTER 3. Critical Contextual Review

The *Contextual Review* Chapter is divided in two Sections in order to provide clarity to the literature reviewing process.

In the first Section (3.1), by providing an overview on the state-of-the-art of *digital crafts*, the researcher will give some background over theoretical debates concerning digital craft practices, anchoring them to practical examples. By introducing to the reader some of the most relevant ongoing debates in the design research field related to a wide variety of *digital crafts,* the researcher gives an overview on the diversity that constitutes the community of *digital craft practitioners*.

In the second Section (3.2), the researcher will treat the notion of Digital and Craftsmanship as separate elements to be understood in relation to the concepts of *Tacit* and *Explicit Knowledge* (Polanyi, 1996). In other words, the researcher will analyse craftsmanship expertise and digital expertise in relation to knowledge transmission theories. Understanding their interrelations will provide the reader with theoretical foundations that are widely used by the researcher in the discussion of the present inquiry (Chapter 6).

3.1 State-of-the-arts of digital crafts

The Crafts Council refers to practitioners engaging with craft processes –both with handmade and digital techniques– as 'makers' (craftcouncil.org.uk at present), although there are multiple definitions of what a maker is. If in certain contexts such as the one of the Crafts Council, a maker is a term contingent to the idea we have of a craftsperson, in other contexts as the *Maker Movement* (Anderson, 2013; Morozov, 2014; Barba, 2015), being a *Maker* is a term recognized to address people using digital manufacturing tools “to make (almost) anything” (Gershenfeld, 2012, pp.43-57).

The researcher Evan Barba asserts that while *Makers* do not hold similar skills, they all have the same desire to experiment and make. Hence, in his opinion, “positing an insider/outsider divide seems ultimately unproductive if the goal is to produce a technologically literate citizenry” (Barba, 2015, p.641). However, the attempt of promoting the term *making* to define a movement that includes radically different practitioners with strong inhomogeneous skill sets did not escape criticism from several quarters (Bean & Rosner, 2014; Chachra, 2015).

On other shores, the attempt of promoting the term *Making* and *Maker* to define a Movement and a selected group of people with radically different characteristics, skills, and material knowledge, had been considered an endeavor of unnecessary *branding* with the result of gathering practitioners with strong inhomogeneous skill sets (Bean & Rosner, 2014). In 2015 with the article “Why I am not a Maker”, Debbie Chachra underlined the problems related to the term *Maker* and how, in her opinion, it referenced back to political and social values which did not reflect many.

In the meantime, while the boundaries between digital and physical materials intertwined and became blurred (Shiner, 2012), in the design research and Human Computer Interaction (HCI) communities a strong focus on making started growing, being described as “craft-based approach” (this will be expanded through subsections 3.1.1, 3.1.2 & 3.1.3).

In the *SIGGRAPH Hybrid Craft Exhibition* conducted by Amit Zoran in 2015, the author showcased fifteen diverse works defining them as *hybrid crafts*. The presented artefacts expressed different techniques and values adopted by practitioners working in the digital craft domain both pertaining to Design and HCI realms.

The selected crafts comprehended (i) a broad selection of pieces made through digital fabrication tools and reflecting their practitioners' expertise in dealing with digital materials, as well as (ii) crafts not produced through digital fabrication tools but through a combination of traditional craft materials and electronic components. Zoran, as curator of the exhibit writes about the authors of the selected crafts as makers:

> "Rather than highlighting the machine, the algorithm or the economic narrative, we present unique makers who use digital design, fabrication or interaction technologies as part of their creative palettes, integrating them with other tools, techniques and making traditions: these are the makers of Hybrid Craft" (Zoran, 2015, p.385).

While the author suggests the term Hybrid to stress the convergence of different making processes, formerly the term *Hybrid Crafting* had been previously defined by the authors Golsteijn, Van den Hoven, Frohlich and Sellen (2014) as a term referring to the specific practice of making which combines physical, digital materials, and electronic components in order to produce "interactive physical-digital creations", where "both crafting process and result ... include both physical and digital elements" (Golstejn et al., 2014, p.594). As a result of these contradictory nomenclatures, the generalised term of *hybrid crafts* articulated by Zoran for some could be disregarded if aligned with Golstejn et al. (2014) definition. The researcher does not want to focus on the term *hybrid* specifically, as critical reflections on the use of the term as descriptor of the merging of the digital and the analogue had been already posed by the scholars Devendorf & Rosner (2017). Thus, this observation is of relevance as it underlines the incoherence and inconsistency of the terminologies used to define examples of *digital crafts*, and it underpins the difference in material perspectives the practitioners in the HCI community wish to be related to, when using craft-based approaches. These contradictions have been underlined to a certain extent by the recent study produced by Frankjaer & Dalsgaard (2018), who try to distinguish different types of craft-based approaches in HCI communities and assign them their corresponding terminologies. Their study addresses the difficulty of the task underlining how, within the last decade, the term *craft* had been frequently applied to numerous research streams, ending up as an accessible descriptor able to chameleonically portray, all at the same time, “any kind of physical making, extending to simple manipulation and reassembling of physical objects, application of software in the fabrication process, to constituting a particular methodological approach and way of thinking in a creative context” (Frankjær & Dalsgaard, 2018, p.474).

In their study Frankjaer and Dalsgaard could identify as a shared common denominator among the artefacts: the aims behind the pieces, carried out through their authors’ craft-based inquiries. The authors could list three main characteristics on the nature of the focus of craft-based inquiries in HCI: “1. Combining aligning and integrating analog and digital crafting techniques and processes; 2. Creating highly refined artefacts, defined by attention to detail and aesthetics; 3. Creating knowledge through deep, embodied engagement” (Frankjær & Dalsgaard, 2018, p.482).

While practitioners adopting craft-based approaches vary in their backgrounds, and their outputs might differ surprisingly, the artefacts produced still take their place in the world under the overarching umbrella general term of *digital crafts*, expanding the radius of what is considered *digital craftsmanship* (Jacobs et al., 2016)[5] . Practitioners owning material competency started framing through research outputs new terms that could better describe their different ways of working.

[5] Jacobs et al. (2016) apply the term very broadly, encompassing computer-aided design, electronic crafts, procedural design, and hybrid human-computer digital fabrication.

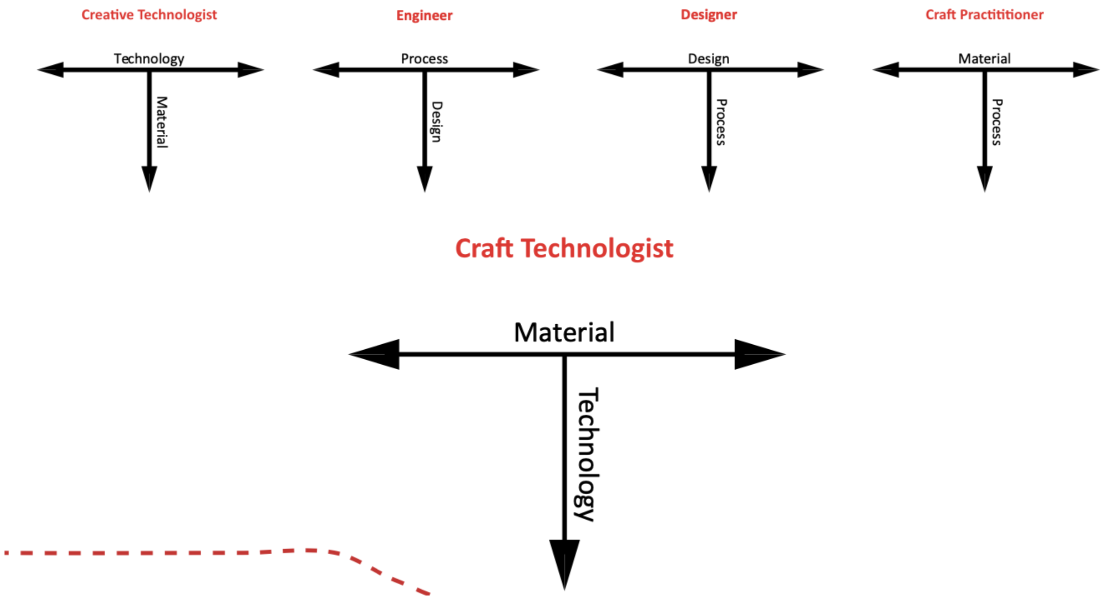
In the design research field, practitioners moving from craftsmanship practices to digital technologies had been characterised as practitioners relying on *technepractice* (Risner, 2012). Instead, practitioners moving from engineering, computer science or digital design realms towards craft-based approaches, had been addressed as *craft technologists* (Shorter, 2015).

Isabelle Risner, in her extended research work on maker practices identified three fundamental pillars of craft skills which are necessary to define a practitioner working between digital technologies and craftsmanship. These pillars revolve around the key element of *technepractice*, a term that explicates how the craft tradition and the networked future made of digital technology can be combined in such ways that go beyond the individual maker, integrating many aspects of the digital practice (Risner, 2012). In her studies, Risner suggests a framework that can evaluate the skills put in a digital craft artefact, given that the following focal points appear in the craft: "the retention of the risk of failure (that the quality of the result is not predetermined); the process and outcome is uncommon; skills (wherever they are sourced from) are used creatively" (Risner, 2012, p.49). Risner, being a maker herself, focuses on the nuances of the making process to frame the qualities that need to be identified in order to define the craft made by a digital craft practitioner. She gives an overview on those values identified by her as needed in the digital realm to be compared, or have analogies with, values related to craft practices (Woolley, 2007).

Differently, a more recent study by Michael Shorter describes the emergent figure of the *craft technologist* (illustrated in Figure 10). The *craft technologist* is described by Shorter as a practitioner able to approach technology like *craft practitioners* would approach materials, applying on technologies the same reflective and creative approaches and processes that would be applied in craftsmanship. He describes the action of being reflective and experimental as core abilities of the *craft technologist* who, in the interplay of being reflective, creative, and playful, is able "to explore and craft with the materiality of technology" (Shorter, 2015, para.5).

Figure 10.

T-shaped practitioners



Note. From "The Craft Technologist" by Shorter, M., 2015, *Studies in Material Thinking*, *13*, p.8. Copyright retained by © 2015 Studies in Material Thinking and © Michael Shorter.

Differently from a *craft practitioner* whose interest mainly levitates between the process adopted to give form to a material and the materials' history (Shorter, 2015), *craft technologists* focus on technology as a material to evoke emotions and connections with a user[6]. *Craft practitioners'* try to solve questions related to materials and processes, using technology as a tool to support their making,

[6] This point will be referred to again in the discussion*

whereas *craft technologists* use technology as a material to pose and, eventually, to try and answer open-ended questions (Shorter, 2015). These points will be referred to again in the discussion (Chapter 6, Sections 6.1.1 & 6.1.2).

Shorter unpacks and describes the compartmentalisation lying behind the practice of *craft technologists* into several points:

> "they use the process of reflect—play/craft—reflect; they learn with their hands and by playing– this leads to a tacit knowledge of their material; by going deep into their subject matter they learn about the history, social context, materiality and economic value of a technology– this can lead to an empathetic understanding of the technology and the ability to consider its future in a thoughtful and respectful way; they understand craft as a verb as well as a noun; they use prototypes to externalise their ideas, disseminate and reflect on their practice; they aspire to crafting magical and intriguing objects through experimentation with materials and technology" (Shorter, 2015, Discussion section, para.1).

From the reviewed literature, the researcher tentatively concluded that a generic inclusive interpretation of the term *digital craft practitioner* is therefore appropriate from the perspective of the present analysis. In this research project, the theoretical example of the *digital craft practitioner* that will be taken under consideration and will be involved in the study, is perhaps a combination of someone using what Risner's *technepractice* and Shorters' description of the *craft practitioner* and *craft technologist*. Therefore, the researcher will be focusing on practitioners that acquired competence in both material knowledge and technologies and that produce *digital crafts* encouraging diversity of practice, cross-fertilisation and interdisciplinarity.

To give an overview on the nuances and variations of the outcomes produced by *digital craft* practitioners*,* the researcher organised a state-of-the-art overview on *digital crafts* aimed to close the gap between the theoretical debates ongoing in the design research field related to craft-based approaches and their practical examples. In the preface to his book *Making*, Tim Ingold claims that the creativity of the productive processes that “bring[s] the artefacts themselves into being” (Ingold, 2013, p.7) is what is often lost in research inquiries. Moreover, the notion of *thinking through things* has been widely referred to in the *ethnographic* fieldwork gaining consent in many disciplines, encouraging researchers to consider artefact-oriented methodologies (Henare et al., 2007; Woodward, 2019). By focusing on both *digital craft* examples and related theoretical debates, the researcher attempts at “referencing the world, not just other books” (Ibid., p.15), providing a deeper analysis on craft-based research communities.

This overview on *digital crafts* should not be read as an in-depth analysis concerning the material culture of *digital crafts*, nor as a study of its visual culture; it is not focusing on how crafts are interpreted from a cultural value perspective (Ingold, 2013). The researcher is not interested in the way humans interact with *digital crafts* socially, or how users consume and treasure these objects. Instead, this section focuses on a repertoire of *digital craft* examples to provide an overview of the varied spectrum of artefacts produced in the field.

The artefacts chosen are not meant to be exhaustive of the produced outputs in the field nor are chosen as “best examples” in the field. Rather, the artefacts were chosen by the researcher as fitting examples that could include considerable diversity of techniques and materials through which differences in skills are visible. Moreover, the pieces were chosen in that they could support a brief introduction of related theoretical debates (the researcher will not focus extensively on each theoretical debate raised).

To address and organise the selection of *digital crafts*, the researcher was inspired by Gaver and Bowers' *Annotated Portfolios* (2012). Their method provides a solid way to represent the "particularity and multidimensionality of design work while meeting many of the demands of generalizable theory" (Gaver & Bowers 2012, p.43). The authors underline how artefacts can be analysed from numerous perspectives and how, only few of those perspectives, might be relevant to the designer (i.e., the author of the design), or to the researcher which is analysing that specific design. For this reason, the practitioners' perspective and the way in which practitioners might highlight certain features of their artefacts, might not overlap with the researchers' interests which generally depend on the context of their inquiry. Relying on *Annotated Portfolios*, researchers can clarify accountable contributions to research, pointing both at "salient features of an artefact" but also providing the means to bridge "between the artefacts and issues of concern to the research community" (ibid., p.43).

Figure 11 illustrates an example of the format used by the researcher to *annotate* her selection of *digital crafts.* To analyse the selected artefacts in relation to the specific inquiry, the researcher decided to highlight on each discussed image representing a *digital craft*, aspects related to the making processes techniques (in yellow, Figure 11) and the materials used to produce the artefacts (in light blue, Figure 11).

Figure 11.

Annotated digital craft example

As all *digital crafts* taken under consideration sit between digital and hand-making techniques, the researcher acknowledges that ultimately in every one of the artefacts selected both hand-making and digital techniques are arguably used, to a certain degree. Thus, the researcher will solely *annotate* those dominant techniques and materials used to achieve the final output that are central to the lens through which the researcher is framing the Critical Contextual Review.

In the following, the researcher will describe several *digital crafts* underlining different aspects related to their conception, material choices or making processes, providing a state-of-the-art overview on *digital crafts.* In order to organise them, the researcher arranged the artefacts through three different sections, namely: *Crafting with digital fabrication technologies* (3.1.1), *Beyond digital fabrication technologies* (3.1.2) and *Without digital fabrication technologies* (3.1.3). By focusing on specific characteristics of the artefacts one at a time, the researcher hopes to shed light on the richness and diversity of the artefacts produced in the field.

3.1.1 Crafting with digital fabrication machines

Adopting digital fabrication machines and translating and/or substituting hand-making abilities with digital crafting changed the dynamics in making processes. Many scholars started perceiving digital fabrication technologies "as a creative method of making (...) to sit more comfortably with mass manufacturing than the realm of craft" (Harris, 2012, p.93).

As early as 1968, David Pye, woodworker, and teacher, talked about *the workmanship of risk vs. the workmanship of certainty*, referring to mass production processes as agents that deliver the final piece without encountering any risks, something that does not happen in handwork, where "the quality of the result is continually at risk during the process of making" (Pye, 1968, p.20). His point of view, originally referring to industrial processes, has been referenced for long in theoretical debates concerning digital craftsmanship. Some debates have been following the criteria that technological practices have been underwriting craftsmanship skills, where human "magnificent, multi-sensory, simultaneous, and synchronic capacities of imagination" (Pallasmaa, 2009, p.12) were suddenly condemned as technology-mediated artefacts started affording virtual and intangible interactions with materials. As a result, for Juhani Pallasmaa, they have been "turning the design process into a passive visual manipulation, a retina journey" (Ibid., p.12). Thus, as pointed out by other researchers, digital craftspeople are untied to industry and are therefore free to intervene at various stages of their production and making process (Harrod, 2007).

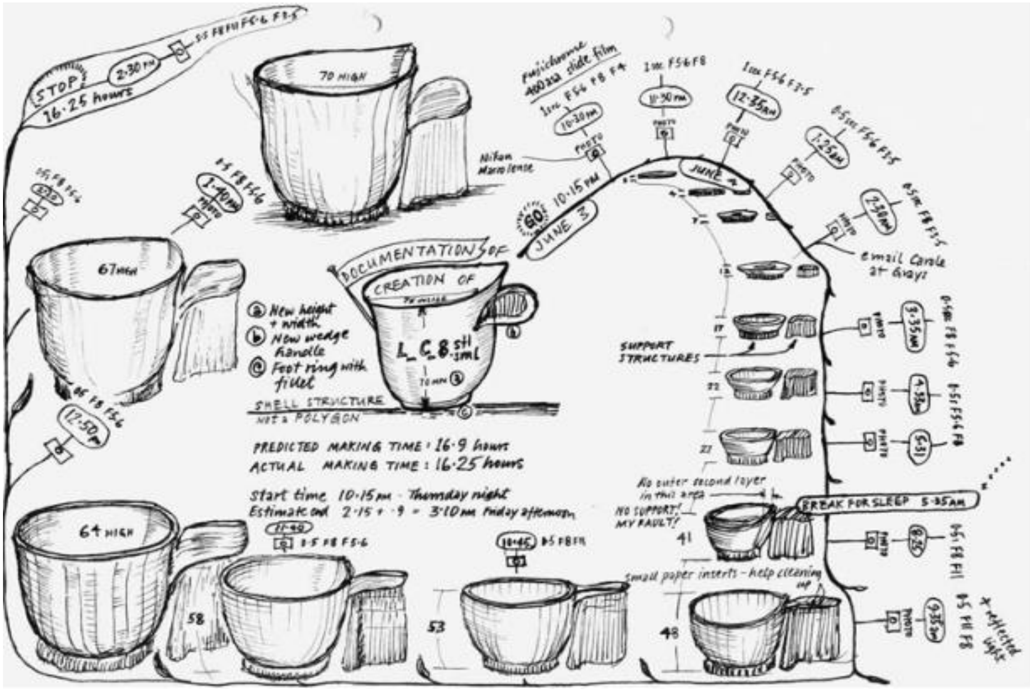
Adopting digital fabrication technologies to one's practice, first requires understanding of different ways fabricating machines work, with different materials. Digital fabrication machines such as the Computerized Numerical Control (CNC) machine, the Laser Cutter (LC) and Water Jet Cutting (WJC) machine, work through the process of material subtraction. CNC machines can work on solid blocks of material, subtracting multiple layers, shaping the original block into designed outcomes. Instead, LC and WJC machines work over thin sheets of materials where a laser beam in the first place, or a water jet in the latter, burns/abrades material into the designed shape.

Differently from subtractive making processes, 3D printing relies on material addition. In Figure 12, the practitioner Gordon Burnett documents and analyses the process of 3D printing a cup. In the image, Burnett (1999) illustrates how, through a making process long 16.25 hours, the extruding mechanics of the machine are layering material particles multiple times, resulting in a 3D printed cup which is 'growing' over time, until its completion.

Therefore, contingently to the growing contemporary desire of "reasserting a human element in the post-industrial, increasingly mechanised, technological era" (Cavalli, 2017, p.11) a report conducted by the Crafts Council in the UK signaled that, among practitioners in the Country by 2010 craft was increasingly understood as "a distinctive set of knowledge, skills and aptitudes, centered around a process of reflective engagement with the material and digital worlds" (Schwarz & Yair, 2010, p.9).

Figure 12.

Analysis of the process of 3D printing a cup



Note. From "Analysis of the process of 3D printing a cup in relation to time passing" by Burnett, G., 1999, *Australian cultural issues re-defined by digitally crafted domestic objects* [Exhibition Catalogue]. Copyright retained by © Monash University and Robert Gordon University.

As a reaction, addressing the incremental loss of material knowledge and craftsmanship techniques in new forms of digital making, in the design research field for many practice-based scholars it became fundamental to raise sensibilities on the importance of craftsmanship skills and material knowledge as underlooked characteristics necessary to produce meaningful artefacts (Wallace & Press, 2004; Niedderer & Townsend, 2010; Rosner, 2012).

From the late '90s to the present, scholars adopting craft-based approaches have been extensively exploring as part of diverse practice-based research studies exploring techniques aimed at merging traditional and *digital craftsmanship* practices. Diverse explorations of the usage of fabricating technologies in making processes had been significantly contributing to the growth of the craft-based community in the design research field (e.g., Bunnell, 1998; Marshall, 1999; Bottomley, 2001; Marshall, 2008; Risner, 2012; Jorgensen, 2015; Tyas, 2015; Shorter, 2015; Mitchell, 2017). Significant research results related to *digital craft* practices had been spread from their authors through platforms such as the Research Through Design (RtD) community and other sources such as the Craft Research Journal and the Design Journal.

Furthermore, research groups such as the early Autonomatic group (see Autonomatic.org.uk) interested in using digital fabrication technologies in relation to more traditional craft practices got momentum, producing a vast number of research results thanks to its multidisciplinary range of scholars with a practice-based research imprint.

In the last two decades, technologies continued evolving, and practitioners in the digital craft domain became more literate in the digital world (Harris, 2012), exploring the potentialities of hand-making and digital fabrication technologies for commissions, exhibitions, research, or personal purposes.

To testify how successfully craftsmanship and digital fabrication started crossing and merging, already in 1996 in the United Kingdom the Crafts Council launched the exhibition *Objects of our Time* curated by Martina Margetts (1996-97). The Crafts Council Gallery provided one of the first platforms for the display of digitally crafted outcomes deriving from the use of novel technologies and craft techniques. Over time, many other examples of artefacts crafted through the crossovers of digital and traditional practices have been exposed through relevant exhibitions such as: the *Fabrication Laboratory* exhibition curated by Ramon Prat (2010-2011) at the DHUB Design Museum in Barcelona, the *Labcraft – Digital Adventures in Contemporary Craft* exhibition organised in London by the Crafts Council and curated by Max

Fraser (2010- 2012), and the exhibition titled *The Power of Making: the importance of being skilled* curated by David Charny (2011) at the V&A Museum in London. Other examples of popular exhibitions on the theme of *digital crafts* are: *Making is thinking is making* organised in Milan by the Korean Craft & Design Foundation in the Triennale Museum and curated by Hong Bora (2015), the exhibition curated by Marta Malé-Alemany (2016) titled *Making a Difference / A Difference in Making* that took place in Essen at the Red Dot Design Museum, the exhibition *Sans Les mains!* curated by Michael Eden (2018-19) in Limoges at the Fondation Bernardaudand, and *Out of Hand: Materialising the Digital* an exhibition held in Sidney and jointly curated by the Museum of Applied Arts and Sciences of Sidney together with the Museum of Arts and Design of New York (2018).

These exhibitions started underlining a new paradox of contemporary artefacts in Museums: digitally crafted artefacts have the power to begin their life “as direction signs of the future. . . on the same plinth representing memorabilia of the past” (Miller in Charny, 2011, p.16). In other words, digital crafts become historical from the very moment they are created, not “merely for the virtue of remaining in time” (Ibid., p.16) but, rather, because they are the first innovative representations of what we might be making in the future. The curatorial domains in the exhibitions and the organisation of their catalogues often highlighted different sets of themes and debates that digital technologies have raised in relation to craftsmanship. Such events aimed to celebrate new means of crafting and the dynamism of digital methods.

Therefore, owing to the variety and diversification of backgrounds and communities of practitioners adopting these new processes and techniques, very different outcomes started populating the overarching term of *digital crafts*. Over the last years, several books from a designer-maker-craft constituency started focusing on these artefacts.

As an example, *Digital Crafts- Industrial Technologies for Applied Artists and Designer Makers* by Ann Marie Shillito (2013) showcases a number of artefacts of talented practitioners using a diverse range of craft processes (from analogue to digital) and argues that with the proper knowledge and equipment, practitioners have the mindset to creatively engage with the new toolkit these computational tools provide. In the same year, other two books showcasing examples of *digital crafts* were published: *Digital Handmade: Craft is the New Industrial Revolution* by Lucy Johnston (2015) and *Postdigital Artisans: Craftsmanship with a New Aesthetic in Fashion, Art, Design and Architecture* by Jonathan Openshaw (2015). Both books present a wide selection of artefacts produced with handmade and digital techniques and processes. Their authors showcase a range of examples, suggesting that these artefacts are proof that the next Industrial Revolution is already happening, and that digital fabrication is, at this point, inseparable from craftsmanship. Openshaw (2015) writes that the “high-tech honeymoon is over" explaining that even if digital technologies radically changed how we see the world, digital craftspeople still “see materials as the heart of design, fashion and architecture” (Openshaw et al., 2015, preface).

Differently from traditional crafting practices where practitioners actively engage with materials in the making process (Sennett, 2008), digital craft practitioners working between digital and analogue worlds heavily engage with intangible, digital materials, together with digital fabrication technologies and traditional craft materials. Digital materials are considered to be “bits and bytes or any digital information that begins with a calculation process of zeros and ones” (Kwon et al. 2014, p. 654) therefore digital materials are intrinsic to anything digital relying on code. In order to design and plan the look and feel of a desired outcome, 3D modeling virtually the artefact requires the ability of imagining it all, in every detail, at the very beginning of the making process[7]. Once the craft is produced virtually, the practitioner faces the challenge of jumping from that virtual space to the real world, where gravity and physical constraints of materials co-exist.

Figure 13.

The Innovo Vase by Michael Eden

Note. Adapted by the researcher from "Innovo Vase" by Michael E., 2016 [Nylon and soft mineral coating, 50x40.5x29.5cm, Los Angeles County Museum of Art, USA]. Copyright of the photo retained by © Michael Eden and © 2016 Museum Associates/LACMA. Retrieved from: http://www.michael-eden.com/new-gallery-1/9tlvskw1drk8tn2qywbqmv2rc95se6

As an example, *Innovo Vase* in Figure 13 shows how its author Micheal Eden (2016) uses his expertise –gained over 10 years or more– in designing through a 3D modeling software. His abilities to create intricate, geometrically complex 3D

[7] to know more about modeling technologies such as CAD/CAM and their role in craft and designer-maker practices see Marshall (1999)

artefacts made it possible to “achieve results that hands would have not been able to achieve” (Eden, n.d.). The practitioner at the same time acknowledges that “particular qualities cannot be achieved with digital technologies” (Ibid.) underlining the paradox between hand skills and technologies.

While it is true that practitioners’ expertise on digital materials enables them to experiment and challenge digital design processes (e.g., producing extraordinarily complex and detailed shapes and textures), it is also true that to be able to translate them successfully into the physical world it requires as much expertise as working with tangible materials. Thereafter, the advent of Digital Technologies has been a catalyst to redefine the relationships between function and form, hand skills and technology, between processes of design generation and processes of design production (Oxman, 2007) but each one of these relationships had to then reckon with physical craft material knowledge.

Silhouette– Shape No.39, Weave by Chris Wight (2018) is an example of a digital craft reflecting the practitioners’ abilities in mastering bone china’s material knowledge together with waterjet cutting knowledge.

Figure 14.

Silhouette– Shape No. 39, Weave by Chris Wight

Silhouette– Shape n. 39, Weave | Chris Wight | 2018 |

Note. Adapted by the researcher from "Silhouette–Shape No.30, Weave" by Wight C., 2018 [Bone China, 39x19x19cm]. Copyright of the photo retained by © 2018 Chris Wight. Retrieved from: https://cone8.co.uk/project/silhouettes/

The core challenge in this piece lies in the formation of very thin bone china sheets: the sheets need to be thin enough to maintain the translucence and the qualities of the refined material while, at the same time, they need to be resistant enough to withstand damage from the water jet cutting stream used in the fabrication process. After years of explorations, the practitioner successfully subjected bone china to such a harsh cutting technique, challenging the conventional notion of the material being fragile and therefore, possibly not being appropriate for this fabrication technique.

Figure 15.

Legion by Jo Mitchell

Note. Adapted by the researcher from "Legion" by Mitchell, J., 2015 [Glass, 12x27x7cm, Shanghai Museum of Glass Collection, China]. Copyright of the photo retained by © Colin Rennie. Retrieved from: https://www.jomitchellglass.com/gallery-?lightbox=image_4nm

Another digital craft showing the practitioners' willingness to expand on the creative possibilities of their craft material is *Legion* by Joanne Mitchell (2015). Focusing on glass, the practitioner explored ways to produce and control complex *air entrapment* through waterjet cutting and kiln technologies. In *Legion,* "multiple air entrapment figures were incorporated in rows, using several layers of cut-out sheets within the piece, separated by uncut layers of the same thickness" (Mitchell, 2017, p. 157), providing the means for Mitchell to establish a new crafting technique involving fabrication technologies.

While many digital craft examples focussed on traditional materials (or multiple traditional materials) and their complexities, trying to find possible fruitful relationships with digital fabrication technologies, other examples of digital crafts focus on how digital technologies might provide ways of producing new, complex visual languages on craft materials.

In *Campionissimo* (2009) by Drummond Masterton, CNC milling fabricating skills combined with material knowledge on aluminum properties and digital material knowledge on CAD software result in a highly refined artefact. The practitioner devolved years of explorations to find interrelations between software (CAD code and CAM tooling) and CNC milling aluminum (Masterton, 2007).

Figure 16.

Campionissimo by Drummond Masterton

Note. Adapted by the researcher from “Campionissimo” by Masterton D., 2009 [Aluminum. –. National Museum of Scotland, Edinburgh, Scotland]. Copyright retained by © 2009 Drummond Masterton. Retrieved from: https://www.nms.ac.uk/explore-our-collections/stories/art-and-design/campionissimo-aluminium-bowl/

His studies resulted in the development of a visual aesthetic language that goes beyond the standardised tool sets provided by CNC milling. *Campionissimo* bowl is sculpted out of an aluminium block, and its intricate and refined details characterised by the alternating of organic forms to evident linear tool paths made by the passage of the machine drill bit. They are so meticulous and precise that they could not have been crafted otherwise. Masterton poses that “the development of a dialogue between CAD code and CNC tooling has resulted in a greater level of control, enabling the realisation of complex and completely controlled patterning on 3D forms that go beyond the restrictions of standard toolsets” (Ibid., no page number).

Figure 17.

Hand Thought Series by Justin Marshall

Hand Thought Series | Justinn Marshall | 2018

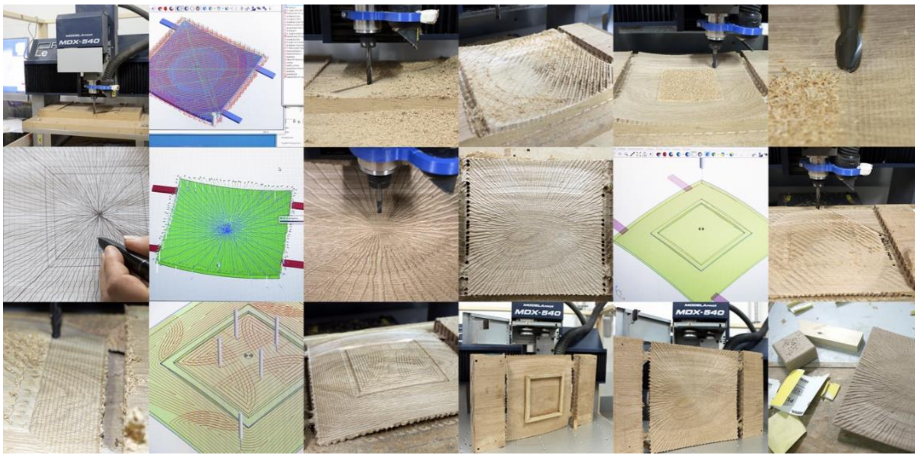
Note. Adapted by the researcher from “Hand Thought Series” by Marshall, J., 2018 [Oak. From left to right: Small Bowl, 210x45mm; Japanese Platter 230x120x40mm; Oval Dish 370x260x60mm]. Copyright retained by © 2018 Justin Marshall. Image courtesy of the artist.

A more recent example working on developing a visual aesthetic language going beyond the standardised CNC milling toolset is *Hand Thought Series* by Justin Marshall (2018). This digital craft was made using entirely digital means of production to create ambiguous surface aesthetic characteristics. The practitioner CNC milled oak blocks contrasting seemingly hand-carved top surfaces with explicitly digitally generated cut undersides. Their apparent handmade flavour is produced by mechanical milling, generating ambiguity and surprise, even to an expert viewer.

Working with digital tools, practitioners became experts at using software, and some became interested in deeper layers of what constitutes machines and software: coding language. Knowledge on coding and software has been recognised as digital material knowledge (Lindell, 2014) rather than solely knowledge bound to the process of writing code or using a digital software (this point will be expanded later in Sections 3.1.2 and 3.1.3).

Figure 18.

Details of the Squared Platter's crafting process by Justin Marshall



Note. Details of the crafting process of a piece for "Hand Thought Series" by Marshall, J., 2018. Copyright retained by © 2018 Justin Marshall. Image courtesy of the Artist.

Masterton claimed that exploring code deeply enables practitioners “to expand the possibilities for control and creative engagement with digital tools and thereby offering more unique opportunities for developing visual vocabularies than using standard toolsets alone” (Masterton, 2007, Abstract).

One of the many examples that resulted from the successful merging between traditional material knowledge and digital knowledge is *Shine* by Geoffrey Mann (2010). The digital craft was created by a process involving digital techniques of 3D scanning to investigate the reflective properties of a Victorian candelabra. From the 3D scanner, reflective information of the candelabra would be documented.

Figure 19.

Shine by Geoffrey Mann

Shine | Geoffrey Mann | 2010 | Crafts Council Collection

Note. Adapted by the researcher from “Shine” by Mann, G., 2010 [Brass and Silver. 24.77×29.21×26.67cm, Crafts Council Collection] Copyright retained by © 2005-2018 Geoffrey Mann Studio. Retrieved from: http://geoffreymann.com/shine

Subsequently, the 3D model was used to create a prototyped form that was then casted with bronze and later silver plated. The peculiarity of this artefact lies in the imperfection of the documented refraction of the candelabra as when scanning a metallic object, the laser beam does not distinguish the surface of the object from the reflection itself.

Another example using digital information in creative ways is *Iceberg Field* (2013) by Johnatan Keep. Using code strings with inbuilt randomness, the practitioner runs an algorithm producing 3D models of unique, non-identical new forms each time.
The delicate ripples of the various shapes of the icebergs produced demonstrate the ability of the artisan sitting equally between tangible and digital material knowledge in a harmonic compromise between the precariousness of ceramics and the 3D printing process. The practitioner writes: “in time digital techniques will just become part of how artists and designers will work with clay – it will become part of the tradition” (Keep, 2013, Q&A Section).

While one of the main debated arguments is that within the practitioners’ workflow, the hand is less present from idea to execution, with digital technologies “forms that one would otherwise probably not visualise or comprehend” (Keep, 2014, p.36), suddenly become possible. Keep believes that training practitioners' ability to explore new and unseen visual content rather than displaying already seen manual dexterity is the power digital mediums have compared to traditional forms of crafting (Keep, 2013, Q&A’s).

Figure 20.

Iceberg Fields by Jonathan Keep

Note. Adapted by the researcher from "Iceberg Fields" by Keep, J., 2013, [Porcelain. Various dimensions.]. Copyright retained by © Jonathan Keep. Retrieved from: http://www.keep-art.co.uk/digitial_icebergs.html

Most of the digital craft practitioners mentioned above originally came from traditional craftsmanship fields of practice, having subsequently integrated digital fabrication technologies in their making processes. Thus, in reverse, as a consequence of the need for a *material turn* (Robles & Wiberg, 2010) addressed by 2010 in the Human-Computer Interaction (HCI) community, numerous designers with a background in digital technologies moved towards craft-based approaches. For many scholars in the field, the new methodological emphasis on the proposition of artefact-oriented perspective shed light onto craft material knowledge and how the approach could bring added values to the digital realm (Jacobs et al., 2016).

Examples such as *Hybrid Reassemblage* (2010) by Zoran & Beuchley in Figure 21, or *Hybrid Basketry* (2013) by Zoran in Figure 22, underlines the practitioners' intentions to fabricate –through the aid of digital fabrication technologies–, structures supporting hand making, traditional techniques and material processes.

In *Hybrid Reassemblage,* the authors intentionally break a previously made glazed ceramic vase to then create a 3D printed skeleton of the missing parts of the original vase shape, in order to bring back the artefact to its original state.

Figure 21.

Hybrid Reassemblage by Amit Zoran

Note. Adapted from *"*Hybrid Reassemblage*"* by Zoran A., 2010 [Nylon and Ceramic]. Retrieved from "Hybrid reassemblage: an exploration of craft, digital fabrication and artefact uniqueness" by Zoran, A., & Buechley, L., 2013, *Leonardo*, *46*(1), p.9. Copyright retained by © Amit Zoran.

The authors describe that the technique used aims at demonstrating how, through mixing different craftsmanship traditions "breakage can be used as an opportunity to join different materials, techniques and aesthetic qualities” (Zoran & Buechley, 2013).

Moreover, in Hybrid Basketry (Zoran, 2013), the 3D printed structure in the basket serves as a skeleton to support hand-weaving techniques. The author, inspired by Botswanans’ traditional weaving craftsmanship, created a digital fabricated structure that could be then combined with traditional weaving skills. Zoran’s investigation had the intention to show the “potential to reclaim a lost material identity in the cyberspace of design and fabrication” (Zoran, 2013, p.330).

Figure 22.

Hybrid Basketry Series: Basket IV by Amit Zoran

Hybrid Basketry Series: Basket IV | Amit Zoran | 2013 | MIT Media Lab

Note. Adapted by the researcher from “Hybrid Basketry Series: Basket IV” by Zoran, A., 2013 [Nylon, jute and canvas ropes]. Copyright retained by © Amit Zoran. Retrieved from: https://amitz.co/hybrid-basketry.html

Their authors named both examples as ‘hybrid’, both in terms of their constituent materials as well as the skills used to make them. The artefacts produced combine pieces of an original structure (e.g., jute and canvas ropes for the weaving part of the basket and clay for the vase) with elements made of novel, synthetic materials (e.g., nylon for the sintered structural parts of the artefacts). While in their realisation, they both include hand-making techniques and processes (e.g., pottery in the first example and basket weaving in the second example). The authors exalt the 3D printed structures to underline distinctive dichotomies between digitally fabricated parts and traditional crafting techniques.

However, outside of the HCI field, keeping unadulterated fabricated material elements –such as PLA and nylon– in digital crafts has been often questioned by craftspeople for its aesthetic qualities. The digital craft practitioner Jane Norris stressed how many examples of digital crafts are, in her opinion, leading towards a very “reduced palette of materials within a limited historical proximity, often based on our linear perceptions of progress” (Norris, 2016, p.4). She suggests that drawing onto traditional material knowledge, a broader and more nuanced selection of traditional materials could be used to exalt digitally fabricated elements directly. Norris questions how come, in the Digital Age, designers do not yet embrace a digital, *aerial viewpoint* of materials which “presents the possibility of a historical map [of materials] that pulls everything into the present and allows all materials in history to become available for use when designing objects” (Ibid., p.4). As a digital craft practitioner and researcher, she proposes a showcase of different bowls that combine a more comprehensive set of materials in their making. She calls them *Polychronic Bowls* (Poly – many, Cronos - time), highlighting her strategy of making objects using multi-temporal materials; synergies of nuanced material choices could, from her perspective, elevate *digital crafts*.

In Figure 23, a 3D printed bowl of PLA dyed in Indian Shellac provides a different kind of material merging. Here the materials are layered on a single object, resulting in a hard-to-place material combination:

> “Experienced designers have expressed surprise at the bowl’s 3D printing origins but also struggled to recognise the shellac exterior. It is almost as if both materials transform each other through their temporal combination” (Norris, 2016, p.2800).

Figure 23.

Bowl from Polycronic Objects Series by Jane Norris

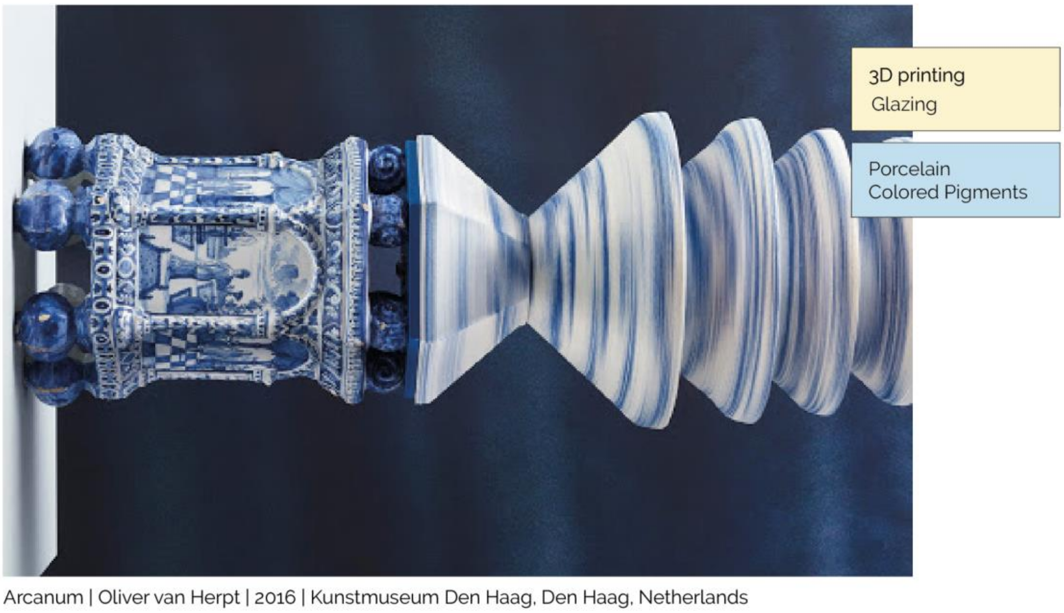
Note. Adapted by the researcher from “PLA 2011 USA+Shellac 3000 BCE India*”* by Norris, J., 2016 [PLA 2011 USA, Shellac 3000 BCE]. Retrieved from “Making polychronic objects for a networked society” by Norris, J., 2016, In Lloyd, P. and Bohemia, E. (Eds.), *Future Focused Thinking - DRS International Conference 2016*, 27 - 30 June, Brighton, United Kingdom, p.2800 (https://doi.org/10.21606/drs.2016.251). Copyright retained by Jane Norris.

While Norris suggests that the use of multi-temporal materials residing in different historical mappings can potentially elevate digital crafts, numerous digital craft examples have been focusing on the use and combination of multiple traditional crafting materials solely.

Practitioners such as Oliver van Herpt , through his piece *Arcanum* (2016) in Figure 24 suggests, to a certain extent, that converging multi-temporal crafting techniques as well as materials could result in new, elevated, contemporary crafts.

Figure 24.

Arcanum by Oliver van Herpt



Note. Adapted by the researcher from "Arcanum*"* by van Herpt, O., 2017 [Porcelain. Printed part: 40x35cm, total height 140cm, Kunstmuseum Den Haag, Den Haag, Netherlands]. Copyright retained by © Gerrit Schreurs and Mr. Frank. Retrieved from: https://oliviervanherpt.com/3d-printing-porcelain/

Arcanum explores the idea that digital fabricated pieces can become physical expansions of existing historical handcrafted artefacts. In this example, van Herpt reinterprets the famous Blauw pottery from Delft, stretching the historically crafted pot into an artistic coloured interpretation of its qualities. By producing a 3D ceramic printed element recalling the colours in the original physical composition of a selected Blauw piece, the practitioner adds a new historical layer to the original craft, transforming it into a digital craft example. Unlike previous examples made by Zoran or Norris, where digital fabricated elements supported traditional hand making, in *Arcanum* vice versa, the traditional crafted element supports the digitally produced one. The idea behind these crafts does not fall too far from Zoran's idea of crafts being *hybrid.* Although*, van* Herpt's use of the traditional craft material of porcelain together with blue pigments recalling the Bleauw original piece try suggesting the merging of two worlds, with less demarcated digital and handmade territories.

Similarly, digital craft practitioners willing to combine handmade and digitally fabricated elements started producing digital crafts smoothing their visual dichotomies by using multiple traditional crafts materials rather than synthetic, new materials combined with traditional ones. Moreover, to successfully combine handmade and digitally fabricated elements or two traditional craft materials, skilled practitioners started collaborating in the production of digital crafts.

The example in Figure 25, Jenner and Irons' *Rush Chair* (2016), combines two practitioners' expertise into the production of a chair. In this collaboration, the designer, Jenner, 3D modelled, and CNC milled a wooden structure made of 28 sculptural components that have been later assembled. Subsequently, Irons, one of the last rush weavers remaining in Europe and living in Bedfordshire, handwoven a pattern within the frame.

Figure 25.

Rush Chair by Christopher Jenner & Felicity Iron

Hand Weaving
CNC milling

Wood
Rush

Rush Chair | Christopher Jenner and Felicity Iron | 2016 | FUMI Gallery, Sardinia

Note. Adapted by the researcher from "Rush Chair" by Jenner, C., & Iron, F., 2016 [Wood and rush, Gallery FUMI, London, United Kingdom]. Copyright retained by © 2018 Christopher Jenner. Retrieved from: https://www.christopher-jenner.com/rush-chair

Another example focusing on the combination of traditional hand-making processes with digital fabrication processes, without losing sight of traditional materials, is the *Set Of Free Blown Vases (2014)* produced by the ceramist Jonathan Keep and the researcher Charles Stern, shown in Figure 26. The collaboration and project have been sponsored by the Unfold Studio.

In *Set Of Free Blown Vases (2014),* applying 3D printing to the problem of ceramic and glass compatibility, Keep & Stern produce a set of composite bowls. Differently from the examples described above, the practitioners worked through the compatibility issues of glass and clay as ‘incompatible’ materials[8]. Through the practitioners’ combined material knowledge –them working both in the digital and the physical material worlds–, a successful method combining 3D ceramic printing and glassblowing techniques was created, producing technically innovative digital crafts.

Figure 26.

Set of Free Blown Vases by Jonathan Keep & Charles Stern

Set of Free Blown Vases | Jonathan Keep & Charles Stern | Unfold Project | 2014 | The Glass Factory Boda

Note. Adapted by the researcher from “Set of Free Blown Vases” by Keep, J., & Stern, C., 2014 [Glass and clay, Various dimensions, The Glass Factory Boda,]. Copyright retained by the Authors and © UNFOLD. Retrieved from: http://unfold.be/pages/the-transaction-project.html

[8] glass and clay contract and expand at different rates making it very difficult for craft practitioners to be able to combine these materials

3.1.2 Beyond digital fabrication technologies

Many digital craft practitioners explored the potentialities of adopting digital fabrication technologies in their practices and of creatively exploring digital material knowledge, constructing elaborated visual languages. Instead, other practitioners producing artefact also considered digital crafts worked differently on the interrelation between hand making and traditional crafting processes and the digital, focusing on creatively tweaking digital fabrication technologies to their making needs and challenging the range of techniques and traditional materials technologies dealt with.

Back in 2009, the ceramist Jonathan Keep, who always had a strong interest in sculptural qualities and form, was involved in a project pioneered by Unfold Studio. Keep was asked to create 3D printers (based on the open-source RepRap project[9]) able to merge 3D printing with his ceramic practice. Being able to find a fine dosage of clay and the needed texture in order for it to be successfully extruded by a 3D printer required deep material knowledge and Keep original training as a traditional ceramist allowed for the creation of the new making process of 3D ceramic printing. This is one of the first examples describing how the practitioners' material knowledge expertise made it possible to readapt the selected digital fabrication technology of 3D printing to be used with ceramic.
Many other digital craft practitioners have been tweaking existing fabrication technologies or had been focusing on the production of new tools –intrinsically combining digital and craft materials–, to obtain certain features in the final artefact.

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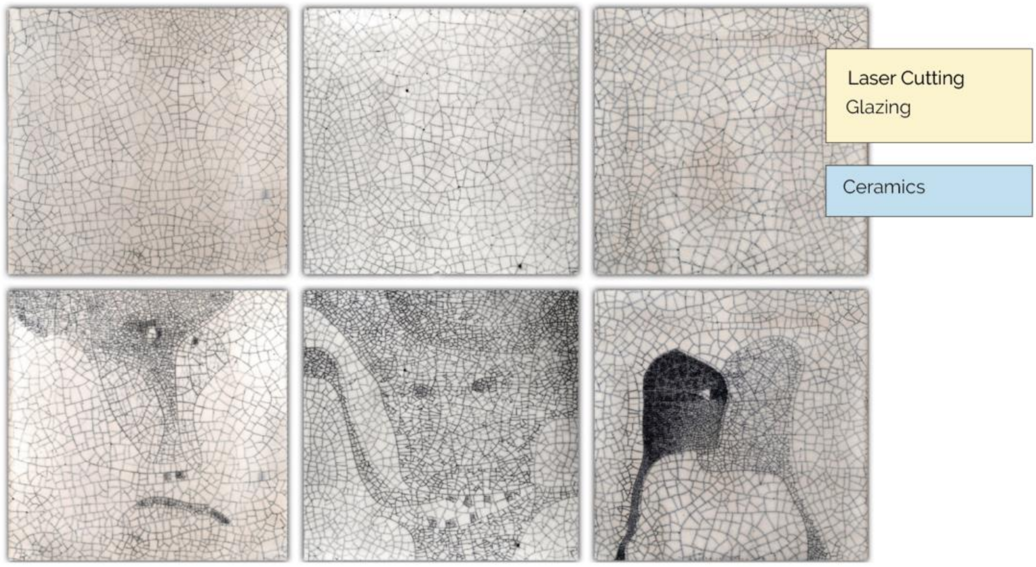
[9] **RepRap** is a free desktop 3D printer capable of printing plastic objects. Many parts of the RepRap are made out of plastic, therefore RepRap is a self-replicable kit of itself that anyone can assemble and use from home, given the time and the materials (for more info https://reprap.org/wiki/RepRap).

Figure 27.

Crackled Tiles by Nir Dick et al.



Note. Adapted by the researcher from "Design with Minimal Intervention: Drawing with Light and Cracks" by Dick, N., Glauber, N., Yehezkeli, A., Mizrahi, M., Reches, S., Ben-Yona, M., … & Zoran, A., 2018, In *Proceedings of the 2018 Designing Interactive Systems Conference,* p.1110 (https://doi.org/10.1145/3196709.3196814).

In *Drawing with Light and Cracks* by Nir Dick et al. (2018) the practitioners, to obtain cracks in the glazing through a controlled laser cutting process, explore a new technique applying it directly on previously handcrafted tiles. 'Crackle' is an explicit pottery phenomenon that naturally happens in ceramic glazing, though, exploiting the laser beam of the cutter, this new making process allows the practitioners to infer a specifically designed pattern of cracks on the tiles. To do so, the authors created a dedicated CAD tool introducing a whole new digital crafting technique able to post-process the natural cracks of the glaze by inferring controlled laser-induced crackled figures (Dick et al., 2018).

Figure 28.

Large Pin Bowl by Tavs Jorgensen

Note. Adapted from "Large Pin Bowl" by Jorgensen, T., 2012 [Glass, 16x57cm, Vessel Gallery, London, United Kingdom]. Copyright retained by © Tavs Jorgensen. Retrieved from: https://www.vesselgallery.com/object-details/844493/0/tavs-j%C3%B8rgensen-pin-bowl-in-grey

Another example of a digital craft produced by a new digital technique is the *Large Pin Bowl,* by Tavs Jorgensen (2012) in Figure 28. The practitioner produced a glass bowl through a free fall slumping technique he invented. Through digital design tools, he developed a tooling system with pins positioned in a matrix of holes, positioned at different heights. The actual use of the final tool is completely analogue through the determination of the pin's heights is dictated by the design, which conversely is digitally produced. Consequently, the practitioner heats up a glass disk and using a free-fall slumping technique, where gravity forces the glass against the pins positioned in the precisely designed matrix, a bowl is created.

Figure 29.

Dripping Clay Bowls by Studio Joachim-Morineau

Dripping Clay | Studio Joachim-Morineau.| 2018 |

Note. Adapted from Dripping Clay by Studio Joachim-Morineau, 2018 [Ceramic]. © Studio Joachim-Morineau, photo © Pierre Castignola. Retrieved from https://studiojoachimmorineau.com/projects/moca-2/graphics.html

Moreover, in the project by Joachim and Morineau illustrated in Figure 29, artefacts are crafted through a *dripping machine,* a machine designed by the artists that works on the theoretical lines of a 3D printer (i.e., it has a nozzle that extrudes materials) through with a very different twist. Through coded electronics and an Arduino, the machine plate spins at different rates, depending on the user's choice. Additionally, to the new pouring method, the duo developed different moulds with varied angles, shapes, and sizes. There is a very thin line between the random nature of the material dripping and the path it undertakes (which depends on gravity and speed and rhythm of the medium poured), and the human intentionality and control behind it (mediating and channelling the nature of such physicalities into desirable shapes and designs). Indeed, there are computational skills involved in the design of the machine. However, considerations on the nature of external physical agents (e.g., gravity) and materials knowledge (e.g., how fast the liquid dripping porcelain dries and solidifies at different stages and in different layers) have a dominant role.

3.1.3 Without digital fabrication technologies

As seen in Section 3.1, the HCI community by 2010 addressed the need of a tempestive *material turn* (Robles & Wiberg, 2010), characterised by a new methodological emphasis on material dimensions. Specifically, in the interaction design domains, Hiroshi Ishii well-articulated this challenge in the abstract of his workshop on Tangible User Interfaces at CHI 2006 writing that:

> "At another seashore between the land of atoms and the sea of bits, we are now facing the challenge of reconciling our dual citizenships in the physical and digital worlds. Our visual and auditory sense organs are steeped in the sea of digital information, but our bodies remain imprisoned in the physical world. Windows to the digital world are confined to flat square screens and pixels, or 'painted bits'. Unfortunately, one can does not feel and confirm the virtual existence of this digital information through one's hands and body" (Ishii, 2006, p.1).

Ishii's reflections suggest that a wider conversion from bits (i.e., digital materials) to atoms (i.e., physical materials) is needed; while humans perceive the world through their bodies and multiple senses, interactive designers are still majorly focusing on the senses of sight and hearing, not exploiting a wider range of perceptive humans' skills.

Moreover, rather than emphasising engineering and production aspects, the community started advocating for more attention to *materials, details,* and *textures* (Wiberg, 2014) and more focus on the importance of the role of *aesthetics, composition* (Wiberg & Robles, 2010) and *form* (Jung & Stolterman, 2012).

As seen through Zorans' digital craft examples in Figure 21 and Figure 22, researchers in HCI started investigating on ways in which craft could be leveraged through technologies and, vice versa, on ways in which craft practitioner's ethos (Bardzell et al., 2012) could be valued more in HCI, to better direct and support the new material turn into craft-based approaches (Gross et al., 2014).

Alongside the rediscovered interest for physical material knowledge and the contributions displaying innovative ways of adopting/adapting/creating new digital tools to craft with traditional materials and techniques (examples of digital crafts in 3.1 and 3.2), scholars in HCI responded differently to the advocated *material turn.* Researchers, challenged to close the gap between abstracted digital materials unanchored to material contexts, gave voice to their different material-lens perspectives. In the first place, closing the theoretical gap between digital and physical materials, researchers started redefining the material catalogue constituting the broad term of 'tangible materials.

The computer, which was originally pointed out as the major cause of the disengagement of designers from the tangible material world, started being perceived as material (Vallgårda & Redström, 2007) with the argument that it has a specific structure, substance, surface, and properties, similarly to traditional materials. Other scholars would instead claim that "their physical characteristics only protect the computing process" (Kwon et al., 2014, p. 654). Nevertheless, the computer entered in its third computing generation by becoming *ubiquitous* (Abowd, 2012), meaning that it started becoming directly permeated into traditional materials and becoming exploited in its combination with other materials and generating 'new materials'.

Among others, new materials such as thermochromic ink and conductive threads, owning the particular trait of being able to convey digital information or, in some cases –like in the digital craft *Ebb* described below–, to even display it, expanded the catalogue of physical materials used to make digital crafts (Shorter, 2015; Devendorf et al., 2016; Kurbak, 2018).

Ebb, produced by Devendorf et al. (2016) in collaboration with the Google project *Jacquard*, is an example realised with new materials. Through pieces of conductive fabrics combined with thermochromic pigments, the practitioners explore new possibilities of weaving and crocheting to leverage the painted geometries on the textile. When solicited by electricity, the thermochromic pigments change colours in subtle ways, creating 'animations' moving across fabrics (Devendorf et al., 2016).

Figure 30.

Ebb by Laura Devendorf et al.

Ebb | Laura Devendorf et al. in collaboration with Google Jacquard Project | 2016

Note. Adapted by the researcher from "Ebb" by Devendorf, L., Howell, N., Lo, J., Lee, D., Paulos, E., Ryokai, K., 2016 [Textiles and conductive paint]. Copyright retained by the Authors and © Project Google Jacquard. Retrieved from: http://artfordorks.com/ebb/

This artefact exemplifies how practitioners knowledgeable on electrical properties can rely on new materials to explore other making shores. Practitioners such as Satomi and Parner Wilson write on this matter: “we consider E-Textiles to be a contemporary craft, not only because it combines novel materials, tools and techniques with those associated with traditional crafts, but the process of creating functional, reliable and aesthetically pleasing E-Textile results relies heavily on the manual skill and technical expertise of the maker - one of the defining notions of what constitutes craftsmanship.“ (Satomi & Perner-Wilson, 2011, p.2).

Nevertheless, close collaboration of engineers and craft-practitioners demonstrated how the complexities of the merging of physical and digital features could be approached from a craft perspective rather than an engineering perspective.

Figure 31.

Embroidered Computer by Ebru Kurbak & Irene Posch

Note. Adapted by the researcher from “Embroidered Computer” by Kurbak, E., & Posch, I., 2018 [Glass beads, golden threads, copper coil, magnets etc.]. Copyright retained by the Authors, photo © Elodie Grethen. Retrieved from: http://www.ireneposch.net/the-embroidered-computer/

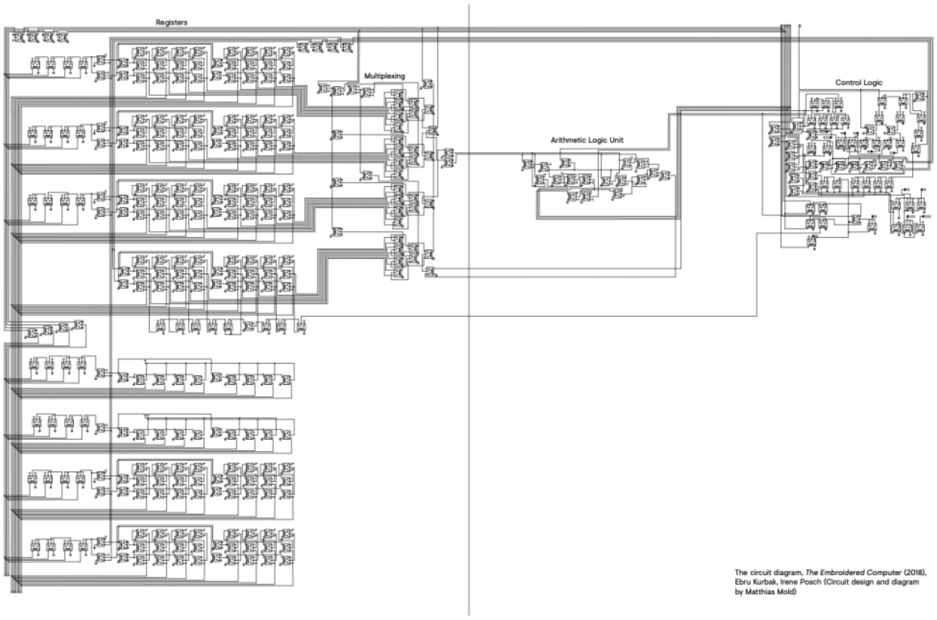
The Embroidered Computer (2018) by Ebru Kurbak & Irene Posch, is an example (Figure 31). The practitioners built a handcrafted computer[10] questioning how a computer would look if approached through traditional craftsmanship materials, rather than from new materials and an engineering perspective. Crafted solely through traditional craft materials –some of which with conductive properties (e.g., gold and silver threads, copper coil)–, the peculiarity of this artefact is that made through traditional material knowledge, the intricacy of the pieces' pattern and the quality of the handcrafted work do not suggest an immediate connection with computational technologies. Thus, the artefact was made through an advanced engineering understanding of circuits. As illustrated in Figure 32, the digital craft includes a total of "369 switches, constituting an 8-bit computer with 1-bit ALU multiplexed to four registers with an 8-bit register width and two additional storage registers" (Kurbak & Posch in Kurbak, 2018, p.130).

Nevertheless, the specificity of the materials used (i.e., conductive properties), was combined with engineering knowledge needed to create complex circuits, enabling the textile to operate as a computer. This would not have been possible without the design of the precise pattern and detailed material knowledge on conductivity, as much as it would not have been possible without the hand embroidery expertise. In the piece, depending on the direction the current passes through, small magnetic hematite beads flip to one side or the other, consequently opening or closing a circuit of interest. However, what if these craft elements were to be replaced with electronic components?

[10] in its capacity *The Embroidered Computer* is comparable to a 8-bit universal electromechanical computer from the 1950s

Figure 32.

The circuit diagram of the Embroidered Computer by Kurbak & Posch designed by Matthias Mold



Note. From "*Stitching Worlds: Exploring Textiles and Electronics"* by Kurbak, E. (Ed.), 2018, Revolver Publishing, pp. 138-139. Copyright retained by © Matthias Mold and © Ebru Kurbak & Contributors.

With new materials, designers in the HCI community started claiming that electronic elements should have been considered other examples of tangible, physical materials to draw from, when making (Mellis et al., 2013; Sundstrom et al., 2011; Wiberg et al., 2013).

The researcher Bdeir (2009) writes on how electronic elements are, for digital designers, "on the same level as . . . paper cardboard and other materials found in design shops" (Bdeir, 2009, p.397). Getting to know the properties of electronic elements and using them involves starting a *conversation with materials* (Schön, 1987), which arguably is what is characteristic of design practices adopting craft-based approaches. Moreover, as debated for new materials, electronic components' digital information needs to be necessarily paired up with other physical materials to come into play. Therefore, making with electronic materials has been compared to the experience of carving, sewing, or painting (Buechley & Perner-Wilson, 2012).

Hence, considering LEDs, sensors, buttons, motors, and other electronic elements as physical materials to be used –through craft-based approaches– with the same value and entitlement of any other traditional craft material, the spectrum of artefacts considered digital crafts considerably enlarged. Examples such as *Living Wall* (2010) by Leah Buechley et al. in Figure 33, have been often showcased as one of the first examples demonstrating the possibilities of integrating electronic components when making.

Figure 33.

Living Wall by Leah Buechley et al.

Note. Adapted by the researcher from *"*Living Wall" by Buechley, L., Mellis, D., Perner-Wilson, H., Lovell, E., Kaufmann, B., Chew, T., and Qi, J., 2010 [Conductive paint and electronic components]. Copyright retained by © 2010 Leah Buechley. Retrieved from: http://highlowtech.org/?p=27

Using conductive, resistive, magnetic paints and sensors, Buechley and her collaborators conceived a wallpaper able to create dynamic spaces (Figure 33). The wallpaper's circuitry –the hand-painted pink flowers–, where several electronic modules are attached through magnets, communicates with networked devices and it can be activated through touch. This means that the whole piece depends on code responding to touch and proximity of its users through specifically programmed outputs. Therefore, differently from other examples of digital crafts presented before here, a mixture of knowledge on electronic components (e.g., sensors, LEDs), new materials (e.g., conductive ink) and coding knowledge (i.e., digital material knowledge) are all needed to produce the outcome. Buechely et al. (2010), to address the multiple dimensions of the artefact, deconstruct the wallpaper into the articulation of three different layers "a magnetic layer, a circuitry layer, and a decoration layer" (Buechley et al., 2010, p.1401). All these layers together make it possible for the electronic components to activate at different times, responding to the human interactions with the artefacts.

A more recent example of a digital craft embedding electronic components is *The Bamboo Whisper* (2012), by Raune Frankjaer and Tricia Flanagan shown in Figure 34. The *Bamboo Whisper* by Frankjaer & Flanagan is a wearable device crafted through traditional techniques and containing different sensors. The artefact is electronically controlled and by translating ambient sounds through vibrations and movements of the bamboo reeds, it explores the theme of tactile sensory input (Frankjaer et al., 2013).

In the process of crafting the code, the practitioners unwillingly produced a delay in the structure of the algorithm but instead of changing it, the practitioners allowed the algorithm to question the qualities of the artefact, focusing on its material as the driver of the crafting process (Frankjaer et al., 2013). The practitioners underline how providing a structure to the technological elements that would recall traditional and organic forms was focal in conceiving the piece. As body-worn technologies can feel artificial, applying crafting techniques such as basketry, weaving, and felting relevant to our tradition, a more organic augmentation could be provided to the wearer, enhancing the range of expressions of the artefact (Ibid.).

Figure 34.

Bamboo Whisper by Raune Frankjaer & Tricia Flanagan

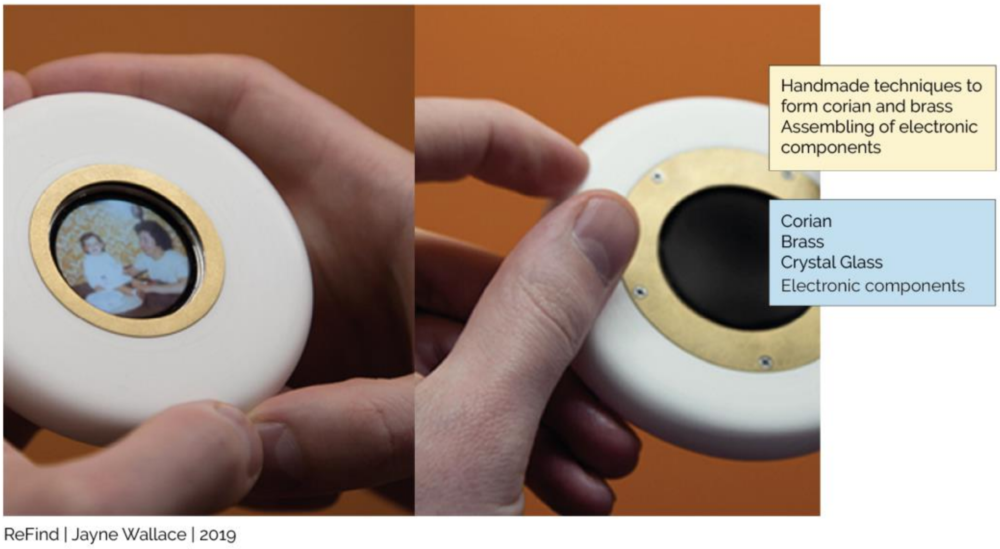
Note. Adapted by the researcher from “Bamboo Whisper” by Frankjaer, R., and Flanagan, T., 2011 [Bamboo, bast fibre, natural dyes, merino wool and electronic components]. Copyright retained by © Raune Frankjaer & Tricia Flanagan. Retrieved from: http://frankjaer.de/bamboo-whisper/

The debate focusing on the use of electronic components on the same plane of craft materials had been extensively argued for, especially in communities with a strong technological emphasis such as the Human Computer Interaction community. Meanwhile, scholars with a craftsmanship background working closely with technologies focused on the importance of material choices based on themes such as beauty, aesthetics, and attention to meaningfulness of the experience that digital crafts can provide through their interactive properties (Wallace & Press, 2004; McCarthy et al., 2006; Wright et al., 2008).

The value of qualities such as enchantment, empathy, and intuition have been widely explored as potential facilitators enabling meaningful experiences between the user and the craft. Through an empathic engagement between maker and user and between maker and materials in the process of making designers use their craft sensibilities to provide unique and meaningful experiences, elevating interactive artefacts from the idea of 'gadgets' to one of crafted objects (Wright et. al, 2008).

Figure 35.

ReFind by Jayne Wallace



Note. Adapted from "Refind" by Wallace, J., 2019 [Corian, brass and electronic components]. Retrieved from "ReFind: design, lived experience and ongoingness in bereavement" by Wallace, J., Montague, K., Duncan, T., Carvalho, L. P., Koulidou, N., Mahoney, J., ... & Fisher, H., 2020, *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, p.1 (https://doi.org/10.1145/3313831.3376531). Copyright retained by © 2019 Jayne Wallace.

ReFind (2019) by Jayne Wallace, is a very recent example focusing on the theme of *ongoingness*, an active and dynamic continued sense of bond and connection "between someone bereaved and a person who has died" (Wallace et. al, 2020, Abstract). By interacting with the artefact and rotating it from or towards the viewer, the user can navigate forwards or backwards through a collection of images connected to the beloved missing[11].

The piece is mainly made with corian, and its tactile qualities were carefully chosen by the practitioner to create an artefact that would feel pleasant to the touch even through its continued use. Corian remains cold even when one handles it for some time, and it is smooth to the touch. Moreover, a brass ring contrasting to Corian's feel and look, frames the screen creating a focal point, Brass was chosen to underline the preciousness of the images shown while providing structure to the hardware of the piece.

The practitioners' research output (Wallace et al., 2020) describes the attentive selection of the materials in light of the possible interactions a hypothetical wearer or user would have with them. By an empathic understanding of materials, the practitioner devotes time to find "personal significance in people's lives and to present fragments of it back to them" (Wright et al., 2008, p.11), underlying the importance of experience-centered design. Therefore, material sensibility for practitioners using electronic components plays an important role in order to support a successful experience with the designed interaction.

As craft-based approaches started rapidly permeating in the HCI community, coders engaging with problem-setting and problem-solving tasks simultaneously, started calling for analogies between craftsmanship and coding (Buechley & Perner-Wilson,

[11] to know more about the interaction specifics of the piece see paper by Wallace et al. (2020)

2012; Lindell, 2014) referring to Sennetts' book *The Craftsman* (2008). In the book, Sennett claims that to explore, identify, understand a design situation, and select the tools and techniques needed to provide a solution to that specific material situation, are qualities at the core of craftsmanship. Coders, identifying their abilities with those of problem-setting and problem-solving started comparing "the ancient potter and the moored programmer" as "members of the same tribe'' (Lindell, 2014, p.622), both engaging with materials in their making processes. The analogies made between the activity of programming to that of crafting led to a second analogy, the one of craft materials to digital materials; "considering code a design material allows the metaphor of craft to be used for the activity of programming" (Lindell, 2014, p. 613). Satomi & Perner-Wilson, heavily relying on Pye's (1968) theory on craftsmanship as the *workmanship of risk* (as previously discussed in subsection 3.1.1), write:

> "We consider e-Textiles to be a contemporary craft, not only because it combines novel materials, tools and techniques with those associated with traditional crafts, but the process of creating functional, reliable and aesthetically pleasing E-Textile results relies heavily on the manual skill and technical expertise of the maker - one of the defining notions of what constitutes craftsmanship" (Satomi & Perner-Wilson, 2011, p.2).

The emphasis on the comparisons and analogies between digital and craft materials and between digital and craft processes will be referred to later in the discussion (Chapter 6) and in the conclusion (Chapter 7, Section 7.2).

3.2 Understanding digital craftsmanship through the complexities of *Tacit* and *Explicit Knowledge*

As endorsed in the 2003 UNESCO Convention[12], among other examples of Intangible Cultural Heritage, *knowledge* and *skills to produce traditional crafts* are to be safeguarded as it is fundamental to preserve and value the intangible cultural heritage associated therewith the instruments, objects, artefacts and cultural spaces (i.e., tangible cultural heritage) of a community. The concepts *craft workers* and *handicraft* play a very important role within the UNESCO Constellation of Intangible Cultural Heritage[13] and its related principles, therewith, traditional crafting techniques started being closely monitored to address those ranked with the minor likelihood to survive to the next generation (e.g., the HCA list of endangered crafts[14]).

With this in mind and ss briefly seen in Section 3.1, numerous scholars outside of the design research field and without a practice-based imprint, have been pointing out at the theoretical controversies arising from the new partnership between hand-making and digital tools and techniques, emphasizing their differences and suggesting that the agency traditional craftspeople used to have over the processes and materials is being increasingly shifted to control and mastery of the digital interface (e.g., McCullough, 1998; Latour, 2008; Sennett, 2008; Pallasmaa, 2009). Such a shift may be not universally described in a negative way, but it certainly has several features which are bound to raise some concerns. The latter includes the polarizing contrast between hand making and digital craftsmanship, the comparison between digital craftsmanship and industrial/automatized processes that work with almost no human involvement in the making (Latour, 2008), and the underlined

[12] https://ich.unesco.org/doc/src/2003_Convention_Basic_Texts-_2020_version-EN.pdf
[13] https://ich.unesco.org/en/dive&display=sdg#tabs
[14] https://heritagecrafts.org.uk/redlist/

shifting role of hands and technologies in the active engagement with materials (Ihde, 1993; McCullough, 1998; Latour, 2008; Sennett, 2008) –as a practice that is devaluing the latter, engendering a sense of loss in our heritage (Pallasmaa, 2009).
The recent literature addressing the foregoing themes, has been broadly used in theoretical debates concerning *digital craftsmanship* to address and emphasise sometimes qualities of the digital material world and its related making processes, other times qualities of craftsmanship approaches and more traditional techniques. However, in order to achieve a better understanding of contemporary debates on the topic it is necessary to widen the scope of the present discussion to some earlier theoretical contributions.

In the first part of the 20th century Merleau-Ponty's (1945) *mind/body interrelation* (based on Husserl, Sartre, and Heidegger's previous advocacy of a phenomenological approach), pushed forward the idea that humans rely on *embodied cognition* (differently from what was thought in the Cartesian mind/body duality theory[15]).
Using different perspectives, the above-cited phenomenologists tried to describe the way tools, in relation with materials of the world and our bodies, play a fundamental role in our embodied cognitive understanding of the world. In particular, Heidegger stresses that tools are used with no more conscious involvement than the act of walking, eventually becoming everyday dealings that are "fundamental yet unobtrusive" (Heidegger as quoted in Krell, 1993, p.19). He notices how the hammer as a tool brings about its purpose without us even noticing it, becoming part of our body while we fix a nail in the wall. It is only on the occasion that something goes

[15] Renè Descartes (1649) was postulating the separation between mind and body establishing the theoretical superiority of mind (i.e., reason) over bodily experiences

awry that attention to the hammer, or the process thereof, is required (such as if the tool itself breaks, or more so if the operator hits their thumb).
Merleau-Ponty (1945) develops further these thoughts describing the way in which the walking stick of a blind person becomes an *extension* of his/her owner's body. This manifests from the moment the person begins to use the item and develops further until the user perceives the world through the stick.

The phenomenological views mentioned were developed to a large extent as a reaction to the increasing role of deductive mathematical models in science[16], the latter being perceived as a threat to the role of bodily experiences and individual perceptions. According to phenomenologists practice-based bodily experiences and individual perceptions[17] are ignored within scientific models. While acknowledging the importance of the phenomenological philosophical framework, the researcher previously emphasised the limitations of such theoretical view adopting instead an heterophenomenological standpoint in this project as discussed in the methodology (Chapter 2, PART II). Despite the researcher's personal approach, the phenomenological philosophical framework has heavily contributed to emphasise the role of the body and of the embodied knowledge in many subsequent studies focusing on craftsmanship and practice-based activities. Therefore, having had a prominent relevance in the field the researcher believes it needed mentioning as a background reminder.

[16] Mathematical models can be regarded as the most typical examples of deductive style of reasoning. Galileo Galilei is a prototypical example producing mathematical models of modern science at the time

[17] Aspects strictly related to the concept of *Tacit Knowledge* (Ryle, 1945; Polanyi,1966) will be articulated later in subsectio 3.2.1

Meanwhile, several scholars promoting practice-based exercises in education (especially in the area of Arts, Design and Architecture) studied extensively applied approaches aiming to promote the value of hands-on experience over solely theoretical education.
Dewey (1986), the prominent American philosopher and educational reformer summarised this concept in “learning by doing” stressing how humans base their whole existence on *experiential knowledge.* Thinking is far from being a theoretical-contemplative activity that is an end in itself, thinking in Dewey’s perspective comes from experience and is aimed at action. The advancement of this pragmatic approach started growing significantly through Schön’s book titled *The Reflective Practitioner* (1938) where he points out that, for practitioners, it is fundamental to have a “reflective conversation with the material” (Schön, 1938, p.6).
In addition, Ryle (1945) emphasizes the distinction between *knowing-how* and *knowing-that,* pointing out that “the concept of *knowing-how* is a concept logically prior to the concept of knowing-that" (Ryle, 1945, p.4). *Know-how* is typically acquired by ingesting information either in written or audio forms (Ibid.). For example, simply by reading a recipe, you gain the ability to follow the theory (though it might not make you a chef!). Instead, acquiring *know-that* requires *learning by doing* as it is propositional knowledge derived as a direct result of having practically done something.

Learning by doing is shared by humans with great apes and other primates (and possibly other mammals as well). However*, learning by doing* in chimpanzees and other primates typically relies on *emulative learning*[18]. What is distinctive and uniquely human, is a variety of *learning by doing* which relies on *imitative learning*,

[18] repeated attempts to find individually a way to achieve the same final state resulting from the observed behavior of some from the same species

including *complex imitative learning* (see Tomasello et al., 1993; Sterelny, 2012). The latter requires the ability to distinguish the final state or goal of a certain behaviour from the actions or means that bring it about, and possibly to decompose it into a finite sequence of simpler acts to be carefully imitated one by one.
Those acts are what we now know as informal, *Tacit Knowledge* (Polanyi, 1966).

Polanyi's overview on knowledge having a *Tacit* dimension is explained through his famous bicycle example: once we learn how to ride a bicycle (a process which must take place via practice) through attempts and failures, we know how to do it for the rest of our lives. The action of cycling can be divided into a sequence of rules, formulae or facts that could possibly capture and explain the action in formal ways (Polanyi, 1966). In Polanyi's view, only experts could be able to describe the particulars of a skilful performance as it "is achieved by the observance of a set of rules which are not known as such to the person following them" (Ibid., p.49). Those rules are a form of *Explicit Knowledge*.
Capturing those rules is often misunderstood as the ability to transform *Tacit* Knowledge into *Explicit Knowledge*. Thus, *Explicit Knowledge* and its possible cognitive acquisition can solely be a general understanding of a particular activity. Without practice "Tacit knowledge cannot be 'captured', 'translated', or 'converted', but only displayed and manifested, in what we do" (Tsoukas, 2005a, p. 123). Tsoukas interprets Polanyi's concept of *Tacit Knowledge* as knowledge that is truly *personal* and *practical*, as it does relate to *context-specific skills* (Ibid.). These two premises make *Tacit Knowledge* ineffable and at least partly non-convertible into *Explicit* forms of knowledge (to be expanded on this point in Section 3.2.1).

Design as a hands-on practice (which is shared in different fields: arts, architecture, gastronomy, fashion..etc.), but most specifically traditional craftsmanship practices, have been often singled out as a *par excellence* example about applying one's personal knowledge to the giving of form. That is so because while crafting with hands humans engage in an intertwined process where material and consciousness advance together. Hence, craftsmanship itself is a prominent representation of the special human condition of "being engaged" (Sennett, 2008, p. 20) with materials, a process in which "improvisation is inherent" (McCullough, 1998, p. 21-22). Indeed, the 'philosophy' of craft provides a key example of the complexity of human learning abilities; abilities that lie in the understanding that cognitive and manual activities are effectively intertwined (Dromer, 1997; Ingold, 2013).

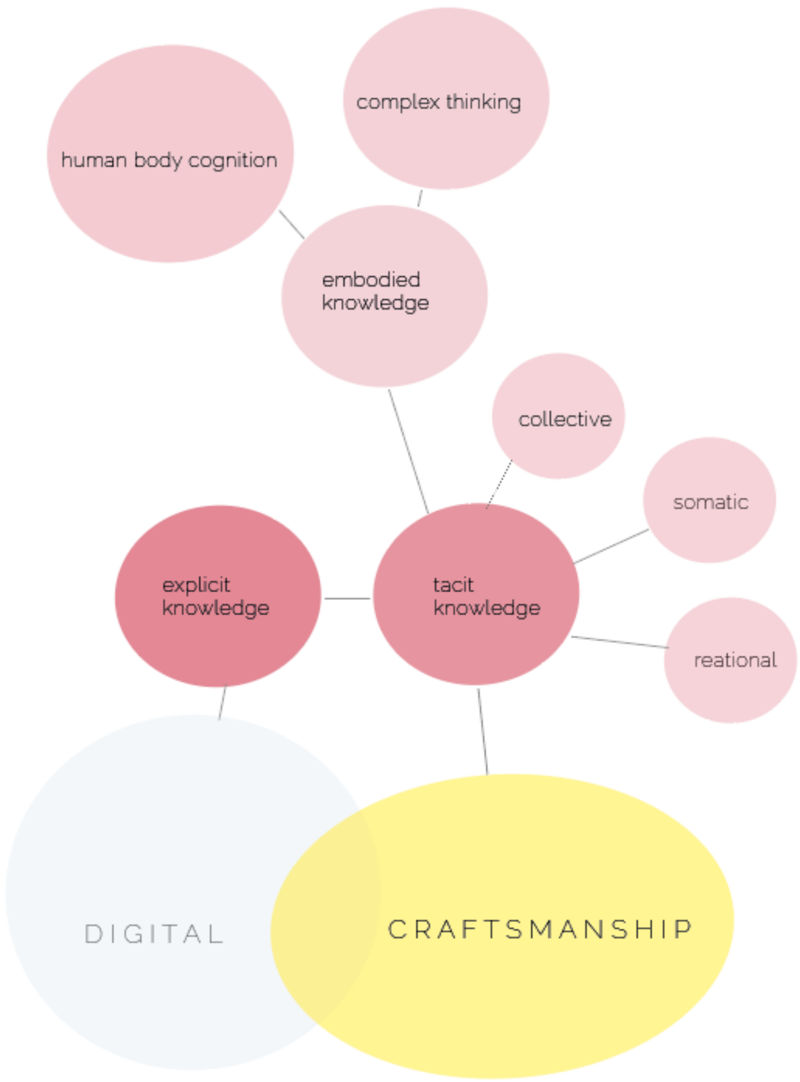
Moreover, *Tacit Knowledge* is typically distributed in a community of practitioners (see section 3.2.1.4).

As seen, the physical interaction of the body has a very dominant role in *Tacit Knowledge* and for this very reason, a significant portion of the knowledge embodied practically in every form of craftsmanship is a prime example of *Tacit Knowledge*. This consideration has generally been a way to explain how embodied actions rely on making expertise and experiential / non-propositional knowledge with their variations (Williams, 2001; Grayling, 2003; Niedderer & Townsend, 2014).

More recent studies over Polanyi's contributions have stressed that in the last few decades the notion of *Tacit Knowledge* has been used to refer to a diverse range of phenomena. This in turn has made it even more difficult to reach a common understanding of what *Tacit Knowledge* actually stands (or should stand) for. As a result, even the traditional link commonly established between craftsmanship and *Tacit Knowledge* seems to require some further clarifications.

Figure 36.

Themes addressed in Section 3.2 in relation to the topic of digital craftsmanship



Note. Craftsmanship is highlighted in yellow as it will be the first term examined through concepts of knowledge acquisition and transmission.

The researcher posits that it is important to analyse both the theoretical position of craftsmanship in order to understand the digital evolution of it and the debates that surround *digital craftsmanship*. Taking a closer look at traditional ways of crafting and making with hands, through the understanding of different theories on knowledge acquisition and transmission, will help to clarify some of the basic motivations underlying the present inquiry.

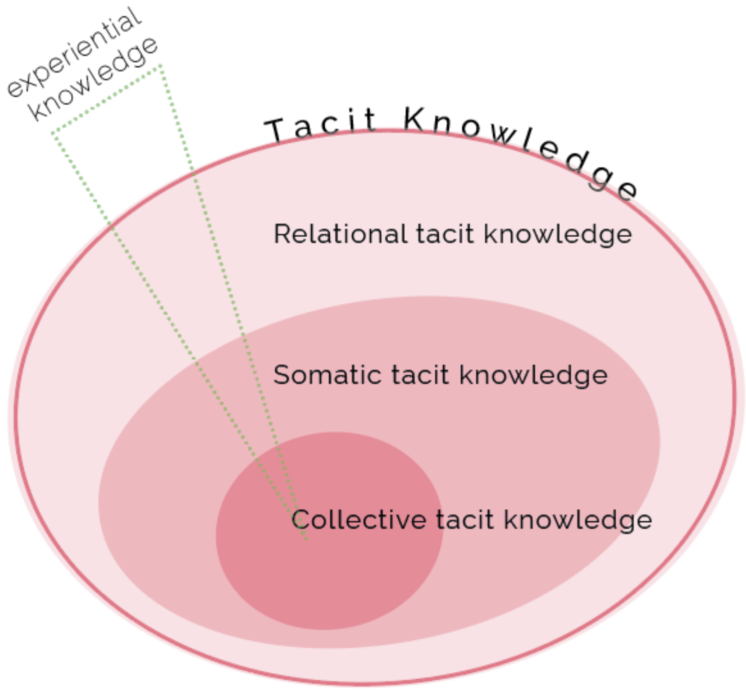
In this section, the notion of *digital craftsmanship* is deconstructed into its core elements of *digital* and *craftsmanship,* treating them as separate elements to be understood in relation to human knowledge acquisition. Accordingly, as illustrated in Figure 36, the researcher will first focus on *craftsmanship* and some of the key components of knowledge acquisition and transmission mentioned above.

3.2.1 Tacit Knowledge

The concept of *Tacit Knowledge* –as opposed to *Explicit Knowledge* (to be articulated in subsection 3.2.2)– can be broken down into three "degrees of resistance of the tacit knowledge to being made explicit" (Collins, 2010, p85). As illustrated in Figure 37, in order of difficulty of transmission, we find: *Collective tacit knowledge*, *Somatic tacit knowledge* and *Relational tacit knowledge*. In order to emphasise the distinction between the overarching notion of *Tacit Knowledge* and its particular specifications (*Collective, Somatic* and *Relational tacit knowledge*) the researcher will rely on the uppercase versus lowercase initials of the word "tacit knowledge". A similar convention will also be occasionally used for the corresponding adjectives *Tacit* vs. *Explicit.*

Figure 37.

Layers of Tacit Knowledge



Note. The different layers of *Tacit Knowledge*: *Relational, Somatic* and *Collective tacit knowledge*. Through experiential knowledge, all layers are accessible to different extents and degrees.

Collective tacit knowledge is considered the strongest example of *Tacit Knowledge*, namely the hardest to be made explicit, as it has to do with the way in which society is constituted. *Somatic tacit knowledge* can be regarded as medium-strength *Tacit Knowledge*: it is knowledge that relates to the human body in relation to its cognitive capacities, and in principle it is possible to articulate as the outcome of thorough and in-depth research studies. Finally, we have *Relational tacit knowledge*, which is the weakest example of *Tacit Knowledge* as it is based on human behaviours and the way in which human relations work (expanded from subsection 3.2.1.2 to 3.2.1.3). It is important to keep in mind that experience (illustrated in Figure 37 as *experiential knowledge*) is fundamental to access *Tacit Knowledge*. Moreover, Collins' (2010) classification of *Tacit Knowledge* in terms of degrees of resistance to knowledge being made explicit underlines the importance of distinguishing what is *Explicit*, *explicable* or none (these points will be discussed later in subsection 3.2.2).

Often within the area of craftsmanship practitioners refer to the central role the body plays in crafting as *Tacit Knowledge* in order to imbue value to skills and technical knowledge as embodied experience can never be fully explained.
There are however ways to uncover aspects of craftsmanship knowledge, often referred to as being *Tacit*, that might have simply been overlooked or just not been made fully explicit yet. This is the reason why it is relevant to have an in-depth overview of what different types of *tacit knowledge* have been classified at present, to understand how craftsmanship might relate to some of these distinctions and if so why so.

3.2.1.1 Relational tacit knowledge

Relational tacit knowledge is considered by Collins as the weakest sort of *Tacit Knowledge* because it *could* be made accessible (in that it can be articulated, understood, and discussed). However, it has not been made accessible due to often unspecified reasons involving the location of the knowledge or the nature of human behaviour. In other words, *Relational tacit knowledge* depends strictly on how people relate to each other, the way in which certain societies are organised or the way in which certain people behave:

> "Both sender and receiver have the cultural and language background to understand each other if the explicated knowledge was detailed and long enough but the sender either feels no inclination to make the string long enough or does not know how to make it long enough" (Collins, 2010, p.86).

In his work Collins explains different cases where the condition of *Relational tacit knowledge* is verified: *concealed knowledge, ostensive knowledge, logistically demanding knowledge, unrecognised knowledge,* and *mismatched saliences*.

Concealed knowledge

Concealed knowledge is knowledge that can be readily transmitted with just a few words, but it is deliberately kept hidden. This secrecy is sometimes adopted by eliterian groups that might want to exclude others from some rituals: this is of course a quite common occurrence in virtually any social network where the need is strongly felt to demarcate the agents/members who have spent enough time in the network from those who have not. Within craftsmanship practices, such natural human behaviour has often been noticed:

> "In the case of apprenticeship, [when] tricks of the trade will not be told because humiliation of the uninitiated seems part of the ritual and the power relations, the tricks will eventually be picked up through watching and trying to copy the master . . . Some of the knowledge that is learned through joining the networks of elite groups or getting close to the masters is knowledge that could be told, and some is not" (Collins, 2010, p.92).

Moreover, in Michael Coy's book *Apprenticeship: from Theory to Methods and Back Again*, the author collects a diverse number of studies of scientists taking the apprentice role in a wide number of craftsmanship practices and around the globe. Introducing the studies Coy underlines how, in many of the written pieces of work collected, "the apprenticeship is often viewed as an education in the 'secrets' of a craft" (Coy, 1989, p.3). Stating that what the authors call *secrets* often refer to implicit ways of seeing or knowing or the proper manner to use in dealing with one's fellow craftsmen or the means of accessing tools or raw materials. He writes: "what is implied to those outside the craft is that there is specialized knowledge that is controlled by those within the craft; knowledge that is essential if one is to successfully and safely practice the craft" (Ibid., p.3). It is not the details of the secrets themselves which bear nothing but that secrets themselves even exist at all.

Ostensive knowledge

Ostensive knowledge refers to that knowledge acquired from the visual stimulus of an "object or practice because the description in words, though everything is there to see and to describe, is too complex to be spoken and apprehended" (Collins, 2010, p.93). Artefacts themselves contain a wealth of information which can be transferred to the observer via *physical contiguity* (Ribeiro, 2007). *Physical contiguity* is what Ribeiro denotes as "proximity to the practices of a domain that falls short of active involvement or 'hands on' experience'" (Ibid., p.713). It should be noted that Ribeiro's observations underpin the view that seeing and manipulating an artefact, often referred to as *strings* (Collins, 2010), enables knowledge absorption to a fuller degree than a mere description of objects and activities via spoken or written words.

Logistically demanding knowledge

If we were to enter a workshop of a craft practitioner with an item made by them and ask them if they could recite the number of the tools / steps used from start to end of the crafting process, the practitioner might not be able to correctly explain and describe everything. This knowledge could in principle be made explicit if the practitioner were to write down every single step and tool used in the sequence they were used, assuming that the practitioner performed exactly the same steps each time. However, such a modality of knowledge transmission would demand an incredible effort and for this very reason most of the time if knowledge is logically demanding it stays tacit.

Unrecognised knowledge

Unrecognised knowledge can be thought of as familiar / routine procedures which are carried out differently by different people. Sometimes, when describing these procedures, we deliver information to others excluding pieces of knowledge that we do not recognise as fundamental – often due to the routine nature of the habit. As the apprentice follows and mimics the practitioner's movements, he might acquire that piece of *Tacit Knowledge* and pass it on inadvertently, perhaps without even noticing that it is fundamental to the whole process as it was not pointed out initially. This type of knowledge might become known if two practitioners start working together and their activities differ in the way they are carried out, in this way the unknown becomes known (Collins, 2010).

Mismatched saliences

Mismatched Saliences occur whenever pieces of information are kept hidden without that intention. If a craft practitioner wants to communicate everything they know to an apprentice, they could submerge said apprentice with information pertaining to the practice. Many pieces of relevant information may not be properly transmitted if there is not a sound alignment between what the practitioner says / shows and available knowledge – meaning that gaps in the learner's comprehension are virtually unavoidable. What seems relevant and understandable to the practitioner, might be completely insignificant for the apprentice who still lacks information which is required to understand and underpin the practitioner's inputs.

3.2.1.2 Somatic tacit knowledge

Somatic tacit knowledge is considered by Collins that part of *Tacit Knowledge* having a medium degree of resistance to be made explainable. It refers to the type

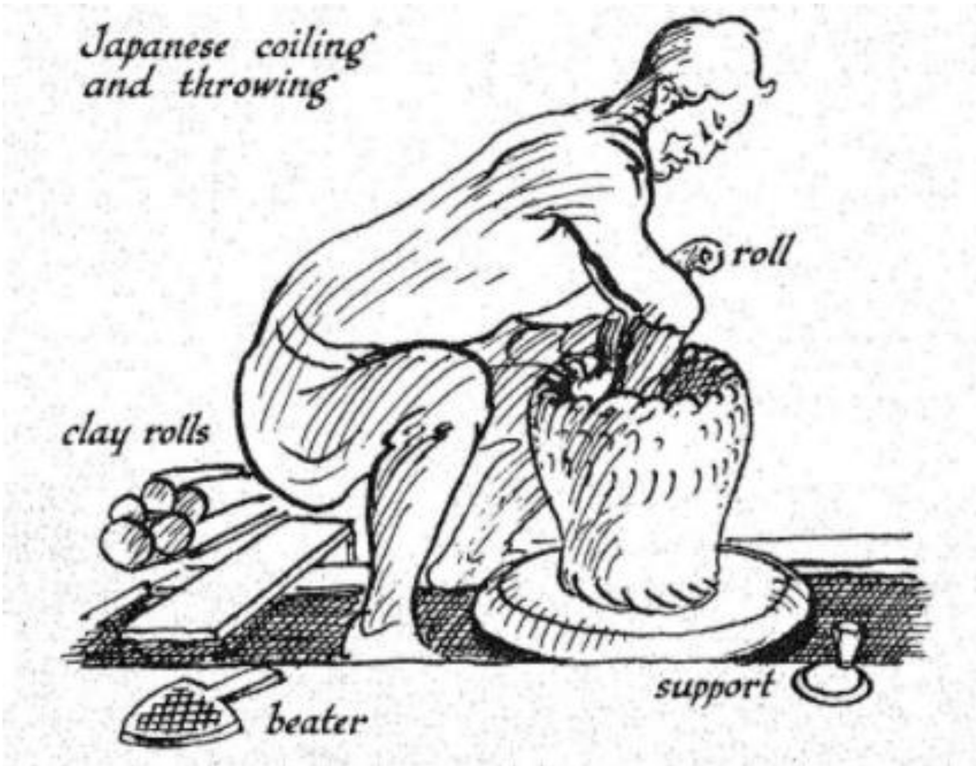
of knowledge involving our cognitive and bodily actions that manifest in examples such as Polanyi's (1966) mentioned *bicycle riding* case. *Somatic knowledge* focuses on the bodily experiences and embodied knowing it is that experiential knowledge involving senses, perceptions, and mind-body action and / or reaction.
We firstly mentioned in section 3.2 the concept of *complex imitative learning* (see Tomasello et al., 1993; Sterelny, 2012) and of *learning by doing.* Polanyi writes that "by acquiring a skill, whether muscular or intellectual, we achieve an understanding which we cannot put into words, and which is continuous with the inarticulate faculties of animals" (Polanyi,1966, p.90) and therefore, it is far more complex to explain and articulate; this is S*omatic tacit knowledge*.

Within many different studies related to craftsmanship researchers have tried to analyse bodies and gestures in the act of making, to try to make explicit how experiential knowledge is created. Leachs' *A Potter's Book* (1945), one of the most important manuals in Pottery, is an example of detailed documentation into Japanese pottery making.

Through the thorough descriptions and illustrations such as the one shown in Figure 38, (cognitive) knowledge transmission of the Japanese practices is possible to the attentive reader. Even if the language is very technical the glossary at the end of the book would make it possible for almost anyone studying it to converse expertly with others. Indeed, as mentioned above, mind and body are jointly involved in the understanding and mastering of any craftsmanship form or technical practice. Therefore, to ensure a successful *knowledge transmission* a practitioner would also have to *experience* (through their body) the specific technique.

Figure 38.

Example of an illustration drawn by Bernard Leach on Japanese coiling and throwing



Note. From "Japanese coiling and throwing" by Leach, B., 1945. In "A potter's book" by Leach, B., 1945. Copyright retained by © Faber & Faber. Retrieved from: http://preview.cambridgeprints.com/wp-content/uploads/2017/09/PB3b.jpg

Here is an extract from the book:

> "The potter who wrote them [referring to measures] knew what they meant, but their formulae were only of general use to me because I could not do more than guess roughly the water content of their slips etc. Again, it was some time before I realized the importance of converting their totals to percentages in order to find a means of relating one glaze or one experiment to the others. In adapting Kenzan's raku glaze to English requirements I

found it possible to use red lead and litharge instead of white lead." (Leach, 1945, p.150)

The above excerpt suggests that only another expert potter would have the ability to analyse the guidelines in the book and to be able to successfully integrate them in their own practice.

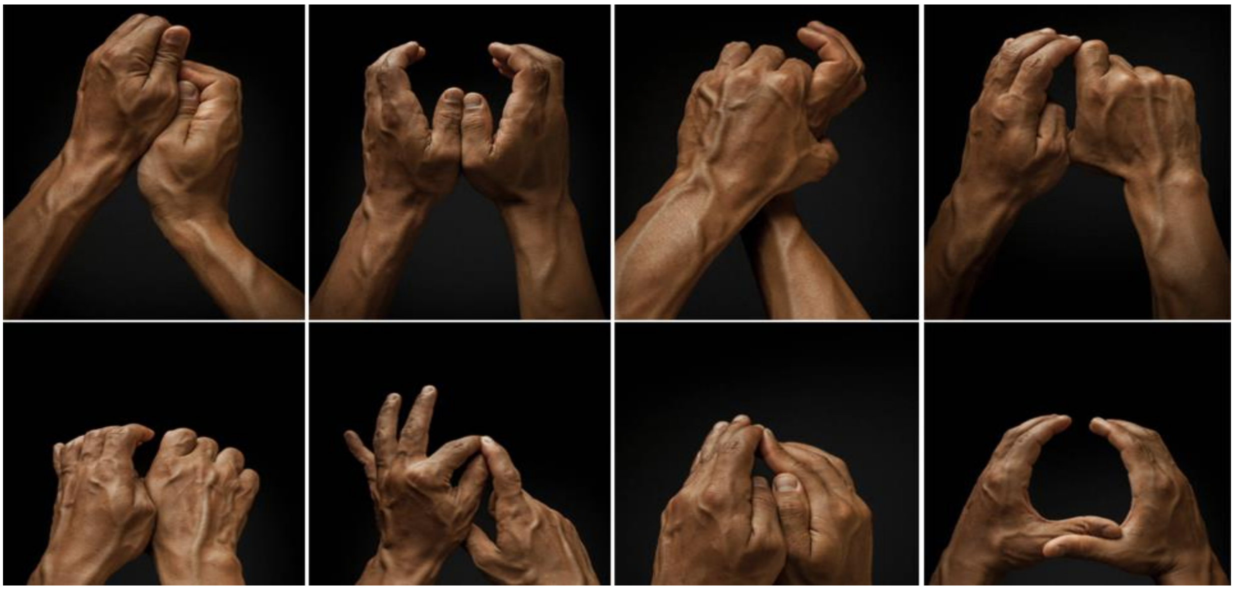
A shared language and expertise of the reader with the practitioner is necessary for a *full* transmission of knowledge. Moreover, the extract underlines how the practitioner can skilfully combine experiential and cognitive knowing through trial and error, aiming towards a specific result, enabling what Eastop refers to as *enacted knowledge* or *embodied knowledge in action* (Eastop, 2014, p.226). Hence, it is important to appreciate how skill acquisition takes on a dominant role between *Explicit* rules and the internalisation of a specific physical skill set: "skills cannot be executed with the same efficiency by humans if they are paying self-conscious attention to the rules through which they were taught" (Collins, 2010, p.104). This sort of knowledge is labelled by Collins as *Somatic-limit tacit knowledge*. The nature of human bodies is complex and the mechanisms of which make humans very tough to understand – more so when we attempt to consciously articulate these human mechanisms / experiences.

Collins does also stress how the obsession with the complexities of embodied knowledge tends to direct the attention of many researchers towards human bodies, preventing them to focus on much more significant areas, such as the nature of said knowledge for example.

By capturing bodily movements, we can begin to analyse them as shown in Figure 38 produced by Tortus Copenhagen Studio, which portrays the movements of a master potter throwing a bowl on the wheel. We could then potentially analyse those movements and code a machine in such a way to mimic a simplified version of those movements – *mimeomorphic actions (*Ribeiro & Collins, 2007). This however would not yet explain *Tacit Knowledge* in its fullness; what is actually leading and guiding the expert practitioner between such movements. That knowledge is *Tacit*, embodied and very difficult to articulate.

Figure 39.

Eric Landon's unique gestures when throwing on the potting wheel



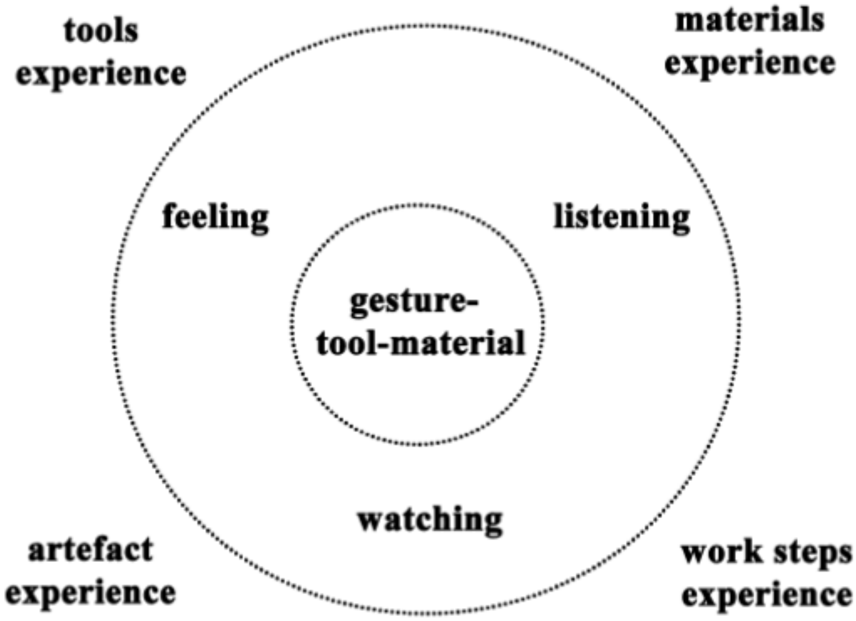
Note. From "Pottery making gestures by Eric Landon, founder of Tortus Studio" by Landon, E., [@Tortus], 24 December 2014 [Instagram Profile]. Copyright retained by © Eric Landon. Retrieved from: https://fi.pinterest.com/pin/410460953533909543/

In *An Apprenticeship with Glass and Fire* Frances Liardet (2014) used a personal reflective approach to analyse the development of his making skills throughout the time spent with his apprenteur in a glass workshop. Liardet, through the illustration shown in Figure 40, describes the core elements coming into play as his bodily experience and dexterity grew with advancing practice. Through an interplay of gestures, tools and materials he started *feeling* a sense of what he terms "rightness"

(Liardet, 2014, p.210). Arguably, we would be able to unpack *Somatic Knowledge* if we were to make explicit what this feeling of "rightness" generates.

Figure 40.

Dexterity: an interplay between tools and materials



Note. From "Movement in Making: An apprenticeship with glass and fire" by Liardet, F., 2014. In Hallam, E., and Ingold, T. (2014), *Making and Growing: Anthropological Studies of Organisms and Artefacts*, Routledge. Copyright retained by © Taylor & Francis.

The *Somatic tacit knowledge* remains inaccessible as the reader would still only be able to single out and discuss the main components of Liardet's experience without really understanding their interdependence.

As shown with Leach's (1945) example of Japanese potting, following the recipe of an experienced potter did not immediately result in Kenzan's Raku glazing. Leach did not succeed immediately, rather before mastering the technique he had to bring the written instructions into practice going through a bodily trial-and-error process. Arguably, had he been in Liardet shoes as an apprentice (2014), he may have absorbed the process more efficiently. Had he observed the pottery maker, replicating his/her movements, and putting into practice the notions observed with the supervision of the Master the learning process may have been more seamless. Instead, through a combination of time and a trial-and-error approach, Leach was able to replicate the techniques and ultimately improve the instructions he had been following by adding new relevant information. By converting the original Japanese units of measure into the British equivalents and including personal tips, describing in detail his failures in obtaining Kenzan Raku glazing, Leach was able to express details that could better explain the nuances to the European reader.

3.2.1.3 Collective Knowledge

To explain *Collective tacit knowledge*, the researcher will refer to Liberman's (2013) study on a concrete phenomenon that most people actively encounter in their everyday lives, for example crossing the street. Liberman studied a particular intersection next to the headquarters of the University of Oregon, Kincaid Crossing, and tried to make sense of the phenomenon of people crossing the street by observing them in their natural setting.

Liberman describes Kincaid Crossing as a particularly busy one, dangerous enough to have raised concerns within the municipality on more than one occasion. The residents and pedestrians around Kincaid Crossing had requested an instant intervention by the authorities in order to tackle the inherent risks associated with the crossing. What captured Liberman’s attention was that, despite new measures introduced by local officials, none of the habitual users of the crossing adapted their behaviours to the new rules. This highlighted that any efforts taken to tackle the problem were doomed to fail, meaning that investment of public funds to address the issue would have been wasteful. For this reason, the municipality shifted the focus of their attention from the pedestrian to the motorist. They claimed that pedestrians had become very experienced in crossing Kincaid, whereas the motorists were the ones who needed to be more careful. As a matter of fact, this study was undertaken by Liberman as an example of *ethnomethodology*, the research field studying how social order is produced naturally within societies. Yet, such a study is useful for our understanding of *Collective knowledge* in that it highlights how pedestrians repeatedly crossing the intersection over time demonstrated highly developed abilities and learning strategies into the crossing, being able to carefully avoid dangerous situations, despite the intensity of the traffic and no matter their activities (they were able to cross while chatting with friends, looking at the phone). Liberman claims within that chaos they had established a *local order*, automatically enacting certain practices that with time, became inherent, common practices.

Similar to the example of Kincaid crossing, riding a bike in traffic "includes understanding social conventions of traffic management and personal interaction" (Collins, 2007, p.121). These actions are moderated and supported through different explicit *strings* that in our culture are represented though physical signs (e.g., the zebra stripes, the traffic lights). However, arguably one would still be able to cross a street, even if these signs were missing, as one would rely on something else: *Collective knowledge*.

Generally, similar national differences apply when crossing the street or driving, thus, some rules might be tweaked: "for example, in Italy a style of driving is adopted that passes responsibility for safety to other drivers – to the collective of drivers" (Liberman, 2013, p.121). Though there are no explicit rules written anywhere, knowledge is tacitly transmitted simply by living within that specific society. As a result, "once this is first noticed one finds it is general for Italian drivers to expect the unexpected and cope with it as a matter of course while driving for the individual becomes much easier, since not everything you do has to be exactly ‘according to the book’. This is driver collectivism.” (Ibid., p.121). In order to acquire this type of knowledge, humans have to be immersed in collective practices and it is *Collective tacit knowledge* that we acquire and that we rely on when immersed in society. A person who has taken part in both practical activities and conversations around those activities in a specific community / society is likely to be further ahead in the acquisition of *Collective tacit knowledge* than a person who was exposed to words alone.

Therefore, *Collective knowledge* is precisely a prominent outcome of the recurrent involvement in interactions and activities, both communicative and practical.

To understand how this relates back to digital craftsmanship practices, we need first to focus on the counterpart of *Tacit Knowledge*: *Explicit Knowledge*.

In his book *Tacit and Explicit Knowledge* (2010), Collins claims that in order to better understand the *Tacit*, it is necessary to make a serious effort to fully understand what *Explicit* really means: “If it were not for the idea of the explicit, we would never have noticed that there was anything special about the tacit –it would just be normal life” (Collins, 2010, p.85). In other words, *Tacit* Knowledge starts precisely where *Explicit* Knowledge cannot be extended any further; they can therefore be thought of as complementary. It is presumably for this very reason that in the last decades Collins devoted a considerable amount of work to improving the general understanding of *Explicit Knowledge* in all its facets.

3.2.2 Explicit knowledge

Understanding *Explicit Knowledge* is as much important as, and arguably instrumental to, understanding the nuances of *Tacit Knowledge* (Section 3.2.1) since the two of them are strongly interconnected. What the researcher refers to as *Explicit Knowledge*, with uppercase initials, is that kind of knowledge that has to do with humans communicating via signs, icons, codes, images, objects: what Collins denotes as *strings* (2010, p.16). Generally speaking, “when we use the term explicit we draw on a subset of the ways we talk about communication” (Ibid., p.81) rather than on knowledge theories. Therefore, occasionally, the researcher will use ‘explicit’ with the lowercase initial as an adjective.

Strings can be either analogue or digital since there is no relevant difference between them until we start interpreting them. However, “analogue strings do have internal form and structure based on the nature of the materials from which they are made” (Ibid., p.34), while digital strings are made of a form and substance that is more “arbitrary than analogue strings” (Collins, 2010, p.34). This means that digital strings are immaterial and volatile as in the case of code or digital images, for example. Collins maintains that an artefact, as an example of a string, needs to be interpreted before it can represent anything to those who observe it as the output of any sort of communication activity.

A fundamental characteristic of human communication is the natural predisposition humans have to interpret strings. Humans interpret strings that they find meaningful, and in the process, they may transmit a transformed piece of *string* when they have to share / communicate notions with others. The meaning of a *string* does not lie in the object itself but in the combination of the personal interpretation of the artefact and the artefact itself. In other words, when the object is being observed, it is strictly connected to the background, cultural knowledge, territorial view and education obtained from the society it derived from.

As Collins reminds us, humans have a tendency to process information even when they try to rectify and avoid any information loss. Hence, there is no way to guarantee no information loss. What it is possible to do is to acknowledge that fact, and to try and minimize such a loss by “explaining better” (Collins, 2010, p.30). Generally speaking, we have a sound instance of *Explicit Knowledge* whenever we are able to communicate what we intended to, no matter how badly the string was produced. Thus, to make that string a successful string (thereby allowing knowledge transmission) the person receiving the string needs to have the means to interpret it without transforming its meaning. Owning the same cultural and linguistic understanding as the speaker helps, moreover, in the case of very technical, embodied practices, owning some practical experience definitely helps. As long as we can communicate and explain something better over and over, we are talking about *Explicit Knowledge* that can be explicated (i.e., made explicable). Collins argues that we can explicate *Explicit Knowledge* through *elaboration* –where a longer *string* affords meaning that a shorter cannot– and through *transformation* –where a physical transformation of a *string* enhances both their effect and affordance (Collins, 2010, p.81).

By contrast as well as by definition, *Tacit Knowledge* cannot be made *Explicit* in any way. This is worth stressing as the concept of *Tacit Knowledge* is often misused (see Chapter 7, subsection 7.1 for in depth discussion). Using Matsushita's development of the Home Bakery machine, Nonaka and Tekuchi’s (1995) study provides a famous example arguing that *Tacit Knowledge* can be made *Explicit,* forming encoded strings and allowing it to be shared in different contexts. As the designers could not perfectly make the dough kneading mechanism for the bread-making machine, a software programmer apprenticed herself to a Master baker in

Osaka's International Hotel – with the aim of acquiring *Tacit Knowledge* by observational methodologies. Nonaka & Takeuchi explain that by the time the observer gained an understanding of the tacit actions involved in the kneading process, the apprentice was able to arrange the acquired information into several sets of instructions. These instructions were in turn converted into specific strings of code by experienced engineers. The research underlined that the result was conveyed in a remarkable machine embodying the tacit "skills of a master baker in a device that can be operated easily by people with no knowledge of bread making" (Nonaka & Takeuchi, 1995, p.95).

Nonanka & Takeuchi's study has been widely discussed and criticized at length in the subsequent literature (Tsoukas, 2005a; Gourlay, 2006; D'Eredita & Barreto, 2006). A remarkably helpful contribution is Ribeiro and Collins (2007), who take a hands-on / practical stance in order to support their critical assessment of the claims made by Nonanka and Takeuchi. Indeed, Ribeiro and Collins proceed to experience the process of baking bread themselves, to the effect of dismantling Nonaka & Tekeuchi's positive claim concerning the possibility of translating *Tacit Knowledge* into *Explicit Knowledge*.

Drawing also from previous studies by Collins and Kusch (1998), Ribeiro and Collins claim that *Tacit Knowledge* cannot be made *Explicit* since, as in the case of bread-making, the action to be analysed is typically *polymorphic* (2007). *Polymorphic* actions heavily rely on social circumstances and because of that, they are executed with many different behaviours: "there are no available instructions for how to vary the behaviour associated with the action in order to carry it out successfully" (Ribeiro & Collins, 2007, p.1419). These actions are indeed rooted in *Tacit Knowledge*.

On the other side of the coin, we find by contrast *mimeomorphic* actions which can be described by means of generally redundant instructions that are carried out always in the same way[19]. To be more precise, *mimeomorphic* actions are those actions carried out in the same exact way and specifically with the same behaviour, regardless of the occasion. These actions *mimic* a certain human movement or process which do not need nor consider further understanding of the surroundings. Due to their nature these actions are easily translatable into codable instructions, either: language, (or in the case of the bread-making machine) code.

Through baking themselves, Collins and Ribeiro unpack the action of making bread into component actions which may be classified as either *mimeomorphic* or *polymorphic* and proceed to showing that overall baking is in fact made of a series of *polymorphic* actions rather than *mimeomorphic* ones. They also stress how, within any *polymorphic* action, we can define a couple of *mimeomorphic* actions that can be easily described and replicated without any variation (e.g., picking up the ingredients). Though this alone does not change the whole action of baking into a *mimeomorphic* action. They write:

> "Not all mimeomorphic actions are explicable to humans. Kneading, though it is a mechanizable mimeomorphic behaviour, is something that is only mastered as a piece of tacit knowledge by humans (like balancing on a bicycle). These heavily tacit-knowledge laden mimeomorphic actions are learned by humans in social groups just as polymorphic actions are learned and that is why the literature on tacit knowledge often does not put the dividing line between what can be automated and what cannot be automated in the right place. (...) The way the breadmaker used by Ribeiro mixes and kneads differs from the way it is done by the Japanese bread-making machine and probably differs from the way humans do it, but the *mimeomorphicity* is demonstrated by the tolerance to variations in the exact

[19] the notion "the same" implies tolerance to a certain extent (Collins and Kusch, 1998, p.47)

behavioural instantiation of the kneading act" (Ribeiro & Collins, 2007, p.1424).

In other words, conversion of *Tacit Knowledge* into *Explicit Knowledge* is not possible: the machine substitutes human bread-making actions with mimicked, simplified versions of those actions: "...what the machine does is to mimic the mechanical counterpart of just a few of certain special kinds of human bread-making actions" (Ibid., p.1418).

The baking master's *Tacit Knowledge* has been neither made *Explicit* nor incorporated into the machine; part of it was substituted by the *Tacit Knowledge* that "other actors brought to the automated bread-making scene (the users at home, the workers in the factory and repair specialists), while the other part has disappeared entirely at the cost of a standardized set of products and procedures" (Ibid., p.1418). Machines trying to mimic specific human actions, thus substituting human actors themselves, are considered as "social prosthesis" (Collins, 1990), for example a pacemaker. The machine can be programmed to mimic specific actions that can be repeated *ad infinitum,* but they do not understand the surrounding culture (Collins & Ribeiro, 2007).

On the contrary, *Tacit Knowledge* is the "unarticulated background in which we dwell" (Tsoukas, 2005b, p.13) and thus is uniquely personal. As such, *Tacit Knowledge* is acquired through innumerable practical experiences which take place over the lifetime of the individual. All of this underlines the close interrelation between *Tacit Knowledge* and *experience* and clarifies that *strings*, transformed into mechanical causes and effects, are capable of mimicking human actions without gaining *Tacit* aspects of knowledge. That observation also impinges upon the relationship between experience and *skills* to which the researcher now turns.

Through Leah's (1945), Nonaka and Takeuchi's (1995) and Ribeiro and Collins' (2007) examples, we can see how *Somatic knowledge* sheds light on the importance of the role of *skills* in hand making practices. Kuijpers defines skills as "the ability to carry out a task and do it well" (Kuijpers, 2013, p.140). Thus, the complexity of skills acquired through craftsmanship and the workmanship involved in mastering a set of very precise and nuanced actions, is a process that has been studied by different scholars coming from various disciplines related to the social and natural sciences (e.g., Ingold, 2000; Sennett, 2008; Gowlland, 2015; Kuijpers, 2017).

As seen in Section 3.2.1, *learning by doing* relies on *complex imitative learning* (Tomasello et al., 1993; Sterelny, 2012). Such learning requires the ability to distinguish the final state or goal of a certain behavior from the actions or means that bring it about. This could possibly extend towards the deconstruction of the act into a finite sequence of simpler acts to be carefully imitated one by one. *Experience* is acquired through both the high number of repetitions of these deconstructed acts as well as the understanding of the relationships between these acts.

Scholars such as Dreyfus and Dreyfus (1986) deeply analysed the process of skill acquisition, working out a five-stage model that tries to unpick different stages in human acquisition of a skill – in this case driving a car. In their opinion we all start from a status of *novice* to then move into *advanced beginners,* to become *competent*, to then evolve into *proficient drivers,* to finally achieve an *expert* status. These five stages were defined by specific differentiations detected by Dreyfus & Dreyfus in the progressive interaction with the car and, ultimately with the world.

Craft practitioners can be defined as *skilled*, or even *specialists.* Archeologist Kuijpers (2017), also emphasises that such labels might mean very different things when we analyse different artefacts. Kuijpers asserts that it is only through non-linear processes within the practice of that specific skill that a craftsperson is able to evolve into a specialist – a viewpoint which clashes somewhat with that of Dreyfus & Dreyfus. Kuijpers differentiates the skills of craftspeople from other skill sets due to the fundamental impact which the materials themselves have upon the crafter, even among specialists (i.e., someone that is highly skilled). Analysing archaeological artefacts of the bronze age, Kuijpers demonstrates how it is possible to differentiate *skills,* not only by looking at embodied or cognitive actions but also through the analysis of artefacts. Hence, he proposes a subdivision of the term *specialist* into four separate groups each holding a different degree of material competence.

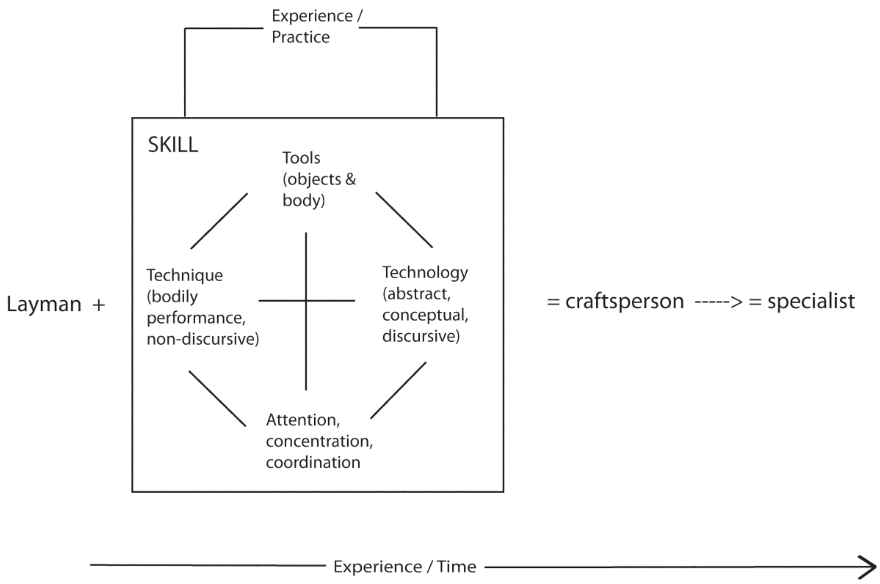
The groups he identifies are:

> 1-*Amateurs:* basic knowledge of the craft, little refinement in the artefacts, little appreciation of materials and susceptible to beginner's mistakes.
>
> 2-*Common Craftspeople*: fully embodied skills that do not stand out, imitative and repetitive details in the production, artefacts serve a specific function, generally they do not take aesthetic risks that could affect the production.
>
> 3-*Master crafters*: distinct, prestigious objects where symmetry, care, surface finish and decorations are common traits.
>
> 4-*Virtuoso*: Exceptionally skilled artisan, creating unique objects through the use of unconventional techniques, exploring the boundaries of material limits, because of the complexity of techniques they use it is very difficult to pass on their knowledge through apprenticeship.

Thus, it can be posited, as control on specific materials and techniques grows the quality and value of the outcome also grows. Therefore, the importance of *skills* strictly depends "on the cultural reference of what is considered 'quality'" (Kuijpers, 2017, p.140) in the *community* of reference. Therefore prestige, rank, status and ultimately the practitioners' identity are reinforced as long as their *skills* improve, in relation to a specific group of people holding the same standards (Landry, 2011).

Figure 41.

The evolution from layman to specialist illustrated by Kuijpers



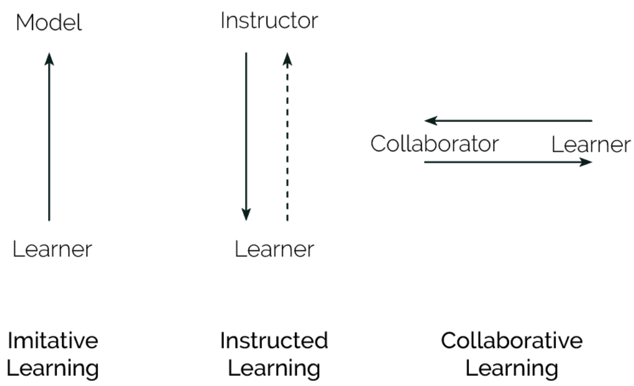
Note. From "The sound of fire, taste of copper, feel of bronze, and colours of the cast: sensory aspects of metalworking technology." by Kuijpers V., 2013. In Sørensen, M. L. S., & Rebay-Salisbury, K. (Eds.). *Embodied Knowledge: Perspectives on Belief and Technology,* p.137. Copyright retained by © Maikel H. G. Kuijpers and © 2012 Oxbow Books, Katharina Rebay-Salisbury, Marie L. S. Sørensen.

As illustrated in Figure 41, Kuijpers underlines that craft practitioners all have a common trait: they have to experience and practice certain *skills* in a nonlinear way, meaning that acquiring skills is a learning process arising from the iterative continuous engagement with tools, technology, techniques and coordination. Ultimately, through repetition and practice of these skills, *experience* becomes embodied and therefore *contributory*; the practitioner is able “to *contribute* to the domain to which the expertise pertains” (Collins & Evans, 2007, p.24) (see chapters 4 and 6). Therefore, it is clear that the holistic nature of the process of crafting is complex and to become a specialised craft practitioner it takes more than learning a specific technique or skill (Sennett, 2008; Crawford, 2009). In particular, to become part of a community of craft practitioners, one’s work has to be appreciated by other practitioners of the same community. People have the need to identify themselves as part of a social group and within this community their members tend to construct and idealise some sort of unity of experience that reinforces the social group – so called *cult values* (Mead, 1934*).* Therefore, as we go to the centre of the concept of knowledge transmission it becomes evident that "human cognition is social and cultural to its core" (Tomasello et al., 1993, p.509). The cognitive and embodied act of acquiring and transmitting *Tacit Knowledge* is bonded to culture which, in turn, plays a dominant role in the learning process. What makes human communities and cultures possible is that knowledge transmission relies on *instructed* and *collaborative learning* alongside the inherent human ability of *imitative learning* (Ibid., 1993). The learner, as illustrated in Figure 42, acquires knowledge through different means via three independently defined learning situations as identified by Tomasello et al (2013).

In *imitative learning* the learner, through trial-and-error processes, internalises behavioural strategies to achieve certain goals and ultimately manages to *imitate* them through personally constructed cognitive models. Differently, *instructed learning* happens between an instructor and a learner, where the instructor breaks down the learning process into simpler acts which, through close guidance, are assimilated by the learner. Whereas, in *collaborative learning,* knowledge transmission does not happen from "mature to immature organism in the classic sense because, by definition, the situation consists of peers collaborating to construct something new that neither had before the interaction began" (Tomasello et al., 1993, p.510).

Figure 42.

Directions of intentionality in the Cultural Learning Processes



Note. Adapted by the researcher from “Cultural learning” by Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993). *Behavioral and brain sciences*, *16*(3), p.497.

Tomasello et al. write on *cultural learning* the following:

> “humans display their unique and most powerful cognitive abilities is in learning from others, in taking multiple perspectives on a situation, or in building cognitive systems based on self-reflection, and all of these rely, ex hypothesis, on the fundamentally social-cognitive process of taking the perspective of other persons and learning from that perspective-taking” (Ibid., p.510).

Through these three learning processes it can be seen that the role played by society and culture in the attempt of transmitting or acquiring knowledge are fundamental as much as they are decisive on the evolution of primate intelligence in general. With regards to craftsmanship, it is for this reason that through Tomasello et al.’s (1993) premises we can comprehend why face to face communication with other practitioners from the same discipline has long been considered the most fruitful medium of exchange.

As Keller and Keller (1996) discuss, sharing craft knowledge and the complexities of the discipline through: workshops, meetings, demonstrations, and exposition of one's artefacts, allows craft practitioners to exchange different perspectives. This is a basis that ultimately constructs a solid learning experience and the identity of the community. The researcher wants to emphasize how *skills* play a big part in defining the degree of the specialism of a practitioner. Also, these skills define a practitioners' access to a community, which if not aligned to the competencies of the community, can limit the knowledge transmission and learning processes of said practitioner. Hence, the importance of cultural learning processes for a successful transmission of knowledge as *skills,* are acquired through the direct encounter with experts in the field of practice (Mareis, 2012) through a *collaborative learning* process (Tomasello et al., 1993).

3.3 Concluding remarks on digital craftsmanship, Tacit and Explicit Knowledge

Theory building on *digital craftsmanship* is still novel, which explains the rather vague and dispersed definitions which form the core of this concept and what it constitutes to be a digital craft practitioner. In their recent study of craft-based approaches in the HCI community, Frankjær and Dalsgaard underline how digital craftsmanship has become a "fuzzy area", where terms used to describe different approaches are often used interchangeably reinforcing ambiguity and "discrepancies of the definition of craft itself" making it harder "to establish a common frame of reference" (Frankjær & Dalsgaard, 2018, p.474).
From the varied overview on digital crafts and its relevant debates, the researcher was not able to clearly define *one* community of practice. Yet by combining Risner's

(2012) *technepractice* and Shorters' (2015) description of the *craft practitioner* and *craft technologist* the researcher concluded that a general and inclusive interpretation of the term *digital craft practitioner* could help in the initial framing of the community of interest.

Therefore, the influence of the above literature to the research is twofold. On one hand, by providing a brief overview of *digital craft* examples and related debates, the researcher hopes to support the reader in navigating the main theoretical debates discussed around craft-based approaches through some practical examples. While not exhaustive, the examples of digital crafts provided allow the reader to get an overview on how broad the outcomes constituting the overarching term *digital crafts* is. These variations are the result of the different practitioners' material lenses and knowledge adopted when making. By focusing on *digital crafts*, their varieties underlined an even more a dislocated, non-homogenous community of practice constituted by:

- technologists working with craft- processes;
- craftspeople who have adopted digital production tools;
- craftspeople who have adopted digital interaction tools;
- digital natives who have only ever used digital tools in their making processes.

What they all had in common is that they acquired competence in both material knowledge and technologies producing *digital crafts* that encourage diversity of practice, cross-fertilisation and interdisciplinarity.

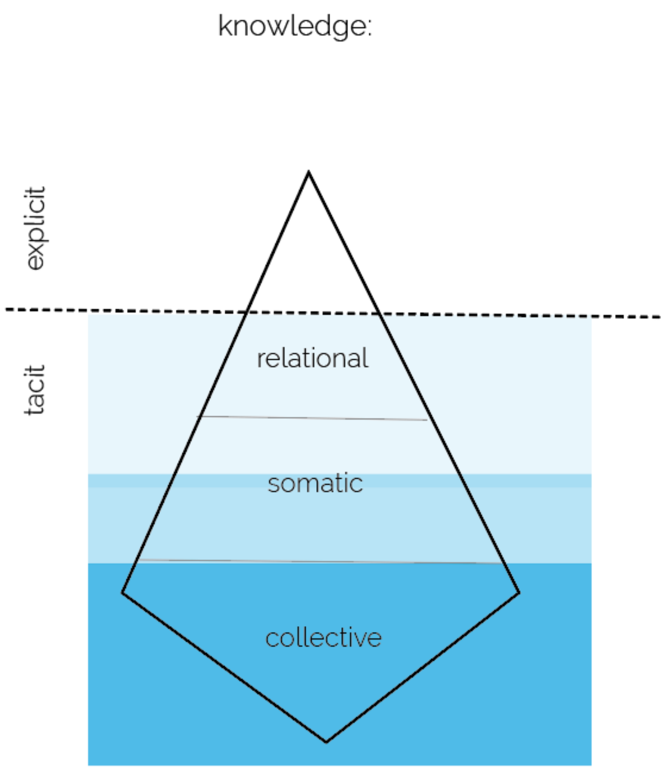
On the other side, the researcher provided the theoretical basis on the concepts of *Tacit* and *Explicit Knowledge* that can be summarised by the following: (i) transmitting knowledge through language alone is often not efficient, (ii) the body plays a far too important role in knowledge transmission, but even more than the body, (iii) the society or community we live in is fundamental in our acquisition of knowledge.

Often practitioners refer to *Tacit Knowledge* as something that can be made *Explicit* in craft practices (Niedderer & Townsend, 2014) when in reality this is not generally feasible. Rather the researcher believes that, as illustrated in the Figure 43, acknowledging and making clear the nuances of *Tacit Knowledge* (i.e., whether they are classed as *Relational, Somatic* or *Collective tacit knowledge*) and referring to *Explicit Knowledge* as complementary of *Tacit Knowledge* is strictly necessary to fully understand and address the theoretical concept.

While helping in providing a better definition for practitioners to use, this in itself could potentially allow for the identification of areas of *Tacit Knowledge* which have a lower resistance (Collins, 2010) to being made explicit within the practice of *digital craftsmanship*. The areas of lower resistance, if identified and described, could lead to the generation of underlying *principles* giving partial access to transmissible knowledge – even if just at a theoretical level. The researcher in Chapter 6 will provide a further articulation of this point.

Figure 43.

Tacit and Explicit Knowledge as complementary



Note. In the illustration *Explicit Knowledge* is drawn as the tip of an iceberg. Instead, *Tacit Knowledge* is represented as the part of the iceberg underwater. While *Relational* and *Somatic tacit knowledge have* lower degrees of resistance to be made *explicit* (i.e., explainable), the bottom of the iceberg, which is represented in deeper waters, is as a matter of fact less to no accessible. *Collective tacit knowledge* is at the lowest point of the iceberg as it cannot be articulated in any way.

CHAPTER 4. Understanding digital craftsmanship through auto-ethnographic and ethnographic methodologies

In this Chapter the researcher will firstly reflect on her own role as a researcher, and on how it was developed and re-negotiated throughout the project (Section 4.1). Moreover, the researcher will briefly refer to the *ethnographic* encounters carried out in the initial phases of the research (Section 4.2). As discussed in the Methodology Chapter (Chapter 2, Section 2.2), due to the nature of the methodologies used, the researcher will in this Chapter refer to herself in the first person. Through the articulation of her *auto-ethnographic* and *ethnographic* journeys, the researcher will provide the basis to understand how these activities were fundamental for the development of her *interactional expertise* (Collins & Evans, 2007), which will be thoroughly articulated by the end of the Chapter (Section 4.3).

4.1 Auto-ethnography

My background and my interest in craftsmanship practices

I was born in Italy, and I lived there the first twenty years of my life, between Rome and Siena. Until I travelled and lived abroad for a few years –to study in Denmark and subsequently in the United Kingdom–, I have always taken for granted the significant presence of artisan workshops within the Italian cities in which I grew up. I always thought that it was more than usual to have, in each neighbourhood, many artisans focused on different craft areas. I have entered their messy labs more than once: they were invariably impregnated with the traditional smells of a maker’s space of previous times. I cherished the images of crafts practitioner's hands, full of dirt and quite often marked by the exercise of the mastery that their work requires.

Later, studying a Master course in IT-Product Design in Denmark, I entered types of workshops very different from those I used to know. These creative making spaces were mainly composed of digital fabrication machines, alongside some manual tools such as hammers or screwdrivers. Coming from a Humanities background, everything related to the design practices that occured there was entirely new to me. I soon began to grasp the nature of design research methodologies and learned the basics of prototype. Discussing among my peer colleagues who had a design background, I soon realised that designers have a very hands-on, practical way of dealing with research problems. This was a significantly different trait from the overall approach suggested by my theoretical training. I have often encountered situations where I had to deal with the fact that I was an outsider trying to integrate at many different levels into a new context (e.g., fabricating myself, joining discussions on making processes with colleagues etc.). Sometimes, I even felt that my theoretical abilities were not as valuable as other’s practice-based skills. However, by the end of my course, I believed I had the knowledge and tools to express myself as a designer would.

Within the same timeframe, I had the opportunity to spend some months as an Intern in a FabLab (Gershenfeld, 2012), specifically in Santa Chiara Fablab, Siena, Italy. The workshop provides the means to *make,* predominantly through digital fabrication processes. There, I had the chance to further develop my digital fabrication skills while getting closer to digital fabrication technologies and making. I have experienced the contagious creativity these making spaces promote from a closer perspective. In the meantime, I took advantage of the territory, visiting many traditional goldsmiths crafting in the Tuscan area and conducting semi-structured interviews using *probes* (Sanders & Strappers, 2014) for personal research interests. In that period, being immersed in two making cultures simultaneously (i.e., makerspaces and artisan workshops), I started noticing their differences as much as their common traits.

From this experience, I learnt that even though these two worlds nurture reciprocal admiration and respect (from the makers' spaces to traditional artisanal workshops and vice versa), it is infrequent that they share the same views concerning production or the idea of craftsmanship. As I started to realize this specific aspect, I started developing my curiosity and research interest concerning the dichotomies and tensions between traditional and digital forms of craft practices.

Previous projects on digital craftsmanship and my learnings

Due to my fascination with craftsmanship, I concluded my Master's with a thesis investigating how the shift from artisanal to computationally-driven processes, and the subsequent removal of the hand from the immediate act of shaping material, might have been shifting values, as well as practices, in Design.

As an outcome of my research, I created a speculative prototype, with the aim to provoke designers, makers and craftspeople dealing with digital practices to re-think how the introduction of computationally driven processes and the subsequent 'removal' of the hand from the immediate act of shaping material was shifting their focus away from their physical interactions with materials and their hand making skills.

Looking back over my Master's project entitled "Crafting Futures–Exploring and converging traditional and digital craftsmanship values", I clearly see that the project's aim was an attempt to talk about technological changes in craftsmanship as well as in design.

The most valuable piece of learning from this work lies in the ethnographical and participatory nature of the methodologies adopted. This taught me how immersing myself within the daily practice and spaces of craft practitioners was a fundamental step to better understand the researched context. Through co-creative design approaches, I designed prompts that could generate discussions over the possible bridging of hand-making and digital craftsmanship values.

4.1.1 Re-negotiating my role as a researcher in the PhD

Relying on *subjectivism* (Neuman, 2000) and on the belief that the researcher's role is always non-neutral within an inquiry, (see Introduction in Chapter 2 for expanded discussion) in the following sections I share my journey around the re-negotiation of my role as a researcher. By *reflecting- on- action* (Schön, 1938), I describe the dilemmas that arose throughout this research process, with the intention of helping the reader to better understand my overall research approach and the decisions taken along its timeline.

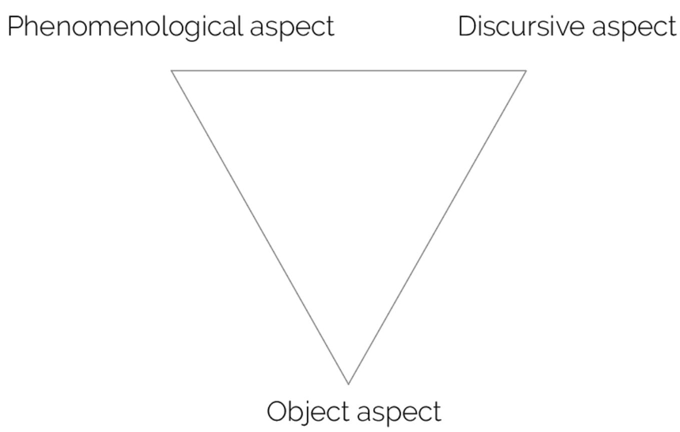
To help framing this reflective process I used the *Ontological Triangle of the Self* presented in Figure 44 and developed by the qualitative researcher Brinkmann (2012) as a reflective tool. In the following paragraphs I will explain what the 'Ontological Triangle of the Self' refers to. Then, I will describe a few salient auto-*ethnographic* reflections that provide some background and context to the understanding of the renegotiating process of my role as a researcher.

Ontological Triangle of the Self by Brinkmann

The *Ontological Triangle* developed by Brinkmann (2012) in his studies on qualitative research in everyday life settings, depicts how different aspects of the social world can be analysed through three different theoretical traditions which are represented by the points of the triangle illustrated in Figure 44. Brinkmann suggests that in order to gain a clearer picture of the world while doing qualitative research, it is best to combine both the phenomenological tradition, the discursive tradition and material aspects of a matter of interest (Brinkmann, 2012, p.41).

Figure 44.

The ontological triangle by Brinkmann



Note. Adapted by the researcher from "Qualitative inquiry in everyday life" by Brinkmann, S. (Ed.), 2012, *Qualitative Inquiry in Everyday Life*, p.40.

Whilst the phenomenological view focuses on human experiences and how the world appears to human beings, the discursive emphasises the human capacities of interpreting the world through conversations and discourses. Moreover, the third aspect that focuses on objects and material related aspects of the world denotes the role objects have in defining our social constructions (Brinkmann, 2012).

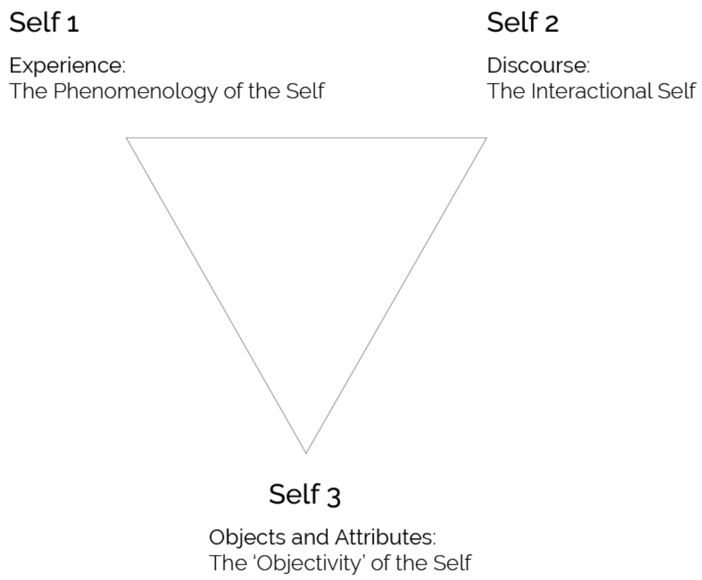
While analysing the world, researchers assume a predominant role in interpreting the gathered data (Ibid.). Therefore, when talking about qualitative data analysis, Brinkmann claims that the researcher should be practising self-observation as a method of inquiry more often, as it is sometimes necessary to better frame the specific chosen lenses through which a particular inquiry is carried out. For this reason, Brinkmann suggests taking a closer look at one's Self. He distinguishes three different angles from which one can address his/her Self, each one relating to a different point of the *Ontological Triangle* shown above. As the different points rely on different theoretical traditions, it is possible to analyse the Self from various angles (see Figure 45). For this reason, Brinkmann distinguishes between three different selves: the Self 1, the Self 2 and the Self 3.

The *Self 1* relates to "one's sense of being someone in a social environment" (Brinkmann, 2012, p.69). This is the first-person perspective, the idea of the 'I' (Mead, 1934).

Generally, when asking somebody to describe how they locate themselves within society and in relation to a specific community, their description will be dependent on the particular way that a person from his/her specific standpoint sees and experiences the world (Brinkmann, 2012). Thus, in order to describe a person in a more objective way there also has to be an introduction to their *Self 2*, what Birkmann describes as the "material resources" (Ibid., p.69) available to the person under consideration in his/her life. We start studying and defining ourselves when we analyse the material objects we own because, somehow, they become over time "extensions of the self's capabilities or their social identity" (Ibid., p.69). We include in the judgement the material extensions of the person under observation because in building his/her social identity, skills and capabilities, objects create the person's attributes (Brinkmann, 2012, p.70).

Figure 45.

The ontological triangle of the Self by Brinkmann



Note. Adapted by the researcher from "Qualitative inquiry in everyday life" by Brinkmann, S. (Ed.), 2012, *Qualitative Inquiry in Everyday Life*, p.71.

The *Self 3*, and last point of the *Ontological Triangle*, is the most social representation of ourselves. This social side of the *Self 3* grows in the interactional and conversational process we have with others: "the self makes personal expressions on others who then use these impressions to interpret the person and act in return" (Brinkmann, 2012, p.70). This process is dialogical in that it is built throughout time, through different episodes of social encounters. That is why growing up we learn to look at ourselves from the outside, objectifying ourselves through the beliefs and the attitudes others have towards us.

The *Ontological Triangle of the Self* helps organise my thoughts in relation to my experience in the re-negotiation of my role as a researcher in this project. In the following paragraphs, through the three different points of the triangle, I will reflect on several significant episodes that happened throughout the research project and which provide concrete examples of the meaning and significance of the different sides of the Self-described above. This reflective work of self-observation helps better frame my role as a researcher.

Self 1- My experience

When moving to the United Kingdom and to my PhD research project, I started expanding my knowledge of the topic through the first steps on my contextual literature review. Moreover, through the first talks with expert designers carrying out craft-based approaches, I soon realised that some of my previous beliefs about, and understanding of, the community of interest were inaccurate or at least partial.

As discussed earlier, in my Master's research project I interviewed several artisans working at the intersection of technologies and hand-making processes, and I had previously immersed myself in maker spaces and design workshops, where designers would actively use practice in their inquiries.

Back then in my research process, I involved traditional craft practitioners, digital makers and a few artisans embracing both approaches. The digital makers I had the chance to interview did not have a background or particular interest in craftsmanship practices. Conversely, the interviewed makers engaging with both traditional and digital processes had a traditional craftsmanship background. Their view and use of fabrication technologies were quite instrumental (see Vannucci et al., 2019 [Appendix E]); they would adopt digital machinery to increase speed of production on very defined, smaller parts of a far more complex hand-driven crafting process.

Therefore, they were adopting few digital processes in their hand-making techniques (e.g., 3D print a mould for a jewellery piece to be then cast manually). It must also be said that the sample size was small, so the insights gained had a greater likelihood of being unrepresentative of a wider community. Moreover, the small number of practitioners involved in the Master's thesis *ethnographic* research process were earlier adopters of fabrication technologies, who had been working with technology for a period of between three to five years in Italy. Perhaps all these factors combined influenced the study. Thus, what was observed back then was that practitioners tended not to consider digital fabrication machines as creative allies, as they would instead for example consider hand tools. Rather, practitioners would frame digital technologies as types of machinery that were most effective in executing predefined processes. Hence, from what I had observed in the locations I worked in while researching (i.e., a Fablab and an IT-Product Design workshop), these first insights significantly shaped my initial understanding of characteristics that described the community of digital craft practitioners.

Starting my PhD, I got the chance to review a much broader spectrum of literature and to meet, from very early stages, several highly experienced craft practitioners working in the intersection of hand making and digital fabrication technologies for more than two decades.

I soon realised that my understanding of digital crafts highly depended on the designer engagement with digital tools I had experienced previously. Consequently, my knowledge of digital craft practitioners also reflected the cultural meaning attributed to that community.

This realisation was decisive for the whole research inquiry as it brought to the fore the necessity to acknowledge, through critical reflections, that my role as a researcher would have been different from what I expected it to be at the beginning of the project. Previously I thought that my past research experience would have advanced and supported me in framing my new research process. However, I soon realised that the security I held onto in my role as a researcher was quite ephemeral. I realised I knew more about *making* from a maker and designer community perspective rather than from a craftsmanship perspective. Once I immersed myself in a community that had different shared cultural values concerning the meaning of terms such as craft and craftsmanship in relation to the digital world, the cultural meaning I was previously exposed to, started blurring and changing. This initial tension was focal in the framing of the research and the re-negotiation of my role in it.

Confronting myself with craft experts, and not being able to use any hand making techniques, nor to differentiate specifics of materials (e.g., oak from ash) or techniques, I started feeling a misfit within my own research project. Somehow, I had not anticipated that the first feelings I would have felt in the new research context would have been ones of disorientation and of self-doubt. These feelings started growing as part of my Self1 and I started interrogating my previous experiences. Knowing that experiences are culturally grounded and having recognised the value of successfully conducting *ethnographic* research in previous projects, I immediately tried to emerge myself to better understand my new context of research and to re-negotiate the cultural meanings I might have relied on before, based on my previous research.

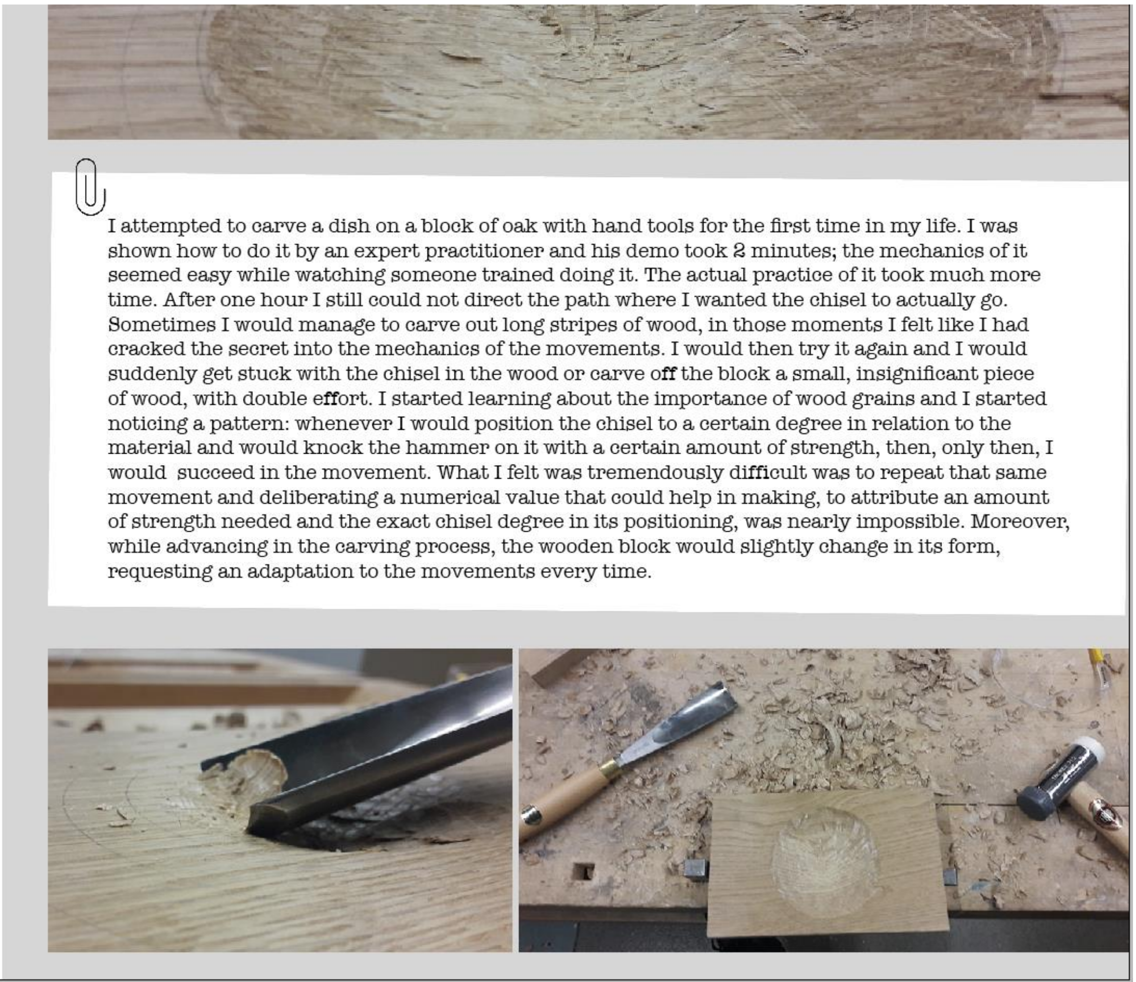
Self 2- My material objects

Being surrounded by craft practitioner's making highly technical, skilful artefacts and being often asked by the same craft practitioners "What is your area of craft practice?" or "Are you a craft practitioner/maker yourself?". I started feeling the need to develop my own craft skills and become, at least as a novice, part of the community I was trying to enter as an observer. The absence of artefacts that represented my making abilities (and my Self 2) was rather contributing to weakening my connection with the practitioners. In fact, practitioners would not understand my identity and what I was searching for in my research practice by observing them, since I was not being able to craft myself.

I had no previous experience of 3D modelling, nor in digital making using a CNC machine, or hand carving. I thought that being a novice in both analogue and digital making, positioned me at a neutral starting point. Therefore, it would have been meaningful for me to try out in practice, and experience what it means to be making using both hand tools and digital fabrication technologies for the first time. The most easily accessible spaces and materials in my university workshops, and specifically the ones where I could start practicing techniques with minor supervision, were the ones related to wood carving and milling. I therefore decided to start with that, and this experience was supported and supervised by craft practitioners. In this period of time, I was taking some notes about my making experience both while hand carving and while CNC milling (examples of the notes in Figures 46, 47). The notes were general observations to myself over the nature of the different making processes.

Figure 46.

Note to myself on hand carving as a making process



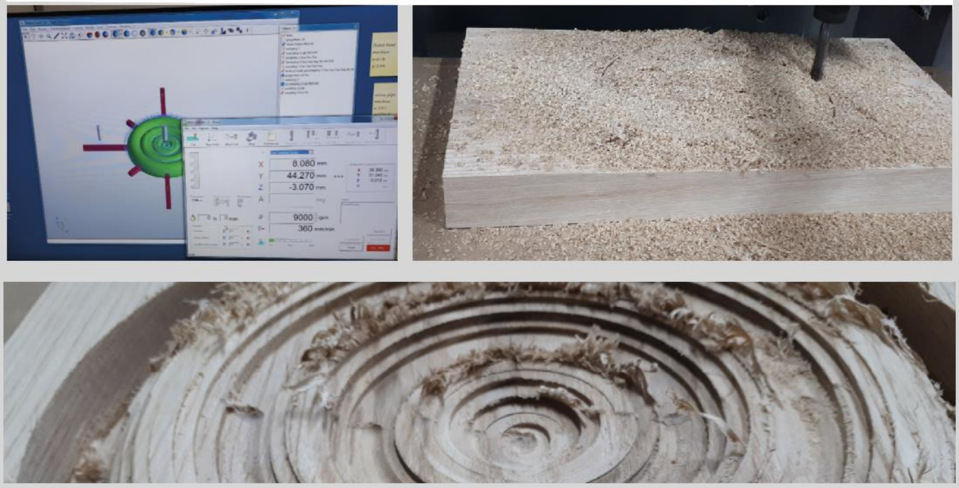
While I was getting acquainted with the different making processes, to give myself a purpose and to support the exploration that I was undertaking, early on I decided that I had to produce a set of artefacts that could help me facilitate conversations with practitioners concerning craftsmanship values. At this point I proposed to my supervisor Justin Marshall, (an expert craft practitioner), to approach the task with me so as to produce two sets of works that could potentially assist my thinking process. The driving questions we were asking ourselves while producing the artefacts were: *How can we explore craft values in digital making through an artefact-oriented method? How could we begin to explore the tensions and overlaps between the digital and the analogue (handmade) in material artefacts?*

Figure 47.

Note to myself on CNC milling as a making process

Material properties when CNC milling, are fundamental as much as they are while hand carving. This was immediately clear as soon as I got the first expert advices on how to approach the machine. An understanding of the differences between wood's morbidities as much as the wood's grains and their orientation appeared to be relevant notions to know in order to complete successfully a CNC milled piece. Once I had the right block of wood for the right piece (a block wide enough, high enough..), I had to learn how to appropriately fix the block to the CNC plane. Then, I needed to learn about different drill bits and the machine settings. Lot's of numbers and coordinates involved there. I had to take notes to store the information somewhere and not to forget any. When I was about to start any new milling process and the drill would start spinning, moving closer to the wood block, I always found myself very tense, in between the feelings of excitement and anxiety. In the timeframe the drill would get closer to the wood, I would find myself overthinking previous actions: "Did I calculate well the depth of material the machine should be taking away? Is the speed right in relation to the material? Will the drill spin out of the machine and drill my face out?"

Then the drill would touch the material starting taking out the first layers of wood, transforming them into dusty, small wood particles while emitting a very inconvenient noise. The dust would end up covering everything, I couldn't see whether the settings given to the machine were actually working in relation to my design and to the material until a later stage. I would feel stuck in my self-doubt until the dust was hoovered away and I could see the first results.



Hand Fought Series

From my exploratory making phase, I produced a set of vessels that I named 'Hand Fought Series' in contrast to the set of vessels produced by the experienced maker, Justin Marshall, that he named 'Hand Thought Series'.

Both sets of works were designed with the idea that they will be used in a workshop to explore ideas of craft in relation to hand making and digital making. The driving motive on why this was carried out was that we both recognised that, although there have been significant and valuable exhibitions focusing on digital and hybrid craftworks (see Chapter 3, Section 3.1), it is less common to see research that actively uses digital craftworks to leverage reflections and understandings into a broader craft value orientated debate. We therefore wanted to *think through things* (Henare et al., 2007) with practitioners in the field, emphasizing visual/physical characteristics of an artefact as potentially valuable aspects to discuss in a workshop context. By using these characteristics explicitly to explore broader values within craft (i.e., it puts artefacts to work in a particular way) we used a combination of digital and analogue design and production technologies in the inception and production of these two bodies of work.

The tableware produced by Justin Marshall (Figure 48), conforms to the expectations of utility and completion, while my work – the result of a novice maker's first experience– is more provisional, open, ambiguous, and unpolished.

Figure 48.

Marshall's Hand Thought series of CNC milled oak tableware

Note. From "Hand Thought Series" by Marshall, J., 2018 [Oak. From left to right: Small bowl, 210x45mm; Japanese platter, 230x120x40mm; Oval dish, 370x260x60mm]. Copyright retained by © 2018 Justin Marshall. Image courtesy of the Artist.

My artefacts reflected my own interpretation on the dichotomies of the production processes explored: they address failures and shortcomings a maker encounters in digital making and hand making for the first time (i.e., being a novice in both) and they demonstrate the struggles and tensions experienced (e.g., Mountain Plate in Figure 49 shows two holes, the results of miscalculations happened during the milling process).

The main goal with my 'open' artefacts was to provide a loose frame for the possible workshop discussions to counterpose Justin Marshall's beautiful, 'finished' artefacts, easily understandable in their form and function.

Figure 49.

Mountained Dish crafted by the researcher

Note. Details of *Mountained Dish* from “Hand Fought Series” by Vannucci, E., 2018 [Oak. 16x17.5mm]. Copyright retained by © Erica Vannucci. Image courtesy of the artist.

The raw unadulterated representation of the processes explored through my vessels (e.g., Figure 50) was considered as a potential element that could encourage different ranges of discussions within the setting of a workshop. Therefore, two workshops were conducted around the vessels.

The workshops sought to get under the skin of the dichotomies that can persist between machine/ digital and handmade processes and thus to identify some underlying motivations and aspirations that could potentially provide a foundation for the way in which handmade values can inform digital making and future technologies. In the workshops I would have exposed the material extension of my Self 2 (i.e., the artefacts I had produced), to the judgement of an audience of expert practitioners.

Figure 50.

Orbital Dish crafted by the researcher

Note. Details of *Orbital DIsh* from “Hand Fought Series” by Vannucci, E., 2018 [Oak, ø16.5mm]. Copyright retained by © Erica Vannucci. Image courtesy of the artist.

Exposing the Vessel Series to an audience of practitioners

The first workshop took place at the Design of Interactive Systems (DIS) conference in Hong Kong in 2019 (see Vannucci et al. 2018, [Appendix E]). Thus, in this first workshop, the participants had a background in interaction design with no experience in digital fabrication technologies nor craftsmanship techniques. Moreover, the workshop revolved around the theme of food, the participants were asked to think about making and the sets of artefacts in relation to food. Hence, the narrative was set from the start, so the artefacts were considered through a very specific food-lens. Under this brief, the practitioners mostly neglected Marshall's artefacts and appeared to be interested in my artefacts because of their roughness. The openness of my artefacts made it possible for them to re-imagine the nature of crafted objects and how you interact with them. The openness of the artefacts and their imperfections provided a context in which discussions suggesting narratives and possible interactions that could have been embedded in the artefacts through computational elements (i.e., electronics) could occur. This led to the creative generation of propositions and concepts but failed in tackling the questions I was trying to aim for. Moreover, even though my artefacts were appreciated by the participants, the range of participants did not reflect the craft-oriented community I was looking to engage with.

Therefore, I organised a second workshop in Northumbria University a couple of months afterwards (the outcomes of the second one have been disseminated through a full paper published in RTD'19 (Vannucci et al., 2019, [Appendix E]).
In the second workshop, the vessels were exposed to an audience of craft/design practitioners who mostly worked with non-digital techniques and had almost no knowledge in digital making. The workshop was carried out with a very thin narrative

around the artefacts (they were not addressed using themes such as the one of food in the previous workshop) and was divided into different phases. Before engaging with the vessels produced by Marshall and I, the practitioners were assigned in group a deck of cards representing six digital artefacts selected from Johnston's book (2015) named *Digital Handmade: Craftsmanship and the New Industrial Revolution*.

The participants were guided into different reflective activities focused on the cards representing digital craft artefacts and then, in a second phase, focusing on the two-vessel series produced by Marshall and I. I will not describe in depth the workshop dynamics here (for a detailed account of this workshop see Vannucci et al., 2019 [Appendix E]). Rather I wish to briefly reflect on the insights gained from my interaction with participants and their interaction with my vessels.

While the workshop failed to explicitly address dichotomies between machine and digital production and hand making which the authors hoped to discuss (Vannucci et al., 2019), a number of themes emerged that were discussed at some length, making it possible to draw away some insights from the activity. The themes most discussed were:

- Novelty in contrast to originality
- Authenticity as a mark of respect for tradition
- Control as a measure of competence and competence as a measure of skill

Broadly "there was little concession that a maker might want to use digital tools for the pleasure of their craft or for the particular aesthethics that a process may give to the final artefact" (Vannucci et al, 2018, p.11). Between the craft practitioners involved there was a shared underlying belief that digital processes are more effective at a predominantly procedural level. This view seemed to reduce their interest in recognising, considering, or appreciating a broader set of aesthetic outcomes that were not measured against traditional crafting technical criteria.

To their eyes, digital craftsmanship rarely seemed to push the boundaries of what the group considered original or innovative.

Moreover, the participants showed resistance towards those artefacts using digital technology where there was already an existing traditional technique that could achieve a specific job, pattern, or form. One of the major concerns felt by the workshop's participants was that sometimes digital crafted artefacts would not have needed digital fabrication technology in their production phase in the first place and could have instead been produced by analogue means. Therefore, the ability of some artisans to bring together traditional and digital techniques was not always considered as something valuable by the practitioners. Moreover, the idea that *control* over the process of making was defined by the ability to produce a preconceived outcome appeared to play a significant part in validating an artefact for the participants. Consequently, the skilled realisation of an *intention* appeared an important measure to establish the value of a piece.

These insights became more relevant to the research inquiry over time as they helped to extend my reflective process further, providing the opportunity to compare different ways of seeing the making process when studying closer digital craft practitioners. Therefore, the insights from the workshop will be addressed later in the discussion (Chapter 6, subsection 6.1.1).

Self 3- My interaction with practitioners

As discussed in the Critical Contextual Review (Chapter 3, Section 3.2), in order to become part of a community of craft practitioners, one's work has to be appreciated by other practitioners of the same community. Individuals have a need to identify themselves as part of a social group, of a *whole.* Within this *social whole,* members tend to construct and idealize some sort of unity of experience that reinforces the social group. These are called *cult values* of a group (Mead, 1934). To establish these values, face to face communication with other practitioners from the same discipline is the most fruitful medium of exchange: sharing knowledge and the complexities of the discipline's technical difficulties through workshops, meetings, demonstrations and the exposure and discussions of one's artefacts to others, is what creates the basis to construct a solid identity of a craft community (Keller & Keller, 1996).

As a researcher with little competence in crafting techniques, from either a traditional perspective or from a digital fabrication perspective, through my very experiences and initial interactions with craft practitioners, I felt that not being able to identify myself within a specific craft community or for that matter, with any at all, was positioning me in a weaker space to observe the community. I thus felt the need to become part of the digital craft community I was studying, thinking that I would then have a connection to this community that would be beneficial and be a means to address it more easily.

The Ontological Triangle of the Self by Brinkmann (2012) depicts the Self 3 as the discursive point of the triangle: the part of ourselves which grows in the social interaction with others. In the initial phase of the project, I was not yet able to identify and reflect upon my Self 3 as my first few interactions with the community showed me how little I knew about the topic itself and how many assumptions I was carrying with me from previous research studies.

Thus, as my encounters with the community grew, through my own making experience and while closely studying digital craft practices and practitioners I was continuously building on my Self 3. As the Self 3 is built through a number of interactions with others it took an extended period of time (i.e., approximately 14 months into my PhD study) to fully understand and address my positioning and role as a researcher, but once it happened it determined the framing of my research process. In the following I will briefly explore how the *ethnographic* encounters had been carried out with the community to then get back to my Self 3 and better explain its development.

4.2 Ethnographic encounters

While carrying out explorations with CNC milling and through the experience built during the workshops conducted, I planned an *ethnographic* study and managed to closely observe five craftspeople in their engagement with craft materials, techniques, and technologies. Using a mix of Qualitative Research Methods I observed, interviewed, and shadowed (Silverman, 2013) the participants, gaining many insights about their practice and their ways of thinking. I closely observed and video recorded on different occasions, artisans approaching craftsmanship in different ways. The artisans interviewed from which I recorded video material are:

- Joanne Mitchell (https://www.jomitchellglass.com/): a glassmaker using digital fabrication technologies (a waterjet milling machine) as well as traditional glassblowing techniques.

-Jonathan Keep (http://www.keep-art.co.uk/): a ceramist using digital fabrication technologies (a 3D printer) to produce ceramic vases.

-Jeff Sarmiento (https://www.jeffreysarmiento.co.uk/): a glassmaker using mostly hand making, traditional techniques.

-Alan Ball (http://www.alanballceramics.co.uk/): a traditional potter maker throwing on the wheel and using a specific Raku technique to glaze of his work

Moreover, I had the chance to meet and engage in open ended conversations over the topic of digital craftsmanship with the following practitioners, some of which across an extensive period:

-Tavs Jorgensen (https://technarte.org/en/portfolio_page/tavs-jorgensen/), a glassmaker and designer using a combination of handmaking techniques and digital technologies);

-Paddy Killer (https://paddykillerart.co.uk/), a traditional textile artist illustrating on many different materials.

-Chris Wight (http://www.cone8.co.uk/), a ceramist using water jet cutting on thin bone china sheets he directly produces himself.

-Micheal Armstrong (https://www.afiddesign.co.uk/), a furniture maker and designer, mainly working with wood)

The aim of this phase was to get closer to the practitioners' daily life, and the local community of practitioners to better understand their practice. Taking several pictures and videos of these encounters and recording the conversations with the practitioners through *ethnographic* methods gave me the chance to be able to reflect in retrospect over these encounters.

The videos and conversations were also analysed through a general inductive approach that allowed research findings to emerge from the frequent, dominant, or significant themes inherent in raw data, without the restraints imposed by structured methodologies (Thomas, 2006, p. 238). The process of coding was carried out following Thomas' analytic procedure:

1. Close reading of the texts derived from the transcription of the interviews: the texts were read in detail until the researchers were familiar with its content.

2. Creation of categories: the researcher identified and defined categories or themes.

3. Overlapping coding and decoding text: coding multiple categories within one segment of text or dismissing irrelevant quotations to the evaluation objectives.

4. Continuing revision and refinement of the category system.

Figure 51.

Analysing the data from the ethnographic encounters

The recurrent themes in the conversations with the practitioners that emerged through the analysis were mostly about the following aspects: errors, time, materials, research, processes.

While these themes addressed values and sensitivities very often recalled in the literature related to craftsmanship practices, I realised that the value of these *ethnographic* encounters was in that they were heavily contributing to deepen my understanding of the complexity of the themes explored. Time passed through and I realised that my ability to interact with the community and pose focused questions was growing.

While observing, analysing, and describing the context of digital craftsmanship and its actors, I was definitely learning and absorbing knowledge that helped enrich my knowledge on craftsmanship. Having spent time with practitioners, reviewing the contextual literature and reflecting over the topic of interest, gave me a deeper understanding of the field and linguistic literacy of making techniques, tools and craft processes. I could ascertain this in my encounters with practitioners which would go much more in depth every next time I would meet them.

Thus, the role of the ethnographer became very tight as soon as I started understanding how the value of the first Phase of my research was strictly dependent on the qualitative insights of the practitioners involved in every stage of the research process.

Being this research so closely dependent on the collaboration with the practitioners from the start, I sought an opportunity here to enhance even more their collaboration and participation by involving them directly in the research process. Therefore, if my initial purpose was to describe and analyse the world from my perspective as a researcher and ethnographer, I felt that having reached a deeper theoretical understanding of the field, put me in a better position to iterate the methodological approach and revise it. In the following, I will go back to describe how the evolution of my Self 3 marked an important developing moment for the research helping me to diminish once and for all the distance between me as researcher and the "informants" of my studies (Blundel et al., 2019).

4.3 Interactional Expertise: understanding the importance of my Self 3 for this research project

As mentioned at the beginning of the chapter, the first feelings I experienced when starting this research inquiry were of self-doubt. All I assumed to know around a topic and, specifically, around the community I used to study, faltered when I started my research in the new context. In this initial phase the understanding of my Self 1, which used to be one of a knowledgeable designer in digital craft practices, wavered while approaching the new research context.

Understanding the context of research and its community by emerging myself into it seemed the best strategy to undertake in order to expand my knowledge and to gain back my self- perception as a designer, knowledgeable of the digital craft area. This desire pushed me to undertake Blundel et al.'s (2019) strategy discussed in the methodology chapter (Chapter 2) which aims at uncovering and observing the community through both archival and *ethnographic* strategies.

As a researcher with no making expertise entering a context of expert practitioners, another salient voi, that initially I found decisive in weakening my beliefs over my own positioning as a researcher, was the lack of examples of material artefacts produced by me, as an extension of my Self's 2 (Brinkmann, 2012). I believed these would have better reflected my competences and social identity. To overcome what I thought to be a necessary expertise when approaching the inquired field, I engaged with what Blundel et al. (2012) identify as an immersive strategy: taking part in making activities. While I was focusing on aspects of my Self 1 and Self 2, thinking that acquiring experience in the field through material competence would have provided me with the basis to deeply understand digital crafts practitioners, I lost sight of the qualitative evolution my Self 3 was making. Focusing on my experience as a researcher by observing and interviewing craft practitioners in their workshops through *ethnographic* processes and through the explorative making journey, my Self 3 was being fed without me even noticing. These first methodological strategies undertaken produced some insights which started feeding back in the *Ontological Triangle of the Self* depicted by Brinkmann (2012). The reflective approach adopted to define my role as researcher strictly depended on a combination of experiences, objects, and discourses (i.e., the points of the triangle).

Collins & Evans (2007) would perhaps identify the Self 3 with their vision of *interactional expertise.* While *contributory expertise* provides to his/her holder to contribute in their field of practice, *interactional expertise* is the mastery of the language of a domain which starts growing through time, while being immersed into a community. This type of expertise "seems to be learned exclusively through interaction with communities who have contributory expertise in that specialism, not persons who have interactional expertise in that specialism" (Collins & Evans, 2007, p.35). When researchers try to access experienced communities holding no expertise and skills to provide a valid contribution to research within the field in practice, they do not necessarily need to hold *contributory expertise* (Collins & Evans, 2007, p.35).

Sociologists, journalists, art critics, to name a few, talk smoothly about their domain by interacting with other people –perhaps the same people they are exercising their judgement on–, even though they would not be able to actively contribute to it. Anthropologist Tim Ingold or the sociologist Richard Sennett, are for example scholars who contributed to the craft fields and who extensively wrote about making and craftsmanship practices while not being makers themselves. Thus, reflecting upon their subject matter and articulating reflective findings, their contributions, together with others from expert makers (e.g., David Pye), provide fundamental sources to read when studying craftsmanship and making. Their reflective and articulative abilities do not necessarily belong to all those who, instead, have *contributory expertise* in their own domain of practice (e.g., craft practitioners). Whenever a craft practitioner's expertise is not spoken out or reflected through and articulated, the practitioner will have little space to interact with others and "the interactional expertise of the contributory expert will become latent rather than expressed" (Collins & Evans, 2007, p.37). In other words, until the practitioner learns to reflect, talk about his/her experience in making, he/she will not be able to express his/her l*atent interactional expertise.* Collins & Evans stress how this might never change in their practice and how *contributory experts* might never become *interactional experts,* while the opposite can instead happen. Sociologists, journalists, art critics, could potentially extract deep insights and reveal some of *contributory experts'* unarticulated *interactional expertise* –by interviewing, probing, and observing them. To do so, they must rely on their *interactive* ability –defined as the person's disposition to naturally interact and observe experts efficiently– and on their reflective ability, which are self-taught abilities (Ibid.).

Keeping in mind Collins & Evans theories on *contributory* and *interactive expertises*, in the following the researcher will refer to the insights emerged from both the Critical Contextual Review (Chapter 3) and the *auto-ethnographic* and *ethnographic* journeys articulated in this Chapter. The triangulation of the insights with Collins & Evans perspective on *expertise* will help to finally define the researcher role and specific expertise in this inquiry in relation to the community of interest.

As seen in the Critical Contextual Review (Chapter 3), the scholars and practitioners Risner (2012) and Shorter (2015), aimed at defining few characteristics describing the way in which digital craft practitioners conduct making processes. Thus, to define what it constitutes to be a practitioner adopting both digital technologies and craft-based approaches in the design research field, they heavily rely on their own *contributory expertise* using their practice as a lens to frame the topic.

Looking at *contributory expertise* from a traditional craftsmanship perspective, in Section 3.3.4 of Chapter 3, the researcher focussed instead on the work of the practitioner Leach (1945) and the anthropologists Keller and Keller (1996).

Leah, as a *contributory expert* (Collins & Evans, 2007) in pottery, tries to unpack her newly acquired expertise of Japanese pottery making into roles and instructions for others to follow.

On the contrary, the *principles* individuated and emphasized by Keller and Keller, which represent the ideals of blacksmith's community members (Keller & Keller, 1996), are the result of their analysis in the field through their *interactional expertise*. The authors articulated principles on the blacksmith's community without holding *contributory expertise* in blacksmithing themselves. While Charles Keller did do an apprenticeship in blacksmithing during the study of their principles, the *principles* described by the authors have been collected from their attentive analysis of conversations between and among smiths, and from the scholars' direct observations of the practitioners (Ibid.).

Perhaps for this reason, scholars such as Keller & Keller (1996) conducted a study where they aim at describing the situated learning behind the practice of blacksmithing (=craft practice where iron is transformed into artistic and utilitarian artefacts). Through the unpacking and the articulation of the virtues lying behind the creativity of blacksmiths, they attempt at revealing the identity of a whole community.

These virtues are addressed as *principles* by the authors and have been collected (i) from an attentive analysis of conversations among smiths about their artefacts, but also (ii) relying on the authors' observations of the practitioners' qualities that "are expressed implicitly in their products, performances and literature" (Keller & Keller, 1996 p.52).

In this research project I rely on autobiographical explorations to frame the designing process. Thus, differently from other researchers who have been studying the field from their *auto-ethnographic* perspective as practitioners (Risener, 2012; Shorter, 2015), I do not hold practical material knowledge and I am not involved in the community of practice. Therefore, I posit that my specific role allows for a more inclusive and varied range of digital craft practitioners' perspectives on what being identified as a practitioner producing *digital crafts* at present means. Independently from the diversity in the backgrounds and material expertise of the practitioners involved in the research, in this thesis I aim at underlying shared *principles* across the community of *digital craft practitioners* that will shed the light on how contemporary practitioners judge and see the world.

Through my making experience, I gained several meaningful insights that helped me reflect on my role as researcher and determined the shape and specific process of this research.

While the making experience was fundamental to better understand what it entails *to make* through digital fabrication machines and hand tools, it also showed me how long it would have taken up, for a novice, to meaningfully contribute[20] to the field of practice through my engagement with materials and technologies. While this did not initially seem an obstacle in my design practice, it was demonstrated otherwise

[20] this is what Collins & Evans (2007) would describe as *contributory expertise.* This point will be further articulated in Chapter 6, together with the notion of *interactional expertise.*

through the practitioner's interaction with my *Fought Vessels Series* (Vannucci et al., 2019, [Appendix E]) during the workshop. Thinking that I could overcome my lack of practical expertise by producing final artefacts that were open and 'unfinished' which could facilitate and entice conversations around 'crafting values', soon showed to be a wrong assumption. The practitioners' attitude was to value more resolved artefacts that demonstrated high skills deployment rather than novice's vessels with imperfections and evident technical flaws. Some of my pieces were judged as "scrap bin pieces" by several practitioners involved in the workshop.

These realisations (also evident in the emergent themes described in Vannucci et al., 2019, [Appendix E]) taught me that the holistic nature of the process of crafting is complex. While I knew that becoming a specialised craft practitioner would have taken me more than learning a specific technique or skill (Sennett, 2008; Crawford, 2009), I experienced that showing the will to learn a craft discipline was not enough to get recognised as part of the community. As the control on specific materials and techniques grows, arguably the *value* of the outcome also grows alongside. Hence, *skill* becomes a culturally laden term as it strictly depends "on the cultural reference of what is considered 'quality'" (Kuijpers, 2017, p.140) in a specific social group. Prestige, rank, and status are reinforced in the social identity of the practitioner into a community as long as his/her *skills* improve and reach the ability to qualitatively contribute to the field of practice, which ultimately generates a community of practitioners holding the same status (Ibid.). This might not be the same in other communities of practice where skills in practical making are not always the most important characteristic to validate a new member in the community (this point will be further developed in the discussion, Chapter 6, subsection 6.3.1). Therefore, I soon realised that in order to become part of a community of craft practitioners, one's work has to be appreciated by other practitioners of the same community.

Hence, it follows that I should not have been surprised at the set of participants in the second workshop, who all belong to the same community of craft professionals, finding it quite difficult to engage with my artefacts (which could not be validated through the established frame that defined value for this community).

4.4 Summary and concluding remarks on the importance of interactional expertise

The challenge I sought at the beginning of my research project was to better define my role as a researcher in the context of exploring digital craft. The Ontological Triangle depicted by Brinkman (2012) supports the analysis of the Self from different perspectives such as those related to one's experiences, material objects and social interactions. As discussed above, though a reflexive approach using the different points of the triangle as reference points, I could unpack different aspects of my identity as a researcher to better understand the evolution of my role in the project.

The first step I went through in the research was to put aside all that I thought I knew on the topic of digital craftsmanship, in an attempt to rebuild my knowledge on the subject by strictly relying on new observations.

For this reason, to better understand the community at the centre of my research project,

from the early stages of my research and based on my masters' learnings, I felt the necessity to adopt an *ethnographic* methodology.

Alongside the *ethnographic* study, I also tried to immerse myself in making, not only to further develop my skills but to also acquire new knowledge and understanding of the community of interest through practice and to potentially produce objects that could facilitate my immersion in the community of interest. While taking these first steps, my thinking process over the re-negotiation of my role as a researcher evolved alongside the researched topic.

Soon after my making exploration I realised how my abilities as a maker in a community of expert makers would have been marginal and ineffective to facilitate meaningful conversations around making principles. Hence, I started focusing more on the rapidly growing specific knowledge I was gathering around the context of inquiry using other methodological approaches (e.g., the *ethnographic* study). While observing, analysing, and trying to describe the context of digital craftsmanship and its actors, I was rapidly learning and absorbing knowledge on the observed actors, much faster than any practical attempt to acquire technical skills.
While focusing on aspects of my Self 1 and Self 2, thinking that acquiring experience in the field through material competence would have provided me with the basis to deeply understand digital crafts practitioners, I lost sight of the qualitative evolution my Self 3 was making. Thus, this is the part of one's Self which is built through frequent interactions with others and, therefore, through time. Hence, my Self 3 manifested itself only after numerous interactions with practitioners in the field, as a result of numerous encounters with craft practitioners.

Reflecting on my experience as a researcher and the brief explorative making journey, were necessary steps that helped me distancing myself from previous assumptions I had over the topic of inquiry. Even more, observing and interviewing craft practitioners in their workshops through *ethnographic* processes was fundamental for the development of my interactional Self 3 (Brinkmann, 2012) which is what can be defined as my *interactional expertise* (Collins, 2004; Collins & Evans, 2007). This newly developed expertise is fundamental to this project in that it plays a significant role in the understanding and in gaining access to the community of digital craft practitioners. Further reflections under a methodological perspective on the fundamental importance of the development of one's *interactional expertise* will be articulated in the conclusion (Chapter 7, subsection 7.3).

PART II

CHAPTER 5. Kelly's Repertory Grid Study: On Digital Craftsmanship

Part I of the thesis described how, through a range of research activities, the researcher gathered insights that helped grow her *interactional expertise* (Collins, 2004; Collins & Evans, 2007). However, as the exploratory strategies undertaken were not providing the depth of insights aimed for, the researcher extended the research strategy, adopting a *para-ethnographic* method (as described in section 2.4).

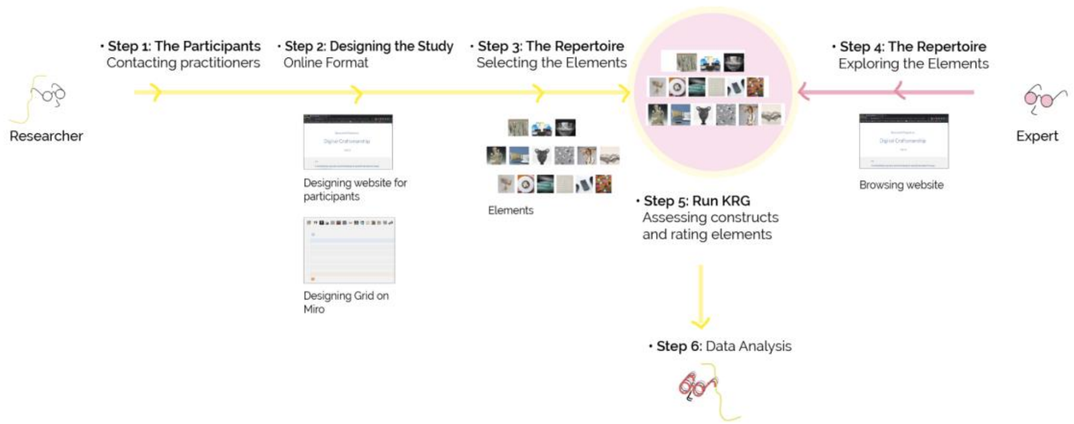
Para-ethnography was chosen, as distinct from ethnography, because it is based on the premise that the participants in a study play an active role as researchers within the study while also being experts in the field. Striving for new insights into digital craftsmanship *principles* and looking for a clearer articulation of those very *principles*, the researcher found in Kelly's Repertory Grid (KRG) a tool able to help bring structure and rigour to the researched topic. This particular subject had been previously studied in different ways but as seen in section 2.5, previous research on the matter tended to be based on anecdotal evidence. Hence, the researcher seeked to provide a structure to singular personal opinions (with the aim of providing more rigorous outputs), by channelling and articulating experts' knowledge through the KRG framework.

Researchers can in fact use the KRG framework to channel insights of experienced practitioners through active interviewing (Gubrium & Holstein, 2001), transforming “the subject behind the respondent from a repository of information and opinions, or a wellspring of emotions, into a productive source of knowledge” (Ibid., p.13). This method supports active co-created meaning-making by creating a non-hierarchical collaborative relationship between the practitioners and the researcher (Islam, 2015). Hence, there is a recognition that the role of the researcher is not passive, and that it will influence the nature of the insights generated through this method, imbuing the exchange between researcher and expert with personal meaning. Therefore, the researcher adopts a *heterophenomenological* approach (Dennett, 2003) while both structuring the study and analysing the gathered data in a second moment (see Chapter 2).

In this chapter, the researcher will describe how the study was designed and conducted (Section 5.1), its outcomes (Section 5.2) and, finally, its data analysis (Section 5.3).

Figure 52.

Illustration on the steps undertaken to set up and run KRG



Note. The researcher’s path (in yellow) and the participant’s path (in pink) come together into Step 5 as, while running the KRG, they collaborate into a reflective, meaning-making process.

5.1 Kelly's Repertory Grid (KRG) in 6 steps

In this section, the researcher will describe how KRG was specifically used in this study[21]. This involves six key steps illustrated in Figure 52 which will be described in detail in the following paragraphs.

<u>STEP 1.</u> The participants –*contacting the participants*

From the knowledge gained through the Critical Contextual Review (Chapter 3), the researcher learned how digital craft practitioners have a variety of backgrounds (Section 3.2). The diversity of backgrounds and skills - often involving one or more traditional hand-making techniques, digital design and production skills, and/or coding abilities– makes it a challenge to define a standard set of qualities or an agreed profile of a digital craft practitioner.

The researcher, through the Critical Contextual Review (Chapter 3, Section 3.3) stressed how the wide variety of digital crafts underlined a dislocated, non-homogenous community of practice constituted by:

1- technologists working with craft- processes;

2- craftspeople who have adopted digital production tools;

3- craftspeople who have adopted digital interaction tools;

4- digital natives who have only ever used digital tools in their making processes.

Therefore, from the knowledge gained through the Contextual Review and to succeed in the aim of identifying a series of *principles* able to describe digital craft practitioners as one community of practice, the researcher decided to include in the KRG study practitioners that would reflect the field's diversity, fitting one of the four

[21] The main driver for the redesign and adaptation of the KRG method was the researcher's need of conducting the planned research in remote, due to the COVID-19 pandemic.

aforementioned *Clusters*. Following a similar premise, participants with a range of ages were also sought as much as possible, as it was considered that this may have an impact on their view and perspectives on the subject under study: a digital native will likely be younger than someone who has adopted digital tools partway through their careers and, as such, may not be as aware of, or sensitive to, the distinctions between digital and analogue processes.

Moreover, following the characteristics outlined by Para-ethnography (see Section 2.4), which recognizes the participants involved in a research process as theorists and experts of the culture in which they participate, the researcher started the selection process yielding to practitioners considered experts within their community of reference.
The researcher started the selection process by considering many of the practitioners involved in the Critical Contextual Review, since they are recognised as experts in digital craftsmanship both for their work and their critical reflections in the field. After a first screening of their profiles, several participants from around the world were contacted through e-mail [Appendix A]. The invitation to participate in the study was accompanied by an Information Sheet [Appendix C] describing in detail the project's aims and objectives. Within one month and a half into the recruiting process, six practitioners agreed to take part in the study. As within the KRG participants openly talk about others' work, to respect their anonymity the researcher will refer to them as Practitioner C, Practitioner D, Practitioner E, Practitioner J, Practitioner K and Practitioner V. In Table 1 the researcher gives an overview on the participants' range, considering their age and their backgrounds.

Table 1.

List of Participants involved in the KRG study

Participants	***Age***	***Technologists working with craft- processes***	***Craftspeople who have adopted digital production tools***	***Craftspeople who have adopted digital interaction tools***	***Digital natives who have only ever used digital tools in their making processes***
Participant C	28				•
Participant D	38	•			
Participant E	67		•		
Participant J	53		•		
Participant K	64		•		
Participant V	43			•	

<u>STEP 2.</u> Designing the Study – *online format*

KRG is a technique rather than a method, and as such it allows for freedom in the form of its application (Fransella et al., 2004). It is not uncommon for KRG to be customized to the specificities of different research contexts or needs – as seen in the examples of KRG used in previous design research studies (Chapter 2, Section 2.4.1). What stays constant are the four main components constituting the framework (i.e., topic, elements, *constructs,* and rating scale system) and the overarching idea of the process being a facilitating technique, enabling the researcher to access the participants view on the world. This freedom allowed the researcher to reimagine the study in an online format, tailoring the research process to the particular circumstances of the study. In the following paragraphs the researcher will describe how the KRG was designed and re-adapted to conduct the study remotely.

Recalling subsection 2.4.1, KRG is a technique constituted of four main components which are:

- ***The topic*** – what is being studied, in this case *Digital Craftsmanship*;

- ***Elements*** – examples that illustrate the topic of study, in this case representing a selection from the world of *digital crafts*;

- ***Constructs*** – These are the criteria and attributes through which the *elements* are compared with one another in order to produce a series of statements which describe what the participant thinks about the topic. These statements will form the eventual units of analysis which are based on diametrically opposed poles. The participant generally comes up with a first *construct* that can be considered as the *emergent pole* and then he/she will need to come up with a binary opposite *construct* for the other pole, the *implicit pole.* Therefore, every statement has to be presented as opposite ends of a spectrum (e.g., small/big, heavy/light etc.);

- ***Rating scale system*** – once the main *constructs* and *elements* are in place, they are entered on a Grid with the *elements* sitting on top and the *constructs* down the side. The participants at this point rate each *element* against each *construct* according to a numerical rating scale. The rating scale is non-evaluative (e.g., running from 1 to 6), as indicating negative or positive poles (e.g., scale running from +3 to -3), may affect the responses of the participants (Fransella et al., 2004).

Two examples of KRG used in previous design related studies were described in the Methodology Chapter (Chapter 2, Section 2.4.1) to give clarity to the process.

Website for the selected elements

In other circumstances, the researcher would have tried to constitute the repertoire of *elements,* using a small selection of representative physical digitally crafted artefacts. and would have likely travelled carrying those artefacts to each selected participant, in order to run KRG in person. Due to the COVID-19 Pandemic, the research circumstances radically changed and the option to both meet the participants and give them the possibility to touch, see and hold the selected artefacts, was lost.

Therefore, in order to provide the participants with a deeper understanding of the repertoire *of* digitally crafted artefacts selected[22] (i.e., the *elements* within this KRG), the researcher built a temporary website[23] containing information to better understand the representative elements chosen. Beyond the fact that undertaking of this KRG online allowed the research to draw from a global pool of potential participants, which would have not been possible to involve in the study if face to face interviews had occurred, the use of a bespoke website allowed the researcher to curate a simply accessible and comprehensive repository of information about each of the artefacts in the repertoire to be used in the KRG. This eased the participant's engagement with a range of material needed to lay the foundations for a rich discussion within the KRG process itself.

The researcher recognised that some participants (as experts in the field) would have likely been previously aware of most of the artefacts. However, she did not make assumptions and sought to provide a holistic view of the pieces, drawing from a range of online sources linking all the information provided back to their original

[22] An overview over the choice of the representative artefacts constituting the Repertoire will be articulated later in Step 3 of the KRG

[23] https://sites.google.com/view/digitalcraftsmanship/home-page

sources. As such, the researcher built an online space where the participants could browse through the *elements*, learning more about the artefacts selected; brief descriptions about the pieces and making processes, snippets of interviews with their makers, descriptions of the materials used, pictures and close ups highlighting the artefact's details and the authors websites where to find more information. Photographs have often been used in visual studies as eliciting methods to "evoke deeper elements of human consciousness" (Harper, 2002, p.13).
Similarly, the researcher tried to present a multiplicity of interactive and visual materials, together with descriptive ones, in order to provide the participants with a better understanding of the *elements* included in the repertoire.

KRG on Miro

To run the KRG sessions remotely, the researcher adopted Miro's creative platform[24] as it allows multiple participants to access the same creative space at the same time. Moreover, this creative space allows for a range of actions which were valuable in facilitating and documenting the KRG process, including the inserting of images that can be moved around on a canvas and adding/ editing post-it notes and text. Simultaneously to accessing Miro, both researcher and participant would communicate via a Whereby online call –which was recorded with the participants' permission for later transcription analysis [see Appendix B]–. Each participant was provided with an information sheet about the aims and objectives of the project, and with a consent form that was to be signed before the meetings took their place.
The researcher designed her version of Kelly's Repertory Grid through Miro's drawing elements, providing a Grid that the participants had to complete.

[24] see http://www.miro.com

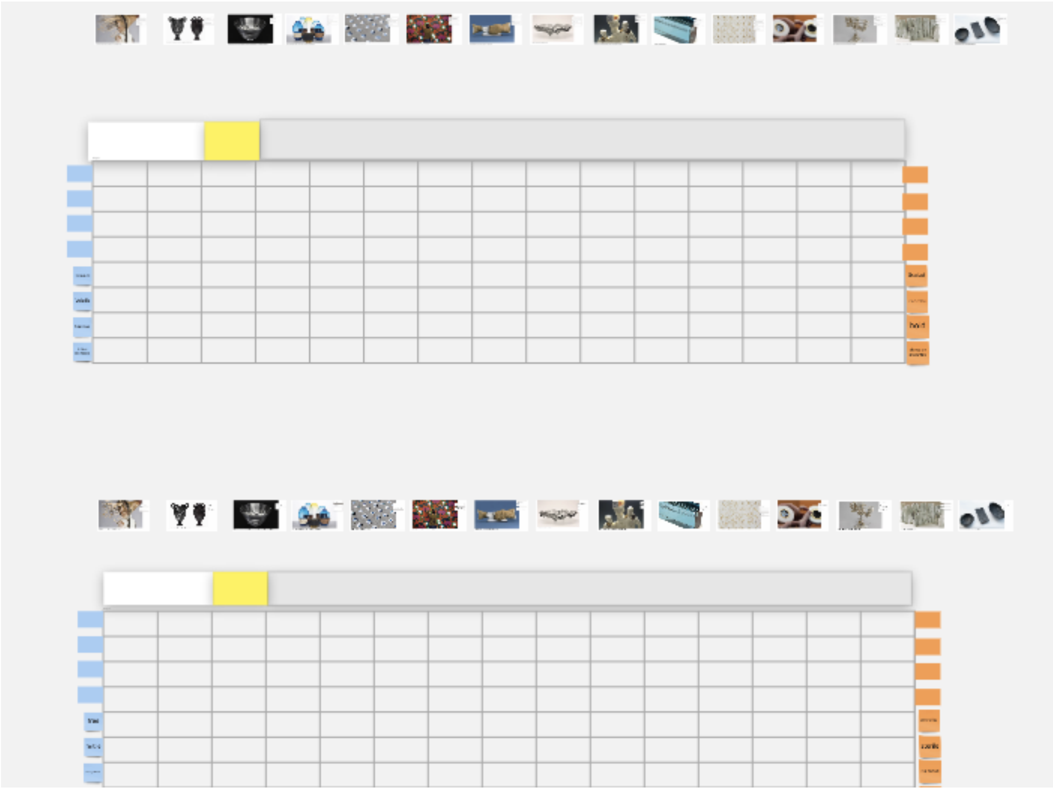
Pilot Studies

To verify the correct flow and design of the activity, the researcher tested the framework through two pilot studies. The feedback gained from the first pilot study informed design decisions that pushed the researcher to reframe parts of the designed activity. These were then tested again through a second iteration of the pilot study with a second participant. Therefore, the pilot studies were carried out at different times with two PhD students in the Design Department; the participants chosen were selected because they had a close connection to materials and making.

In these first trials, the researcher ran the first designed Grid (see Figure 53). The researcher facilitated the process of guiding the participants through different tasks. As shown through the example in Figure 53, the horizontal Grid was repeated three times on the Miro canvas to suggest the study's iterative process. The *elements* (i.e., the digital craft artefacts selected for the study) were represented on the canvas as miniaturised images and were placed in a line, on top of each Grid. Initially, participants in the pilot test were asked to select a triad among the elements provided and to drag the two chosen similar elements into the white box and the third, differentiating *element,* in the yellow box.

Figure 53.

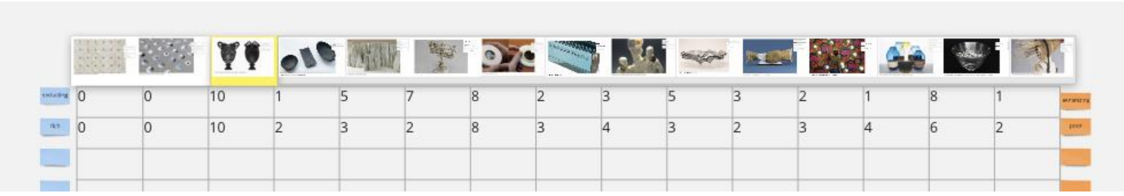
The initial Grid designed on Miro



At this stage all the other elements were placed by the researcher randomly along the same horizontal grey line. While doing so, the researcher would ask the participants to explain out loud why the elements in the triad were selected from the wider group. In this phase, the practitioners provided a verbal explanation that would describe their perspective on the differences and/or similarities between the elements. The researcher would facilitate this process by asking them to write down on the virtual post-its notes in Miro (in sky blue and orange on the side of the Grid), a synthesis of their response into a simple phrase, or ideally, a single adjective (e.g., anonymous). These expressions would become the *constructs* within the KRG, and as such, the researcher would explain that they would be required to define an opposite (e.g., artist evidence). Lastly, the practitioners were asked to rate each *element,* the only rule being that the two similar elements would always need to be given the same number in the scale (e.g., 0 or 10) and to assign to the third *element* the opposite scale number. Aside from the initial triad, all the other elements were rated accordingly to the degree to which the participant believed their characteristics could be aligned to the *constructs*, (i.e., using 2-9 but excluding 0 and 10 which had already been used (see Figure 54).

Figure 54.

The initial Grid designed on Miro being assessed by a participant in the Pilot Study



Through these first pilots, the researcher realised fundamental issues concerning the Grid design and the process carried out to facilitate the study. These were:

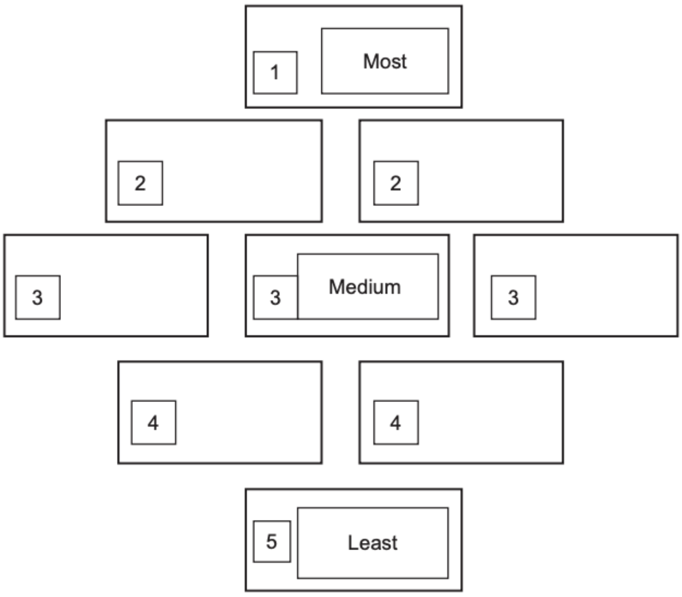
- The Grid provided was not as understandable as initially hoped for: the researcher had to intervene during the process as it was not very clear to the participants what was required of them.
- The Grid promoted a mechanistic approach: the participants during the pilots found the whole process quite repetitive.
- The Grid promoted a non-reflective approach: the scaling system chosen (0-10) seemed too broad and the participants were more preoccupied with the rating task and with assigning the “right number”, rather than commenting on their decisions, reflecting on the *elements* in relation to the *constructs*.

In sum, the Grid was not facilitating the process as expected, and needed some fundamental readjustments.

Based on the observations and feedback gained from the pilot studies, the researcher adapted the design of the Grid trying to provide a system that would best support and promote reflexivity, rather than a dry mechanical process. The scaling/rating system was never the researcher's goal. Rather, it was seen as a facilitating aid that could lead to interesting conversations, disclosing the expert's opinions on the *elements* in relation to the *constructs*.
To better facilitate participant's reflections and discussions and to elicit deeper conversations while running the KRG process, the researcher designed a new Grid taking inspiration from the thinking tool and visualising system called *diamond ranking* (Rockett & Percival, 2002). The system provides an aid to order information, allowing sequencing; sorting, classifying, or grouping elements and enabling reflections on their relationships, contrasting and comparing *elements*, and helping to generate new insights and ideas (Ibid.).

Figure 55.

Diamond ranking system and visualizing tool by Clark



Note. From "Using diamond ranking as visual cues to engage young people in the research process" by Clark, J., 2012, *Qualitative Research Journal, Vol. 12 No. 2, p.224* (https://doi.org/10.1108/14439881211248365). Copyright retained by © Emerald Group Publishing Limited.

According to the *diamond ranking system* illustrated in Figure 55, the *elements* considered should be organised by the participants in such a manner/shape that resembles a diamond. The ranking criteria are open, and once opposing *constructs* are chosen, the *elements* are placed incrementally based on the most, medium and least values related to the *constructs*.

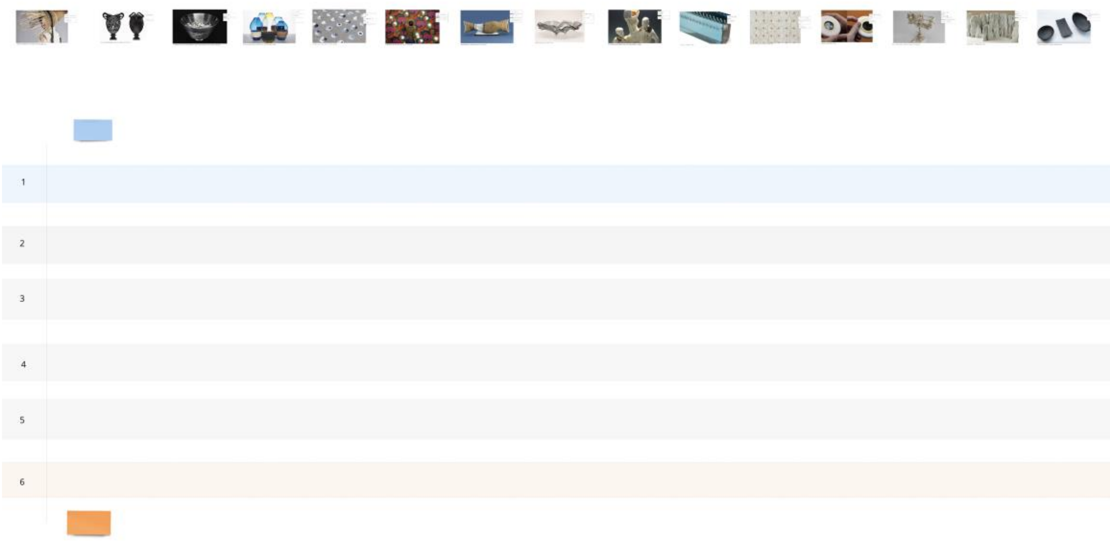
The researcher chose this system as it aligns well with the overarching aim of using the KRG method; its relevance is in fact not in the ranking features, rather it is significant because it allows a process of discussion, reflection and negotiation, central to the aims of finding meaning through this co-created[25] design process. The researcher co-created the KRG process in that she guided the participant while

[25] The term co-creation is here used with the meaning of an "act of collective creativity, i.e., creativity that is shared by two or more people" (Sanders & Strappers, 2008, p.6)

running the framework, using the framework as a conversational trigger. The researcher actively elicited information concerning the competences that were considered crucial by each participant, with an eye to clarify and articulate their beliefs and make them explicable as much as possible. Accordingly, the researcher would intervene in the conversation whenever further articulation of a point was seen as attainable.

Figure 56.

Redesign of the KRG using Miro



In practice, the researcher re-designed the KRG, positioning the given *elements* on top of a structural Grid defined by numerated horizontal lines as shown in Figure 56. Two post-it were positioned at the top and the bottom of the Grid in which to write the *constructs*. The researcher could have left *most, medium,* and *least* as differentiators on the scale, as shown in the diamond ranking Grid. Instead, the researcher chose to stick to the established KRG framework as maintaining a rigorous numbered system would have facilitated the task of the subsequent data analysis and the comparison between ratings in different Grids.

<u>STEP 3.</u> The Repertoire – *selecting the elements*

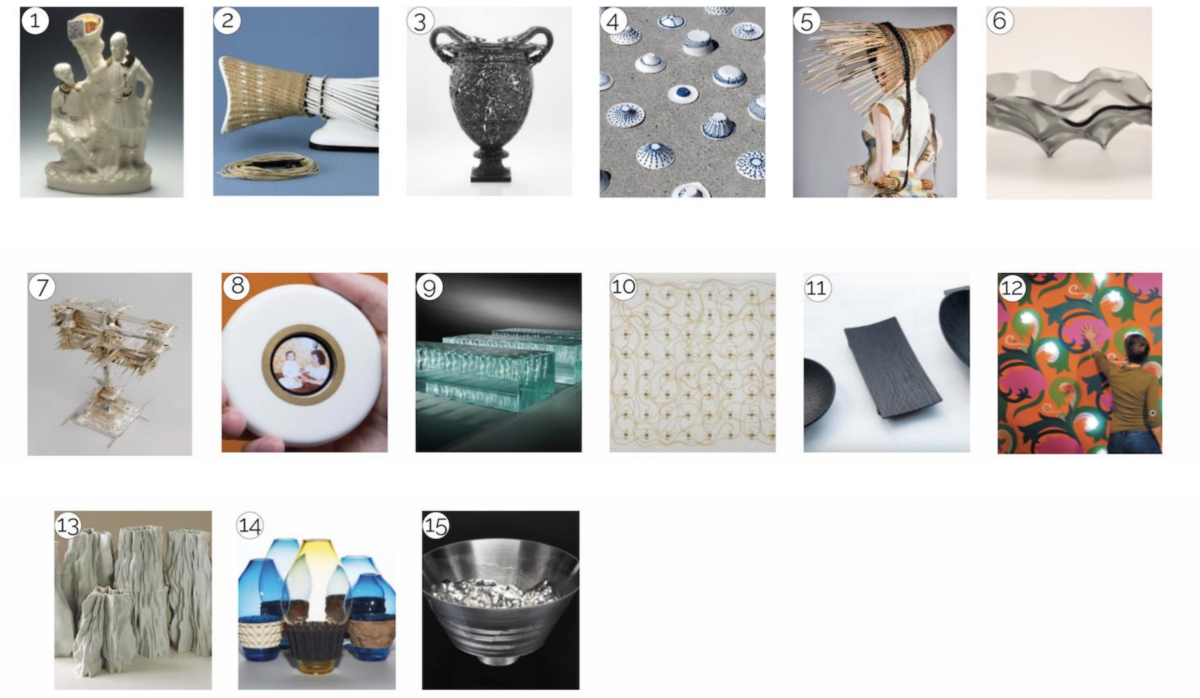
As seen in subsection 2.4.1, Kelly's Repertory Grid heavily relies on the choice of the *elements* that are discussed throughout the study. With this in mind, the researcher carefully selected the Repertoire.

The researcher wanted to offer a broad selection of examples that could provide participants with broader opportunities for reflective insights. At the same time, the researcher tried to keep the selection of the artefacts down to 15 pieces. The researcher believes that while a higher number would have possibly provided a higher set of responses, it would have diluted the quality of the conversations.

Therefore, in the end fifteen artefacts that could represent a spectrum of Digital Crafts were selected from the Critical Contextual Review (Chapter 3, section 3.1). These artefacts were not selected as best artefacts produced in the field, rather they were chosen to include a variety of craft with diverse characteristics (e.g., background of their authors, age of their authors, techniques used). Hence, they can be considered as a non-exhaustive spectrum of artefacts made in the intersection between digital fabrication processes and hand-making.

Figure 57.

The Repertoire of elements selected by the researcher



Note. The image is composed by minutiarised versions of the artefacts the researcher selected as elements. Legend:

1. *A day at the Hunt*, Ingrid Murphy, 2016, Hunt Museum
2. *Hybrid Basketry,* Amit Zoran, 2014, MIT Media Lab
3. *Innovo Vase*, Michael Eden, 2016, Collection of Los Angeles County Museum of Art, London
4. *Dripping Clay*, Studio Joachim- Morineau, 2018, part of the Moca ceramic Project, Eindhoven
5. *Bamboo Whisper*, Raune Frankjaer & Tricia Flanagan, 2011
6. *Large Pin Bowl*, Tavs Jorgensen, 2012, Crafts Council Collection
7. *Shine*, Geoffrey Mann, 2010, Crafts Council Collection
8. *ReFind*, Jayne Wallace, 2019
9. *Legion*, Jo Mitchell, 2015, Shanghai Museum of Glass Collection

10. *Embroidered Computer*, Irene Posch & Ebru Kurbak, 2018
11. *Hand Thought Series*, Justin Marshall, 2018
12. *Living Wall*, Leah Buechley, 2010
13. *Iceberg Field*, Jonathan Keep, 2013, National Museum of Scotland
14. *Set of Free Blown Vases*, Jonathan Keep & Charles Stern, 2014
15. *Campionissimo Bowl*, Drummond Masterton, 2009

STEP 4. Exploring the Repertoire – *participants browsing through the elements*

To give to the participants a rich and rounded understanding of the selected *elements*, the researcher designed a website[26] containing information related to each piece (see Step 2). The researcher drew on a range of different sources for each *element*, providing information in a spectrum of formats including: images, videos, snippets of interviews, written outputs by the authors of the pieces. The researcher invited each participant to visit the website once they had accepted an invite to participate in the study. The participants were given a week to browse the information before running the KRG process.

STEP 5. Facilitating the process – *running the KRG framework*

Each participant was individually scheduled for a video call session of approximately one and a half hours in duration. As all participants agreed through consent forms, each session was audiotaped and transcribed later by the researcher.

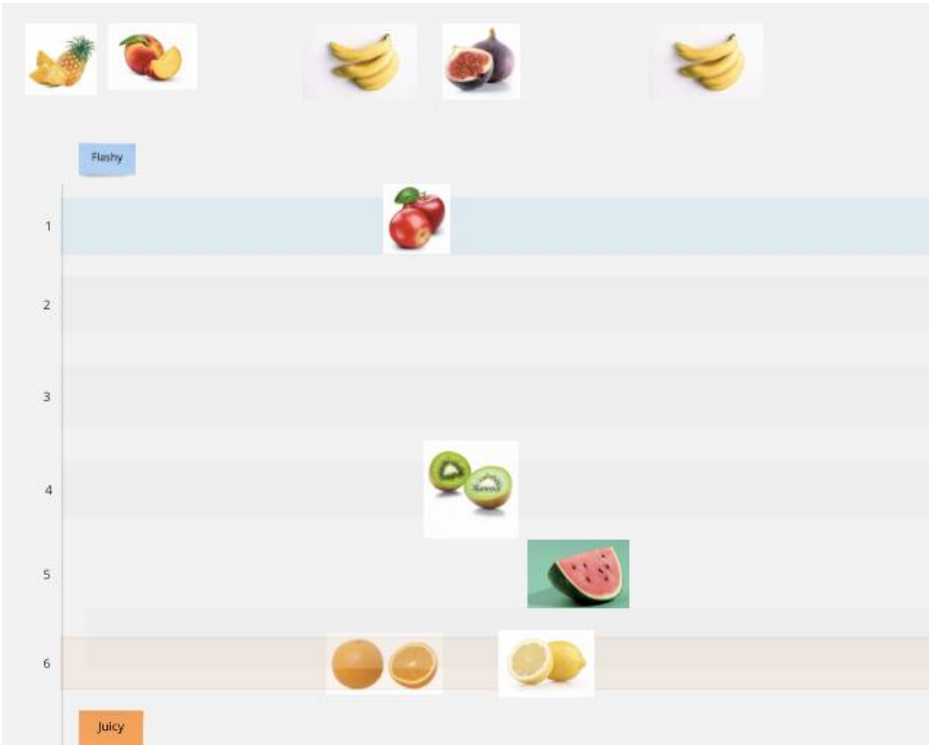
At the beginning of each call, the researcher provided a link to the Miro board created for the session. As a 'training' exercise to provide a clear explanation on

[26] https://sites.google.com/d/1T79E-YcsuMPl4ajlmnW232plKjpweEgd/p/1_KEOOw5f4vC8dsy-DT8sk5c5tTvVotsR/edit

how the Grid worked, the researcher designed a small, practical example of using KRG involving fruits as *elements.* The researcher ran the framework while explaining to the participants the practicalities of the *elements, constructs*, the *triad,* and the *rating scale system*, allowing them to familiarise themselves with the framework and ask related questions.

Figure 58.

Example of KRG using fruits as elements



Note. The example was designed for the participants in the study to explain the *constructs/elements* in relation to the *rating scale system* before running the actual study with the chosen repertoire

When the participant felt confident about the process, the researcher would reintroduce the *elements* that had been described in the website, and that had been displayed on the Miro board Grid *as* miniaturised images of the works (see Step 2,

Figure 56). Moreover, the researcher reminded the participants of the process and the repetitions that are inherent in this method.
During the session, while running the KRG, the participants were asked to think aloud as they went throughout the different steps of the process (e.g., while choosing the triad, while assessing and *rating* the *elements* in the KRG). The *think aloud* method (Fonteyn et al., 1993) provided access to the opinion and interpretation on the *elements* that the practitioners would process, talking through each task. This reflective process was a rich source of qualitative data. The transcribed commentary provided access to the nuances and complexities of the participants' thinking and decisional processes undertaking each step of the framework. Thinking aloud adds “credibility to study findings, because the results obtained from each step of the analysis can be retracted and explained” (Ibid., p.440).

The researcher guided the participants through the various steps of the framework but tried to always have a facilitating role in the process. The first thing that the researcher asked the participants was to select a triad of elements, “two of which are identified as having similarities, and the third as being ‘different’” (Kettely, 2016, p.169). Moreover, the researcher would remind the participant to try and explain their choices and their reflections while choosing the *elements*. When all the other *elements* in the repertoire needed to consequently be collocated into the Grid, the researcher would try to maintain a very marginal role throughout the process and would intervene and ask questions just when she sought opportunities to better understand the participants view on the crafts. As pointed out by Siraj-Blatchford, when adopting KRG to talk about personal and meaningful themes for the participants “strongly held, conflicting values, may be identified” (Siraj-Blatchford, 1995, p.195). Therefore, the researcher is charged with the responsibility of helping to articulate these values, facilitating the research process, intervening as a mediator and collaborator in an active effort of meaning-making.

Designing a suitable Grid that is able to provide the right support to the researcher and participant in the online research process format, was a fundamental step of the process. As Fransella et al. point out: “all forms of Grid are sorting tasks which enable the subject to tell us something of the way in which he or she sees and orders the world (Fransella et al., p.81). Through this process, data was collected in different ways and at different levels.

<u>STEP 6.</u> Data Analysis – *analysing the data gathered in the study*

KRG it is used as a means to collect data and as such, once the Grids had been completed by the participants, they became sources of visual data that the researcher was able to interpret and analyse – in addition to the recorded and transcribed conversation that occurred during their completion.

The transcribed commentaries revealed:

- which elements were most difficult to be described by participants through the opposing *constructs* and why.
- which elements were found more difficult/easy to position within the Grid and why;
- individual opinions and points of view on different themes analysed, concerning digital crafts and the practice of digital craftsmanship.
- the overall experience of the participants while running KRG and its value as a framework.

Through the KRG the researcher was able to:

- visualise a set of *elements* characterised in terms of what we call *constructs*;
- observe dependencies between the *constructs* chosen and therefore the objects in multiple Grids ran by different participants;
- calculate statistical numerical correlations of *constructs* and *elements* dependent on the rating scale.

5.2 Gathered Data

The researcher in this section organises the results obtained through the KRG.
A listing of the *construct* chosen by each participant followed by their Grids was created and each pair of *constructs* was identified by a letter which corresponds to its Grid.
Working with some participants the researcher managed to reiterate the framework's process three times, in others even four. Therefore, in some cases some participants explored three pairs of *constructs* and in other ones more. This depended on the participant availability and on the quality of the conversational engagement built up in each of the sessions. Moreover, sometimes the participants would start generating more than one *construct* to try to better articulate the meaning of a concept in each pole. Therefore, the Grids often present opposite pole *constructs* with multiple synonyms alongside as the participants would come up with variations of the first *constructs* articulated during each conversation. These synonyms are listed alongside the first chosen *constructs* as shown below in the table 1 (e.g., in Grid L, ran with Practitioner E, the constructs 'chance/unpredictable /risk' and 'determined/prescribed/certainty' were chosen as synonyms to better describe opposite poles).

The *constructs* proposed by the practitioners are organised in two different lines: one stands for the *construct* chosen to stand by the lowest value of the Grid (1) and the other line stands for its opposite and counterposing *construct*, relating to the higher number of the Grid's scale (6) (see Table 2).

Table 2.

List of constructs chosen by each Participant in the KRG session

Practitioner C		
a)	Modern Looking	Traditional looking
	Controversial	Reflecting the past
b)	Generic	Unique Identity of the author
c)	Digital	Analog
	Machine made	Hands-on
Practitioner D		
d)	Not coded	Coded
e)	Fluidity	Control
f)	Craft	Product
g)	Experiential Value	Contemplative Value
Practitioner E		
h)	Objects to experience	Objects of contemplation
i)	Collaborative	Personal
l)	Chance	Determined
	Unpredictable	Prescribed
	Risk	Certainty
Practitioner J		
m)	Artefact as facilitators	Artefact as self expression
n)	Process specific aesthetic	Design driven aesthetic
o)	Digital	Non Digital
Practitioner K		
p)	Fault as poetry	Emergent poetry
q)	Open ended	Closed
r)	Tacit human expression	Explicit commands
s)	Less collaborative	Collaborative

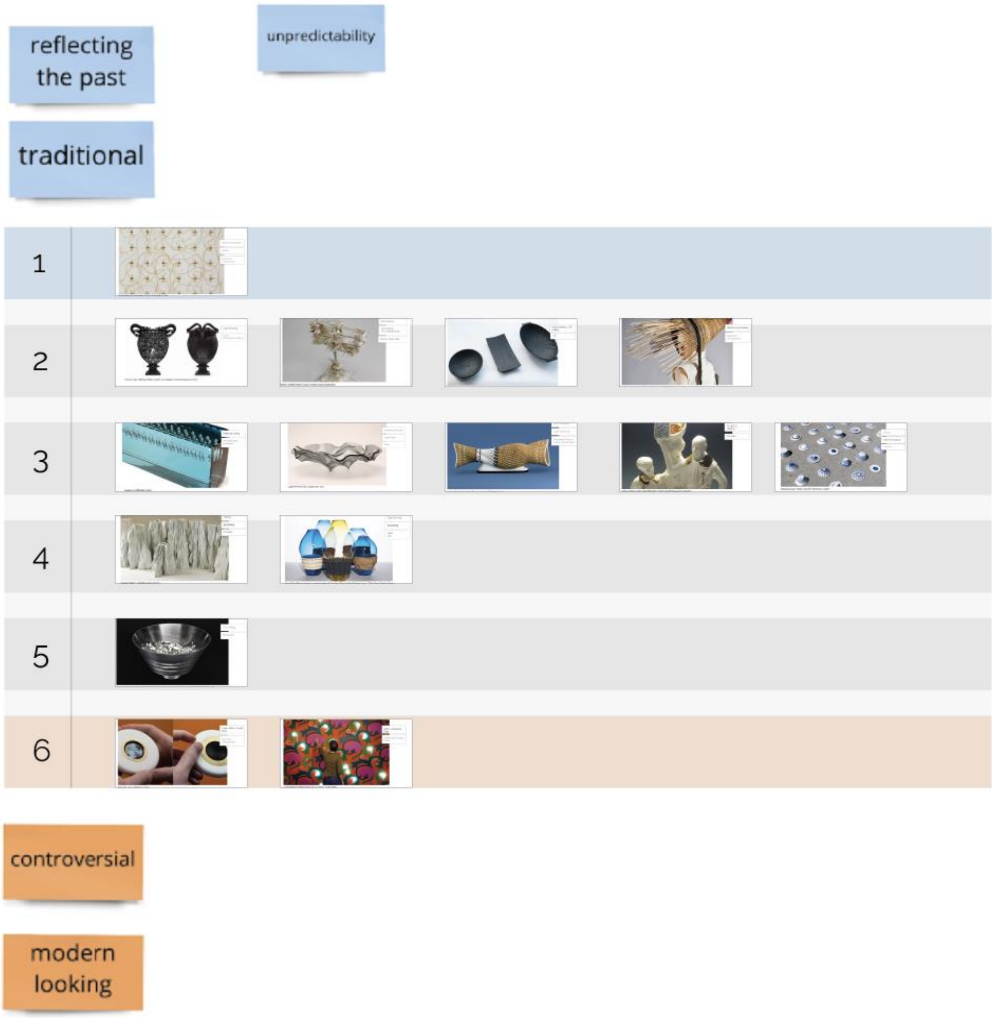
	Concrete	Volatile
Practitioner V		
t)	Structural	
	Predetermined	Serendipitous
u)	Constructed	Casted
		One Piece
		Unified
	Assembled	Cohesive
v)	Initial stage of the tradition of the digital	Last stage of the tradition of the digital

In the following the researcher displays the Grids that were completed by each participant during their session. For convenience, the Grids are identified with a letter of the alphabet going from ‘a’ to ‘t’. The *elements* placed on each row do not have a specific order and their relevance does not change in relation to their positioning. Participants positioned the elements while conversing with the researcher in the study and, as a consequence, certain *elements* were positioned before others. When in doubt on how to rate or position an *element*, or when in need to slightly differentiate certain *elements* from each other, participants tended to place *elements* in between rows rather than on a precise rating scale number. Hence, in the Grids shown below it can be noticed how *elements* often acquired a position in between rating numbers (i.e., in between rows) during the study. Moreover, during the running of each Grid, the participants would start with articulating a *construct* but more often tended to continue to develop its articulation throughout the conversation. For this reason, often more post-its are placed on the poles. The researcher will refer to the first articulated one for convenience, therefore, in the descriptions of the figures representing the Grids, the reader will find in brackets the *constructs* expressed in a second moment.

5.2.1 Practitioner C

Figure 59.

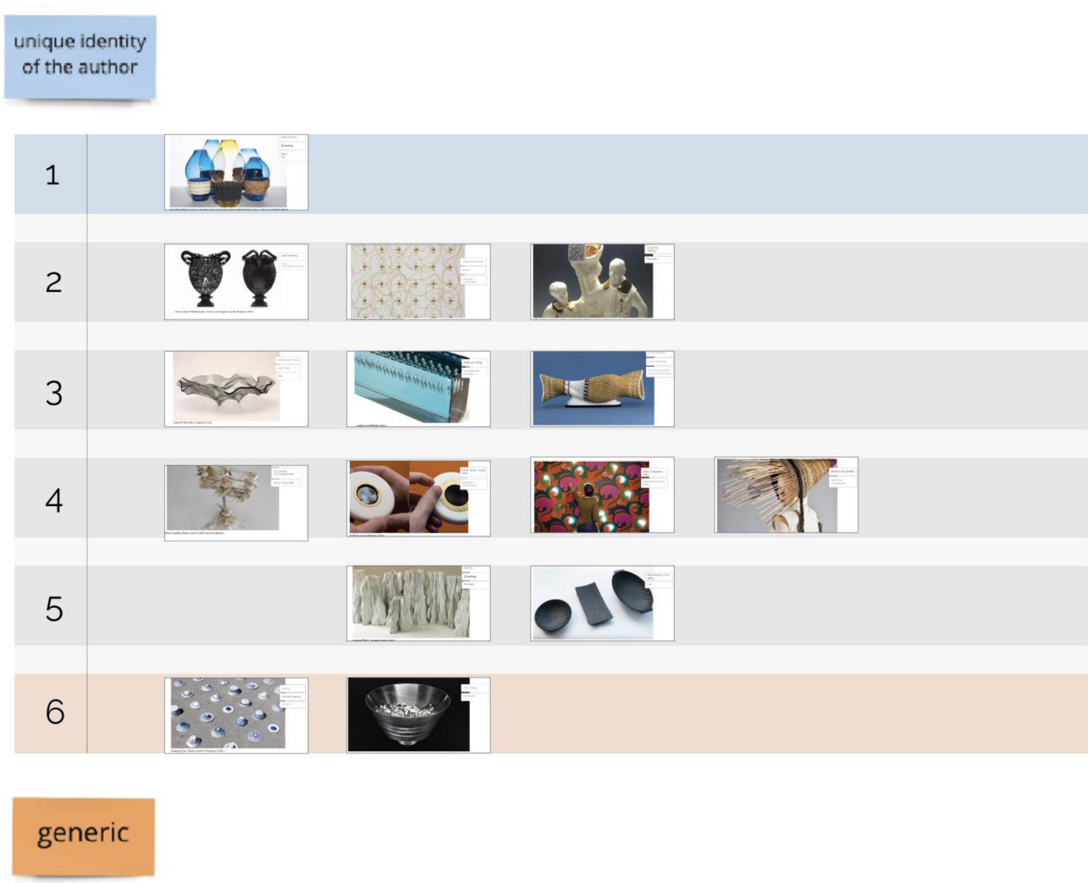
Grid a



Note. Constructs articulated: ‘Modern Looking’ (‘Controversial’) vs. ‘Traditional’ (‘Reflecting the Past’)

Figure 60.

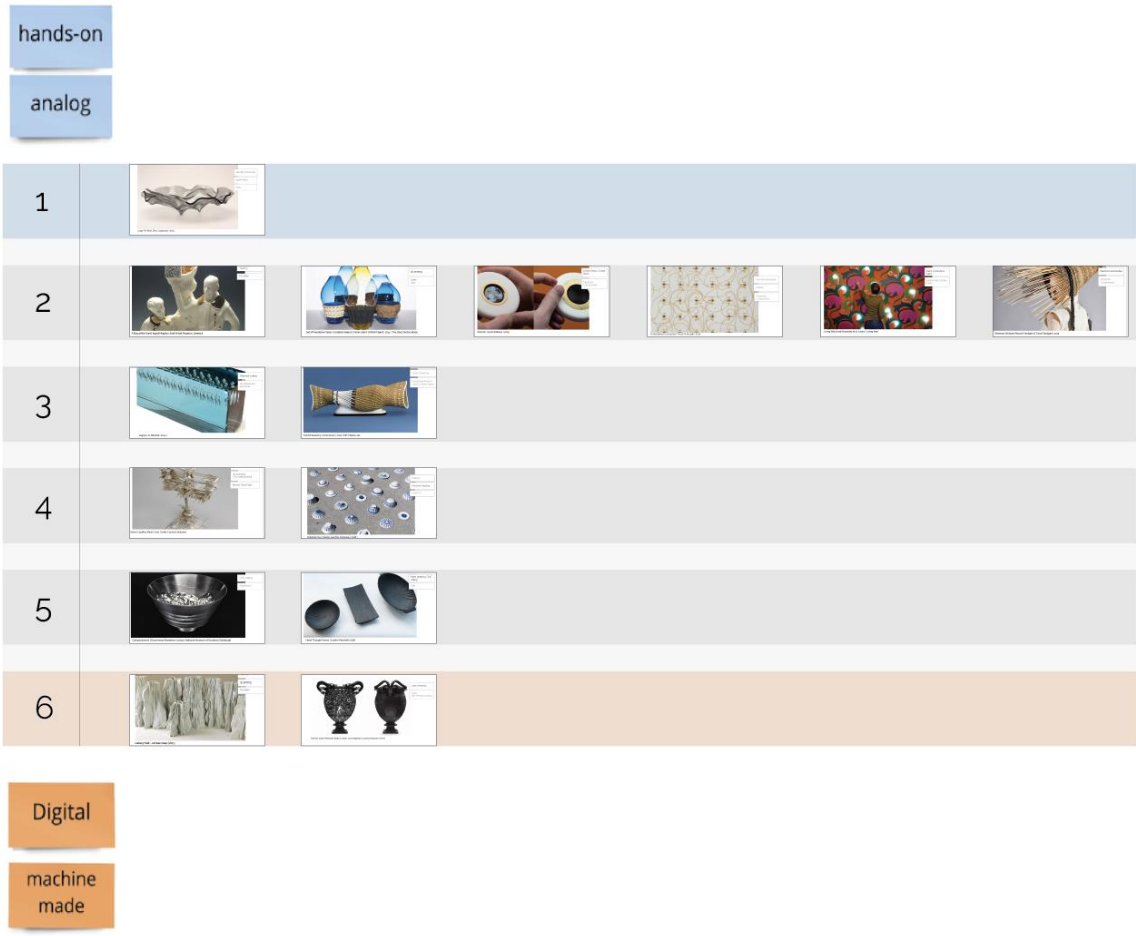
Grid b



Note. Constructs articulated: ‘Unique identity of the Author’ (the participant further articulates the *construct*’s meaning saying: “if given a set of instructions the maker’s work would still be recognisable and stand out” (C)) vs. ‘Generic’ (the participants further articulates the *construct*’s meaning saying: “if given a set of instructions I would be able to do it and would not recognise the difference” (C))

Figure 61.

Grid c

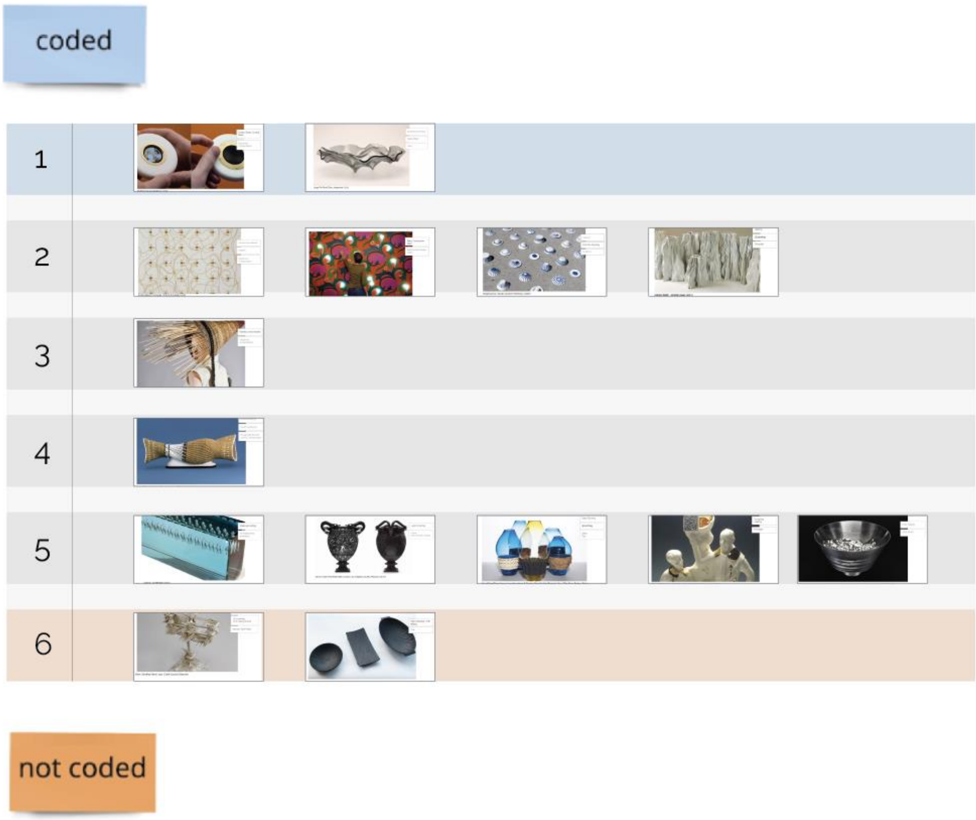


Note. Constructs articulated: ‘Analog’ (‘Hands-on’) vs. ‘Digital’ (‘Machine Made).

5.2.2 Practitioner D

Figure 62.

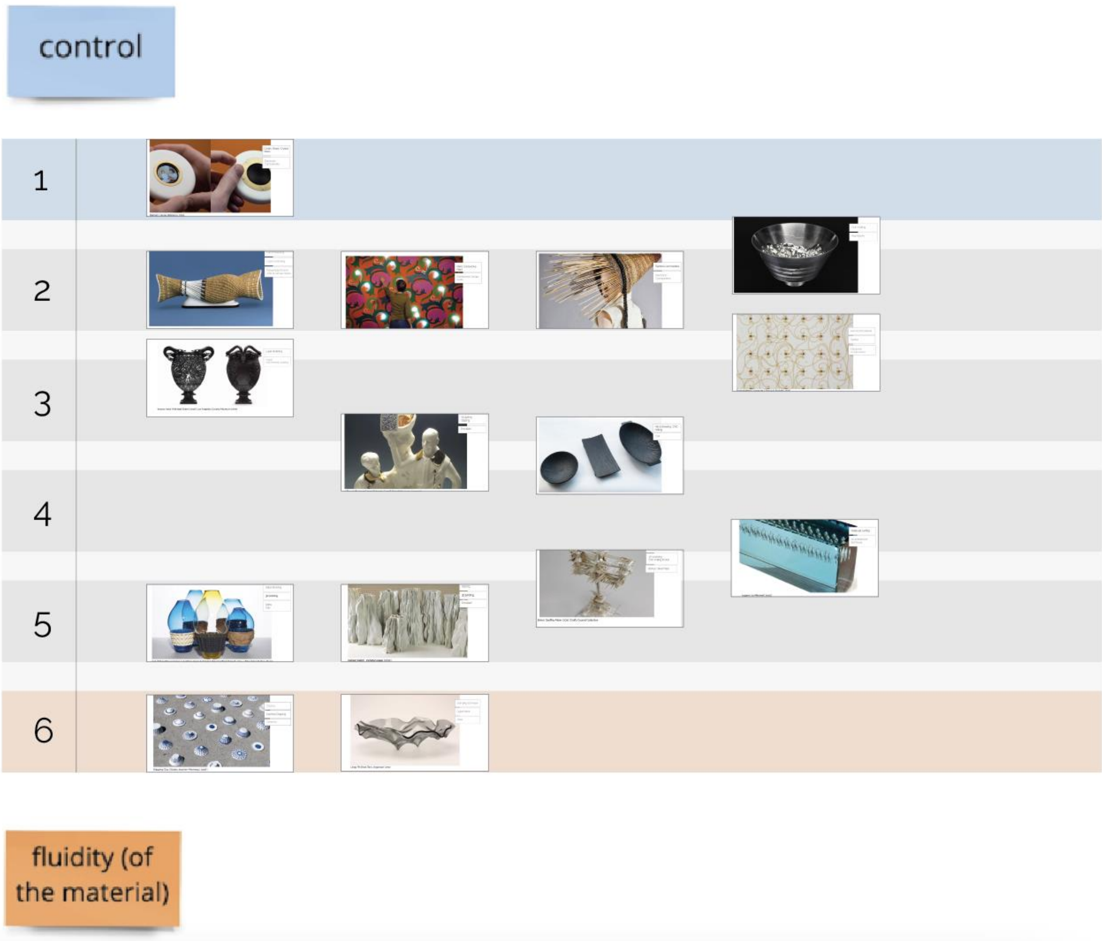
Grid d



Note. Constructs articulated: ‘Coded’ vs. ‘Not coded

Figure 63.

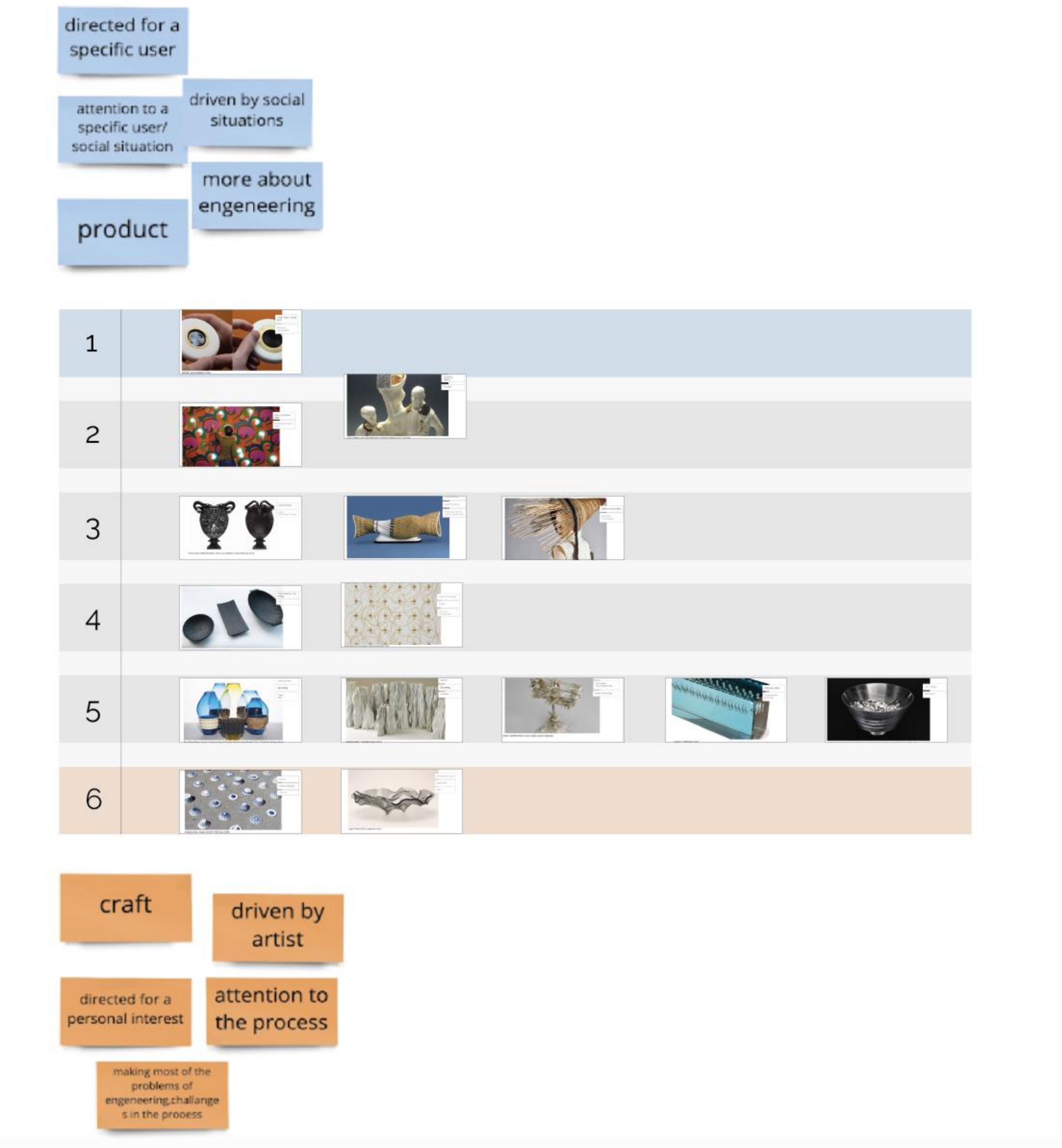
Grid e



Note. Constructs articulated: ‘Control’ vs. ‘Fluidity (of the material)’.

Figure 64.

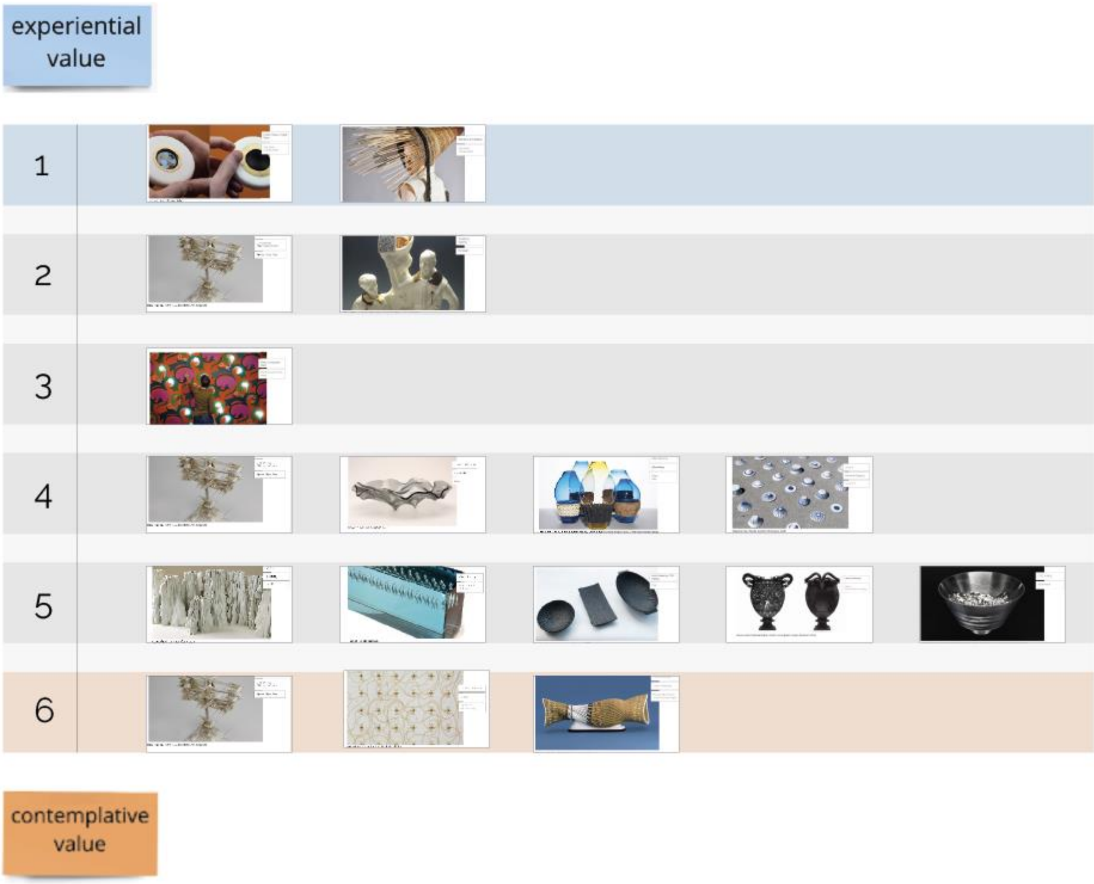
Grid f



Note. Constructs articulated: 'Product' ('More about engineering', 'Driven by social situations', 'Directed for a specific user') vs. 'Craft' ('Attention to the process, 'Directed for a personal interest', 'Driven by the artist','Attention to the process').

Figure 65.

Grid g

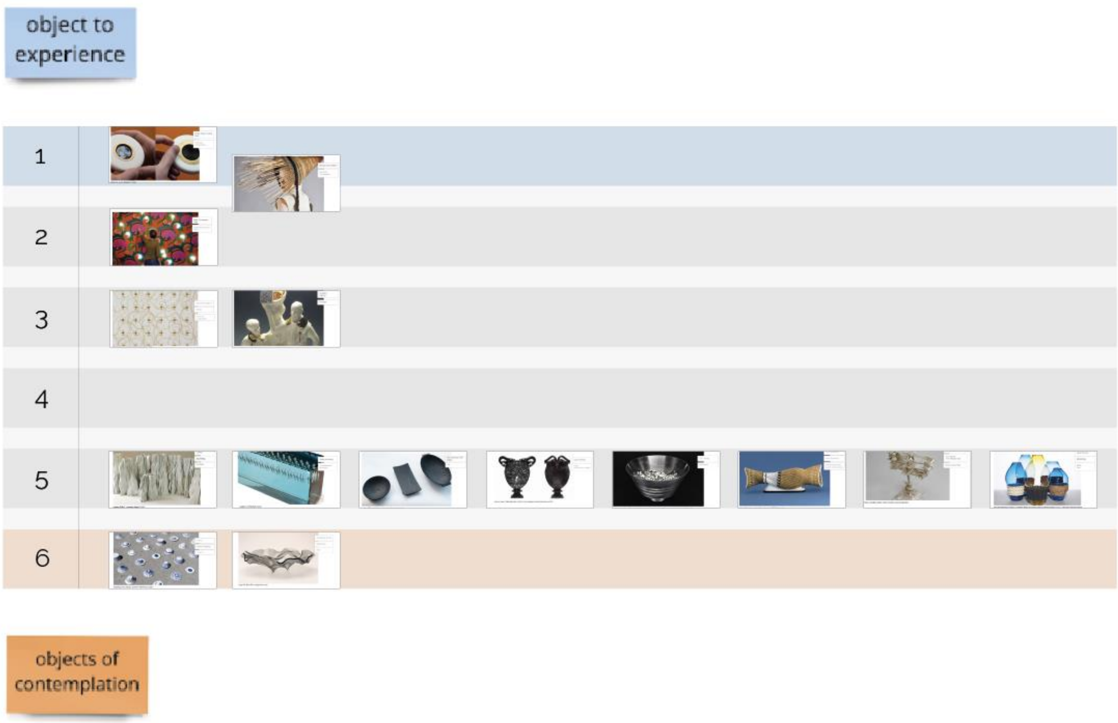


Note. Constructs articulated: ‘Experiential Value’ vs. ‘Contemplative Value’.

5.2.3 Practitioner E

Figure 66.

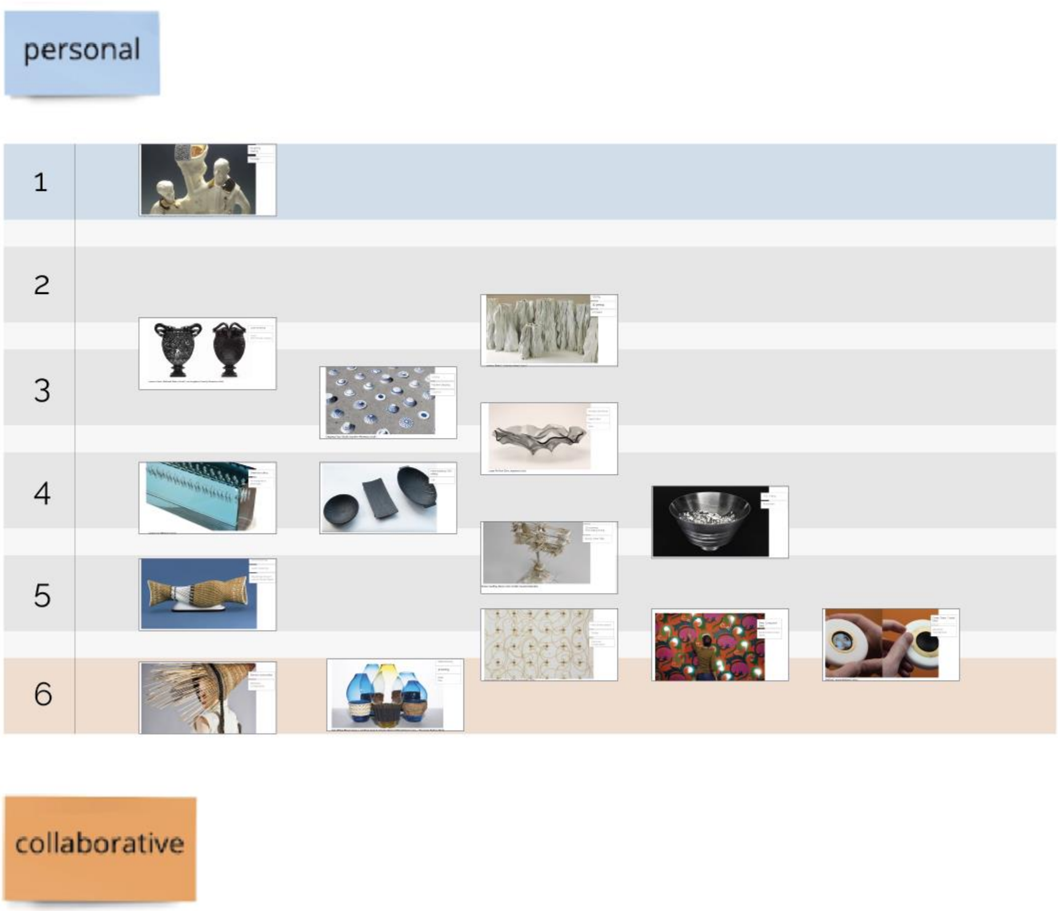
Grid h



Note. Constructs articulated: ‘Objects to Experience’ vs. ‘Objects of Contemplation’

Figure 67.

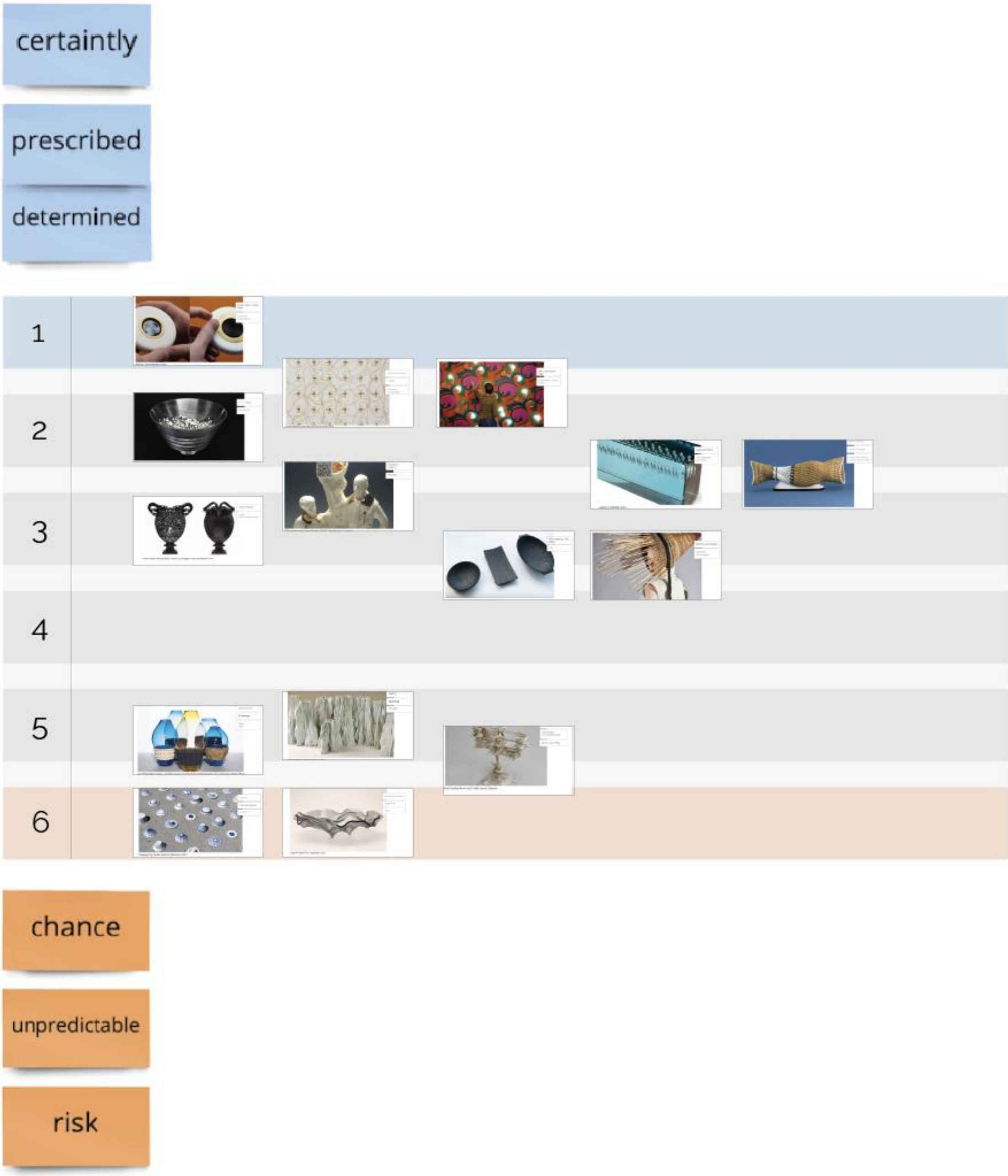
Grid i



Note. Constructs articulated: ‘Personal’ vs. ‘Collaborative’.

Figure 68.

Grid I

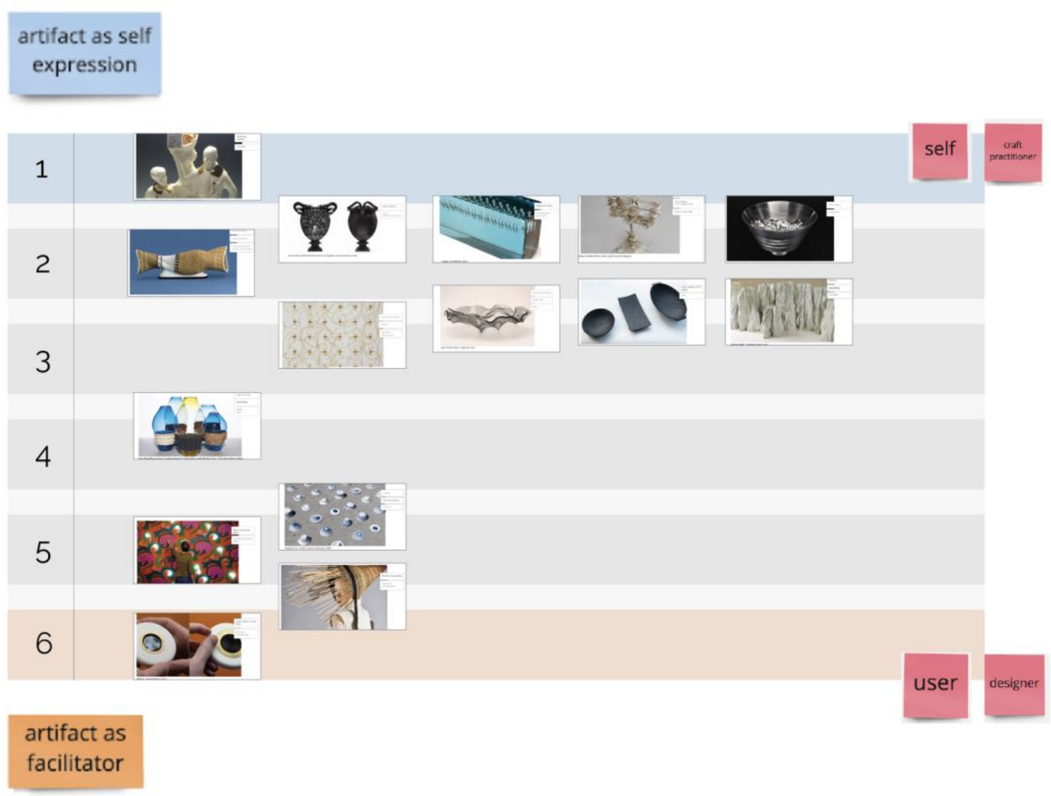


Note. Constructs articulated: ‘Determined’ (‘Prescribed’, ‘Certainty’) vs. ‘Chance’ (‘Unpredictable’, ‘Risk’)

5.2.4 Practitioner J

Figure 69.

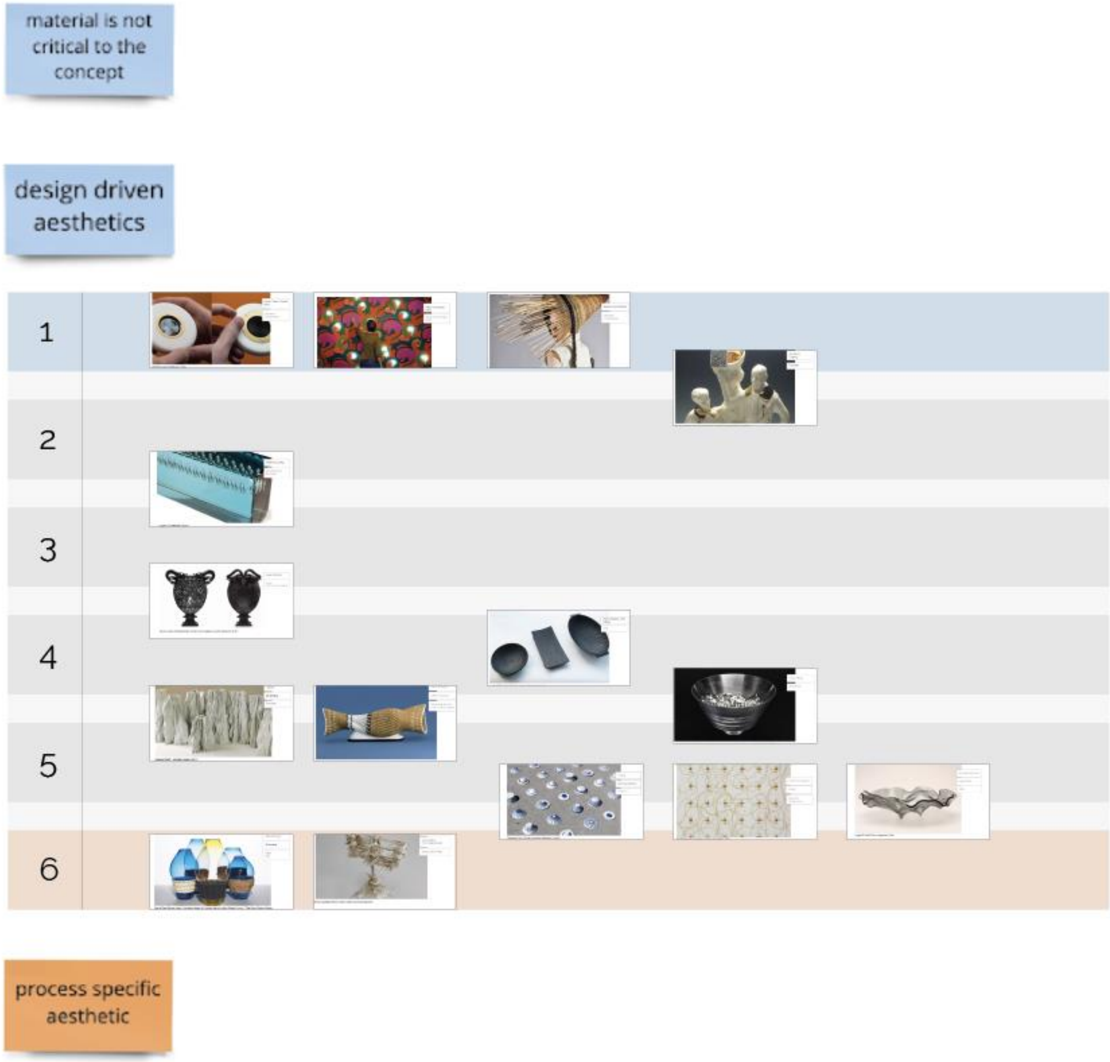
Grid m



Note. Constructs articulated: 'Artefacts as Self Expression' vs. 'Artefacts as Facilitators'. The practitioner used additional pink post-its to add in the framework the words: user / designer and self / craft practitioner in relation to the artefacts positioned in the Grid.

Figure 70.

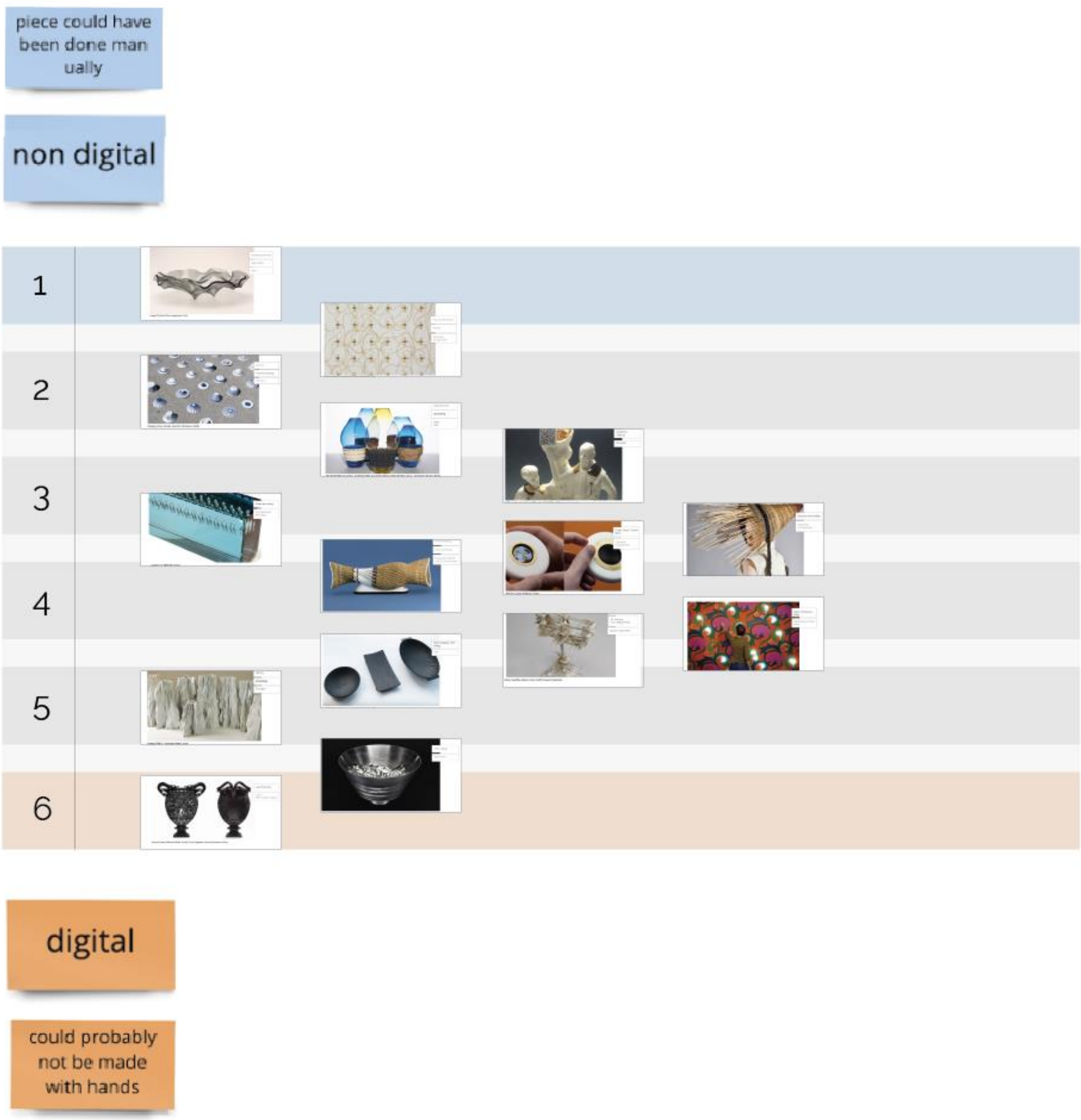
Grid n



Note. Constructs articulated: ‘Design Driven Aesthetics’ (‘Material is not critical for the concept ideation’) vs. ‘Process Specific Aesthetic’.

Figure 71.

Grid o

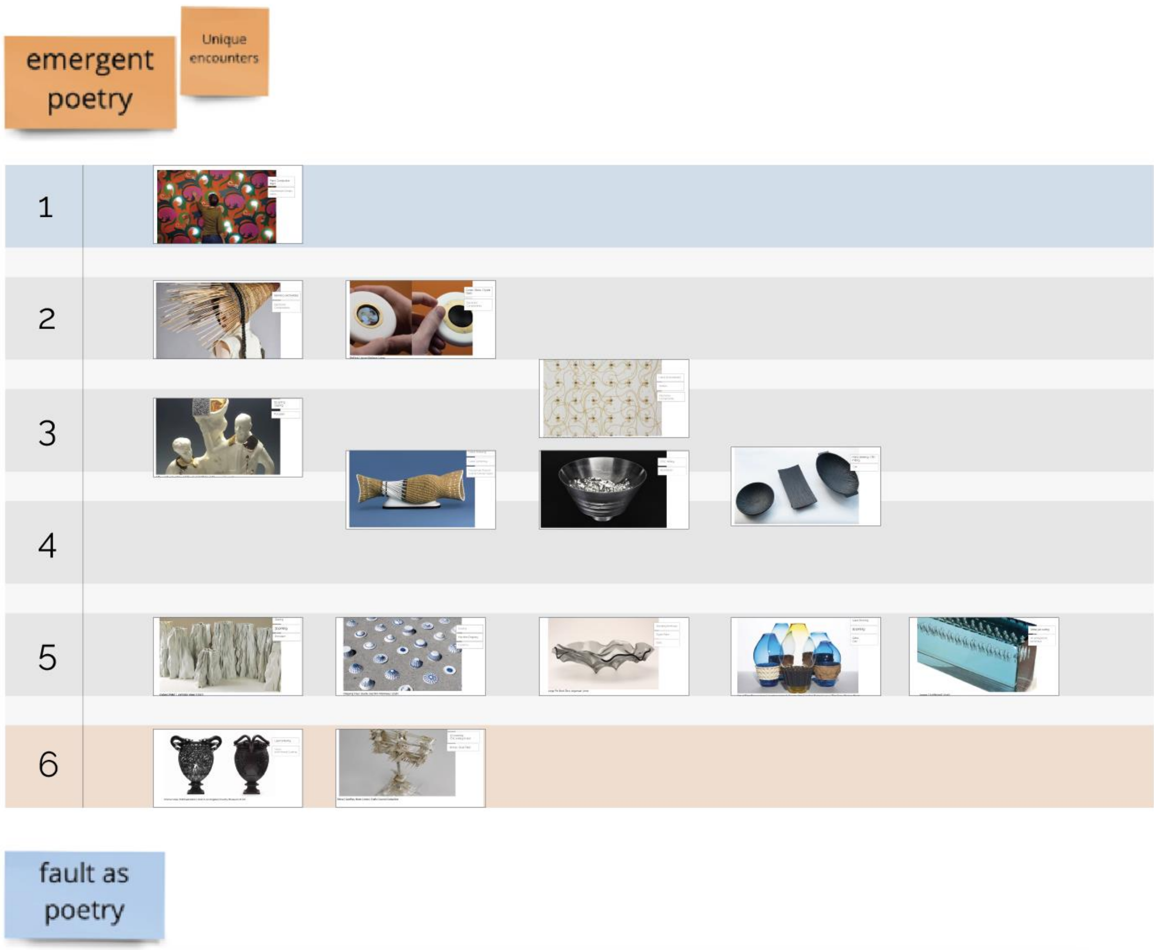


Note. Constructs articulated: ‘Non Digital’ (‘Could have been done manually’) vs. ‘Digital’ (‘Could probably not be made with hands’)

5.2.5 Practitioner K

Figure 72.

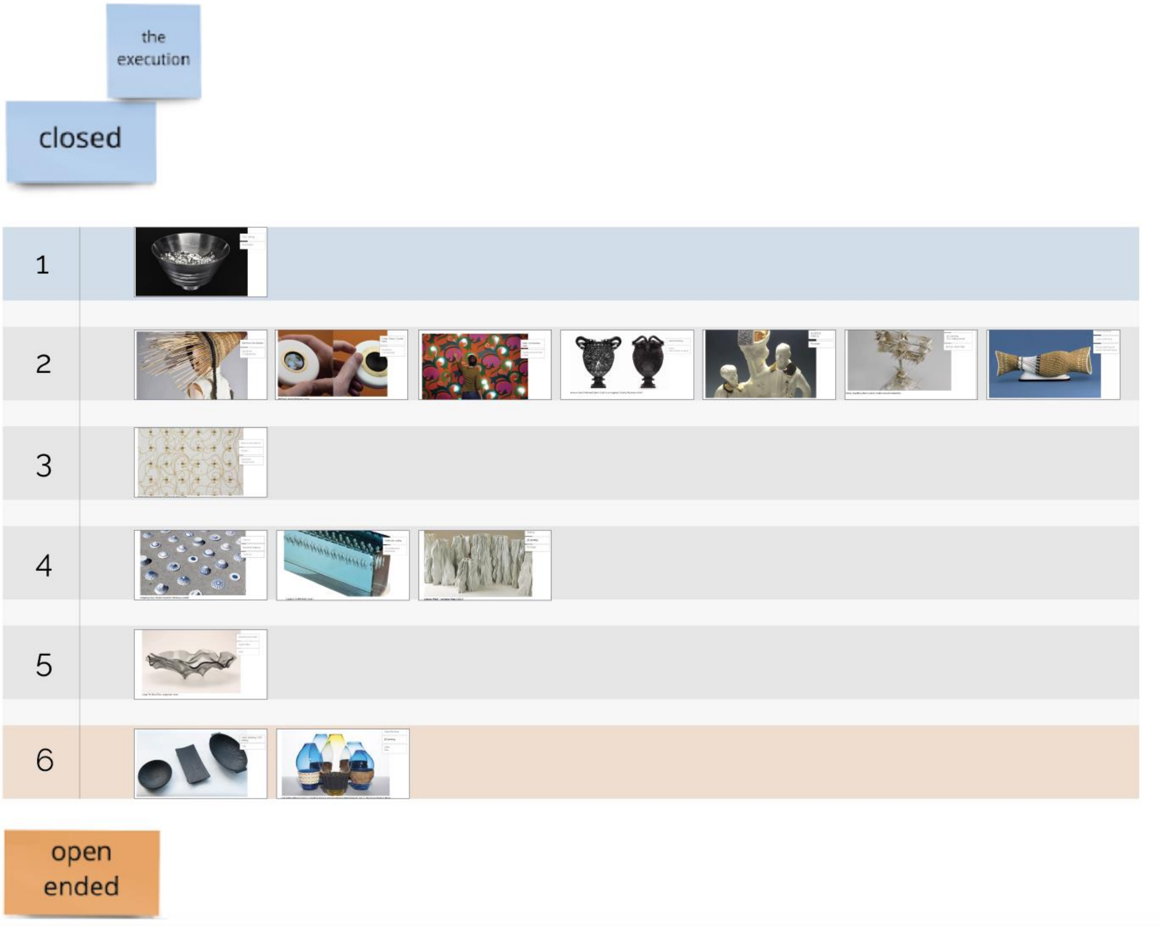
Grid p



Note. Constructs articulated: ‘Emergent Poetry’ (‘unique encounters’) vs. ‘Fault as poetry’

Figure 73.

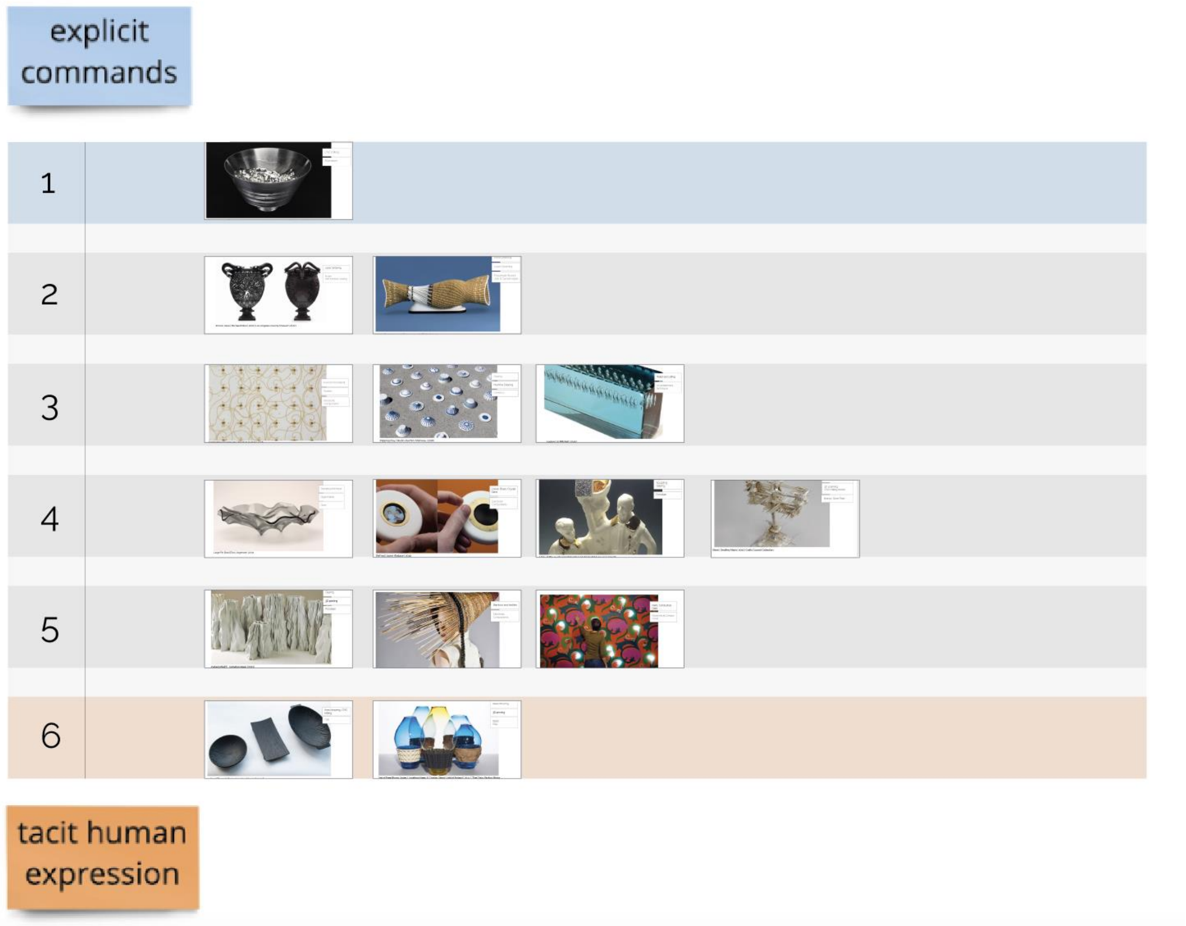
Grid q



Note. Constructs articulated: ‘Closed’ (‘The execution’) vs. ‘Open ended’.

Figure 74.

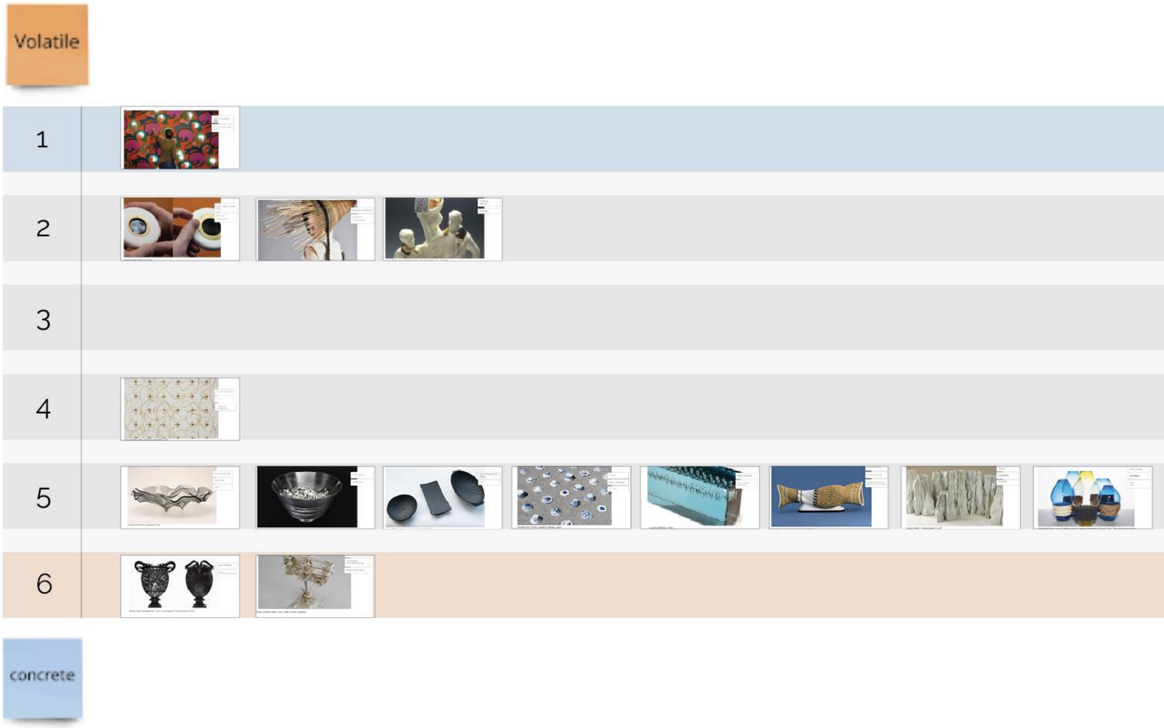
Grid r



Note. Constructs articulated: 'Explicit Commands' vs. 'Tacit Human Expression'.

Figure 75.

Grid s

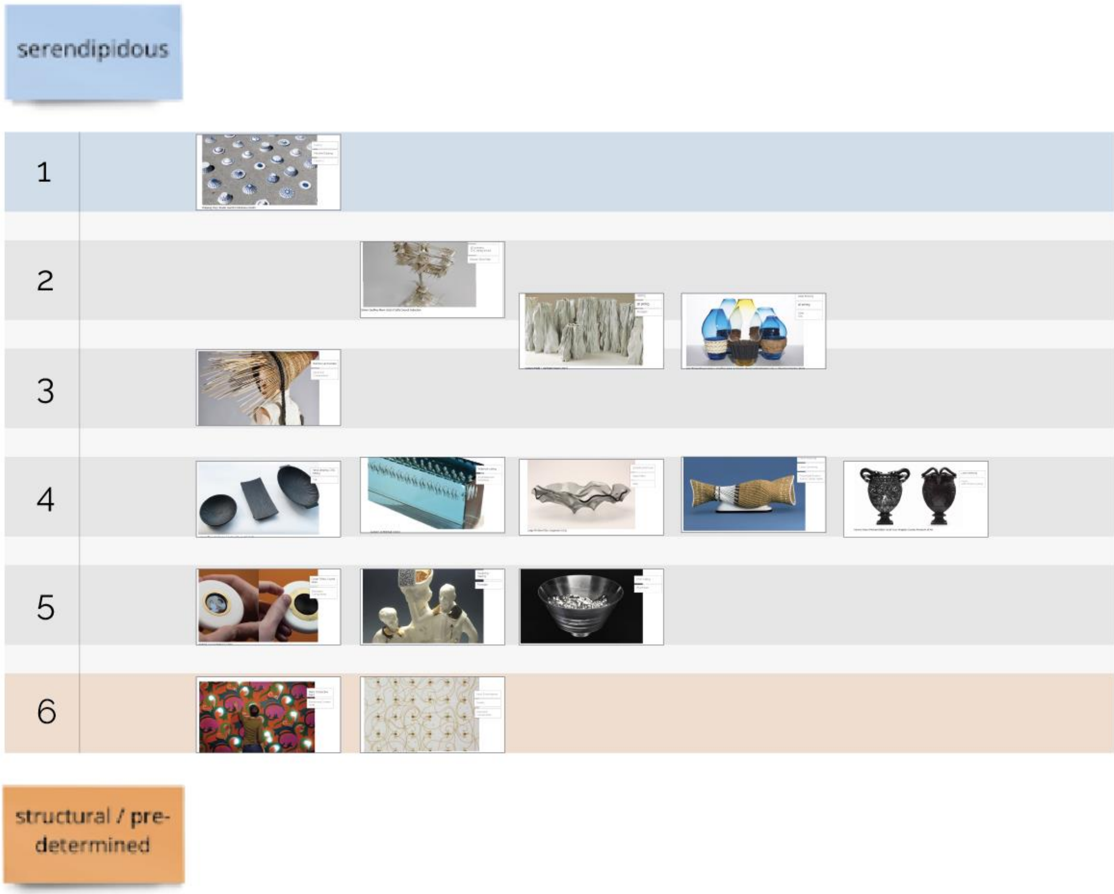


Note. Constructs articulated: 'Volatile' vs. 'Concrete' .

5.2.6 Practitioner V

Figure 76.

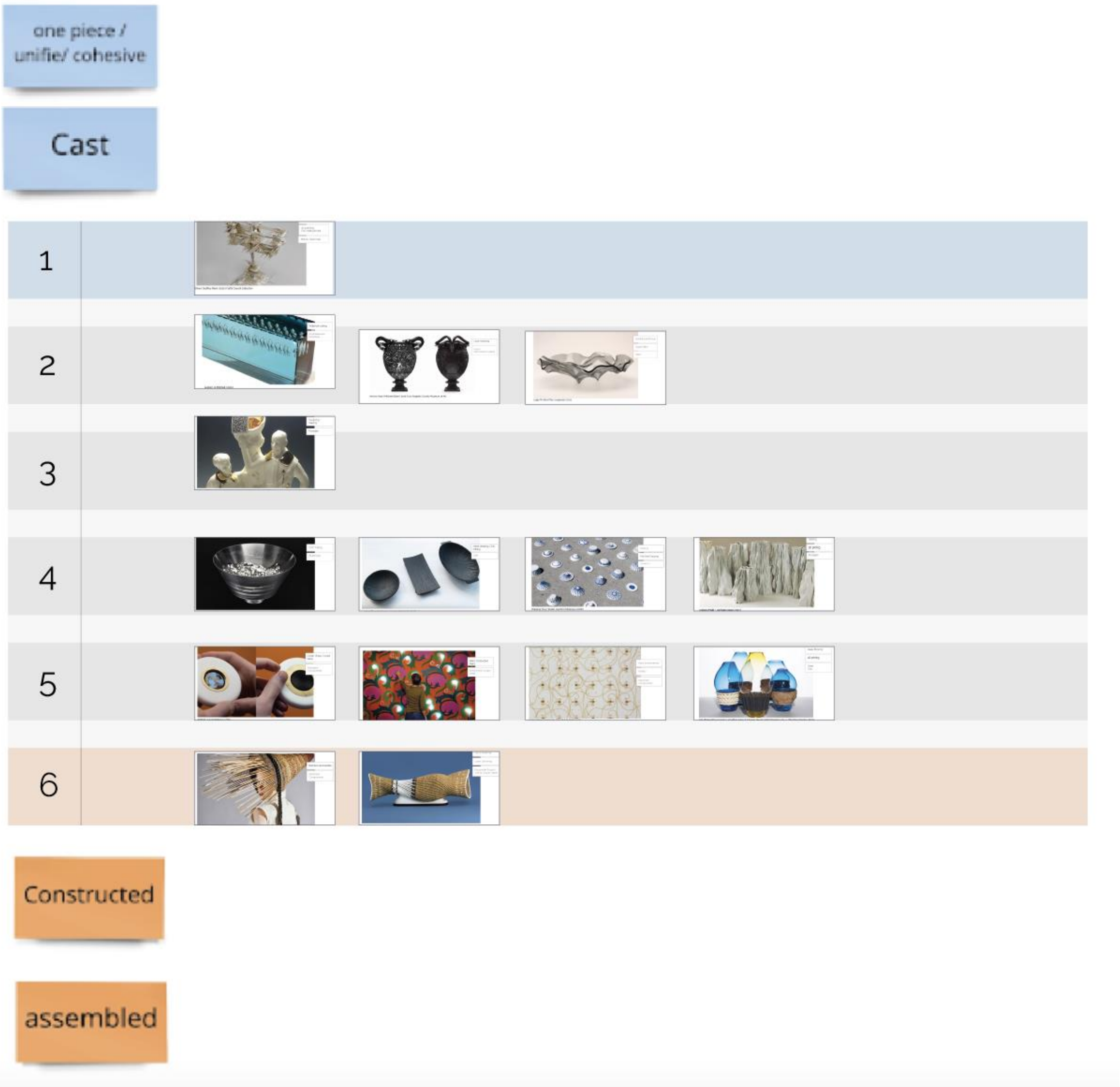
Grid t



Note. Constructs articulated: ‘Serendipitous’ vs. ‘Structural/ Predetermined’.

Figure 77.

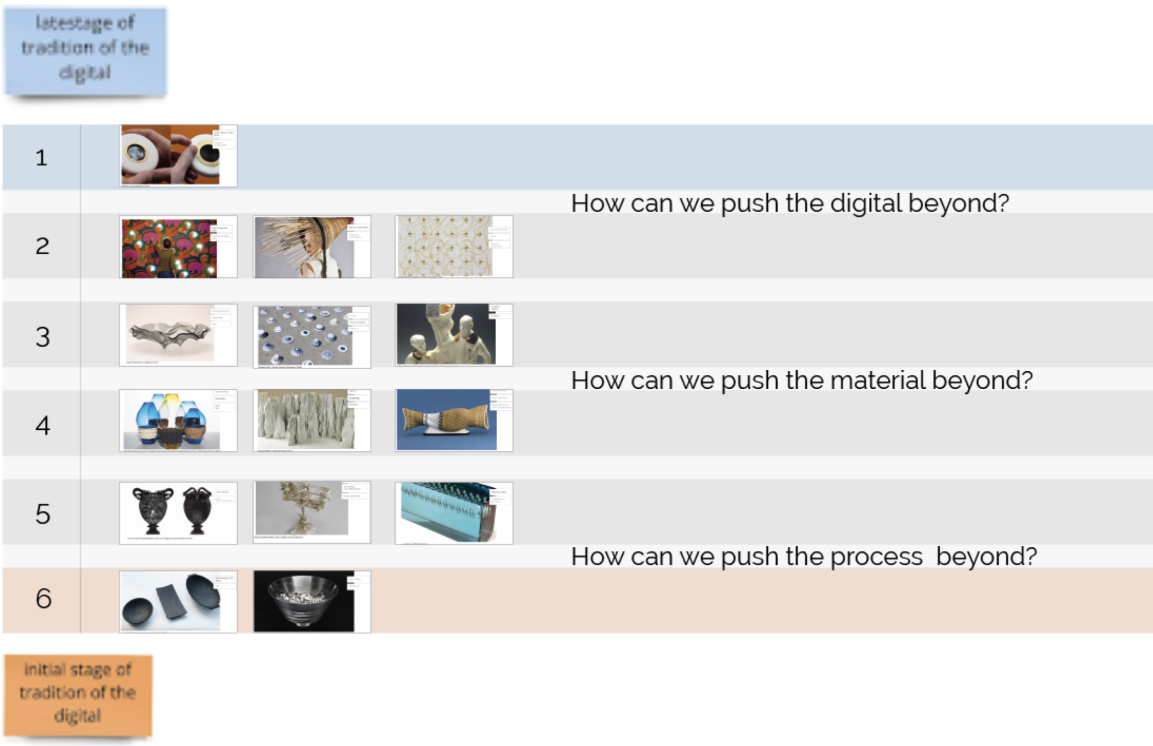
Grid u



Note. Constructs articulated: 'Cast' ('One piece/Unified/ Cohesive') vs. Constructed ('Assembled').

Figure 78.

Grid v



Note. Constructs articulated: ‘Initial Stage of the Tradition of the Digital’ vs. Last Stage of the Tradition of the Digital. The practitioner adds to the Grid the questions: “How can we push the process beyond?”, “How can we push materiality beyond?” and “How can we push the digital beyond?”.

5.3 Data Analysis

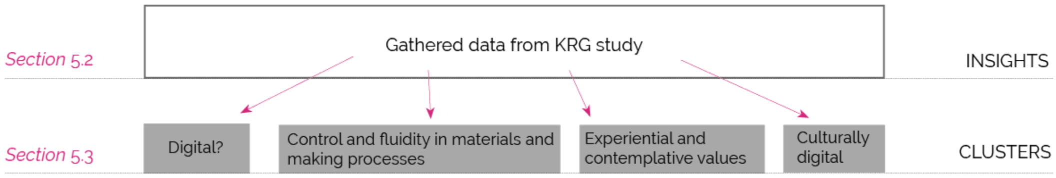
Using KRG's technique the researcher was able to retrieve two different layers of information: i) on a visual level, through the Grids, and ii) on a verbal level through the *think aloud transcribed commentary* of the process. The Grid defines the relationships between *elements* and *constructs* through the rating system and with the support of the commentary. This allows for both qualitative and quantitative analysis the data (Fransella et al., 2004)

Therefore, the process of data analysis was on the one hand supported by the visual data on the Grids, representing the decision taken by the Participants while assessing the repertoire of *elements* based on their articulated *constructs* (see Section 5.2). On the other hand, verbal articulations of the *constructs* and relevant reflections expressed while mapping the elements were recorded and could contribute to the researchers' analysis.

The data derived from the conversations with the participants while involved in the meaning-making process of running the Grid can be analysed as informal conversational interviews (Gallet al., 2003; Turner, 2010). Iterative coding and grouping of categories encapsulate "aspects of the social world that respondents portray" (Holstein & Gubrium, 2002, p. 127). Through the use of KRG, the researcher is implicitly helped by the participants in this grouping process through their own articulation of the *constructs. T*hrough the responses feeding the Grids and specifically by the *constructs*, the researcher was able to rapidly *Cluster* the gathered data. As illustrated in Figure 79, in the following sections (from 5.3.1 to 5.3.4), the researcher will describe the gathered data through four main Clusters identified.

Figure 79.

Organisation of the gathered data in four Clusters



It can be recognised that there are benefits to using the KRG both as a framework for instigating discussion and reflection, and as an aid for the researcher to organise the analysis of the gathered data. Relying on close reading of the transcribed texts of each interview and comparing the Grids bodies, the researcher was able to identify recurrent *constructs* and relevant information discussed over specific elements and over specific Clusters. As the sessions were conducted as informal *conversational interviews* with no predetermined scripts (Turner, 2010), the commentary over the Grids did not correspond solely to the *construct* elicitation, but also revealed participant's personal opinions and insights concerning the *elements* under discussion – and other incidental, but valuable information.

The rating scale issue

Together with the clustering of the verbal, qualitative data, the researcher analysed the quantitative data the KRG system provides: the numerical rating scale attributed by participants to each *element* in relation to the *constructs* chosen. These results will be provided in the next subsections (from subsection 5.3.1 to 5.3.4), through the analysis of the gathered data.

Thus, as stressed by Fransella et al. (2004), there are some issues with the data analysis of the elements within the Grid. One issue that she addresses, and that the researcher encountered during the analysis process, relates to the fact that the *constructs* chosen are arbitrarily placed by each participant on the Grid.

This means that the *constructs* can be placed on the pole indicating the higher rating number in the scale (6) or on the minor pole (1) with no distinction. This free interpretation and choice is left open to the Participants to avoid any bias later in the rating decision. For example, if one participant places the *construct* 'big*'* to the pole indicating 6 and the opposite *construct 'small'* to the pole indicating 1 and later on a second participant articulates the exact same *constructs* but places them in a reversed order in the Grid (e.g., *big* on the pole indicating 1 and *small* on the pole indicating 6), then the researcher ends up with two Grids with reversed numerical codings. This frequently happened in the study and the researcher, who wanted to take advantage of the rigour the rating system allows, had difficulties in making comparisons between Grids with similar *constructs* as the *elements* on each Grid were assigned very different numbers while having the same *constructs*.

However, as Frensella points out, even if the order changes, "one statistic that does not change is any kind of distance measure between elements" (Frensella et al., 2004, p.93) which is called *correlation value*. Correlations will remain the same ones even if we switch the ratings to the other end of the scale. We can do so by subtracting each reversed rating from the maximum value in the scale (in this case 6) and adding 1 (Fransella et al., 2004). By doing so, the researcher, when clustering *constructs* with similar meanings, can also compare the positions of the elements within the Grids (i.e., the ratings assigned to each *element* by diverse practitioners).

In the following, the researcher takes as an example the gathered data from Participant K and Paricipant V in Grids **q**, and **t** respectively (see Section 5.2). In Figure 80 we can see how, in the first case, Participant K arbitrarily decided to position ‘closed’ as a *construct* on the pole end of the rating value 1 and ‘open-ended’ as a *construct* on the opposite end pole 6. At the same time, Participant V decided to assign the articulated *construct* ‘serendipitous’ to the pole rating number 1 and the *construct* ‘structural/ pre-determined’ on the opposite rate of 6.

Figure 80.

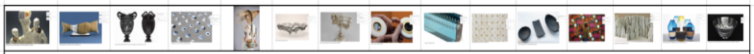
Practical example illustrating the rating scale issue

Practitioner K	q)	Open ended (6) / Closed (1)	2	2	2	4	2	5	2	2	4	3	6	2	4	6	1
Practitioner V	t)	Structural / Predetermined (6) / Serendipetous (1)	5	4	4	1	3	4	2	2	4	6	3	6	3	3	5

Based on the qualitative conversational data gathered, where the Participants articulated the meaning underlying the *constructs* chosen, the researcher was able to understand that the meaning attributed to the practitioners’ *constructs* was very much aligned. Hence, to analyse the Grids, the researcher wanted to compare the positioning of the elements and calculate the median value, thus, due to the reverse rating system used, the *construct* ‘closed’, which could have been paired with the *construct* ‘structural/ predetermined’ referred to opposite values. As the comparing process was not immediate, the researcher had to switch the ratings of the *constructs* ‘structural/predetermined’ and ‘serendipitous’ to the other end of the scale and had to switch the rating of all *elements* by subtracting each rating that needed to be reversed from the maximum value in the scale (i.e., 6) and adding 1 (Fransella et al., 2004).

Figure 81.

Practical example illustrating how to solve the rating scale issue



Participant K	**q)**	Open ended (6) / Closed (1)	2	2	2	4	2	5	2	2	4	3	6	2	4	6	1
Participant V	**t)**	Structural / Predetermined (1)	6-5+1	6-4+1	6-4+1	6-1+1	6-3+1	6-4+1	6-2+1	6-5+1	6-4+1	6-6+1	6-3+1	6-6+1	6-3+1	6-3+1	6-5+1
		Serendipetous (6)	**2**	**3**	**3**	**6**	**4**	**3**	**5**	**2**	**3**	**1**	**4**	**1**	**4**	**4**	**2**

This process was put into practice whenever the researcher wished to compare *constructs* that were clustered together based on their *constructs' meaning*.

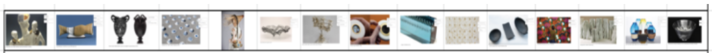
With this in mind, the researcher analysed the data organising the process as much as possible, giving it clarity and rigor by triangulating both the analysis of the conversations and the Participants Grids.

The Median Value

The researcher could have extracted many statistical data from the information in the Grid but given for the purposes of this study, the researcher focussed upon calculating the median value among the ratings assigned by different practitioners to the same elements in Grids with the same *constructs.* The median is “a measure of central tendency” which is able to point out where different practitioners focus “their range of convenience between the *construct*’s two poles” (Fransella et al., 2004).

Figure 82.

Practical example on the median value



Participant K	**q)**	Open ended (6) / Closed (1)	2	2	2	4	2	5	2	2	4	3	6	2	4	6	1
Participant V	**t)**	Structural / Predetermined (1) / Serendipetous (6)	2	3	3	6	4	3	5	2	3	1	4	1	4	4	2
		Median value	2	2,5	2,5	5	3	4	3,5	2	3,5	2	**5**	**1,5**	4	**5**	**1,5**

In Figure 82 the researcher shows the median value (in red), over the previously discussed example (the ratings were first switched in order to be properly compared as shown in Figure 81). The median value calculated allows the researcher to address the elements that on average were rated more often as closer elements to the *constructs* analysed by the Participant's Grids taken in consideration. As illustrated in Figure 82, the two highest (i.e., closer to the 6) and two lowest (i.e., closer to 1) median values are demarcated in red. Moreover, as the scaling system goes from 1 to 6, the median value allows the researcher to find out whether the practitioners had the tendency to rate all the repertoire closer to the poles (e.g., 1,2 or 5,6) or if they rather assigned a more neutral numerical rating to the elements (e.g., 3 and 4).

The researchers' intentions are not to limit the qualitative process KRG allows, reducing it to a dry classification. Rather, by finding the median value between the ratings assigned to the elements by a diverse set of practitioners using *constructs* with the same underlying meaning, the researcher is able to discuss further the way in which the interviewed Participants see the world. Moreover, this process can sometimes uncover similarities and discrepancies between the participant's rating judgements that might say something more on how their backgrounds and practices influence how they relate and judge the elements. Therefore, while the researcher is interested in exposing the nuances and particular viewpoints of each singular participant, she also wants to adopt the rigour KRG allows so as to create a solid basis to discuss possible digital craft principles (see Section 1.2) that the participants interviewed share and that might be *tacit*. Through the data analysis researcher seeks for the qualitative richness deriving from the singular participants' lenses, which, together with the clear objective results deriving from the Grids rating system, will support the discussion of the principles (later in Chapter 6).

5.3.1 Cluster 1 – Digital?

In general, all practitioners involved in the study recognised the different choices of materials represented in the *elements* collected through the Repertoire, and they discussed this aspect, throughout the 15 pieces presented.
However, the shared understanding among the practitioners was that the physical material choices used in the different making processes **do not** have a preference or hierarchy of importance when talking about digital crafting.
“Pure traditional crafting materials” were considered “more malleable.. like glass and clay. and wood.it moves over time, wood has grains.. they are less fixed by nature” (K).
Whereas, in contrast, when talking about electronic components, Participant D discusses how, in his opinion, they ”do not have fluidity in their materiality. Their physicality is static, they won’t change through physical conditions like clay might, you have to consider this when you use them” (D). Therefore, material knowledge is fundamental as “the notion of using a specific process or a specific material becomes an integral part of the design decision” (J), which in turn has a “big impact

on the shape, the texture, the aesthetics but mostly, the [making] process itself" (J). Participant J focuses on his making processes in order to "let the material speak" (J). This Is what he defines as the main characteristic necessary to determine whether it is possible to attribute the term 'craft', 'craftsmanship' or anything related to the ethos of 'crafting' –when considering a making process involving digital fabrication–, or not. When this is done and the material is the main actor speaking throughout the process and in the final outcome, Participant J believes that the artefact appears to be far less digital than it actually might be. For this reason, Participant J decided to create the *constructs* 'digital' and 'non digital' in his first Grid (see section 5.2, Participant J, Grid o).

On the same line of discussion, Participant K pointed out how some materials are much more tameable than others. With those materials, the digital practitioner does not have to manipulate the material much; the making process can be brought out mainly through the use of digital fabrication machines. When this happens, the practitioner needs to produce precise *Explicit* commands that the machine will execute, thus, by doing so, he/she will not be able to reach an embodied, tacit conversation with the materials which in Participant K's opinion is fundamental. Based on this reflection, Participant K articulated the *constructs* 'Tacit Human Expression' and 'Explicit Commands'.
While materials play a central and fundamental role for digital craft practitioners, in Participant C's opinion, in ongoing debates related to digital craftsmanship, making processes are wrongly loaded with more significance than practitioners' expertise and material knowledge. Participant C initiated a more general discourse on people's obsession with pointing out the digital side of the making process, rather than focusing on the maker expressing his/her talent through materials. To explain

his point he provided an example using the analogy of people judging digital craft practitioner’s talent as someone would if you were to make a drawing on a computer and then print out the result: “you show your drawing to friends… are they going to say “ooh, you have such a talent, cannot believe you drew such a thing, it's incredible” [laughs] or are they going to say “shame on you, you used a printer to print this out”? I mean, I don’t know your friends but mine would never focus on the printer, they would focus on my beautiful drawing” (C).

In Participant C’s opinion, scholars and the public have been more preoccupied in pointing out the digital side of things, shedding light over the presence of digital making processes, that they ended up underlooking the capabilities and deep material knowledge needed to produce what digital craft practitioners make:

“Everyone here is making, through materials. Isn’t this making me as “crafty” as any traditional maker? I use clay trying to produce beautiful artefacts while surrounded with digital machines of any sort. I bet anyone could do what I do, but are they doing it? Did they take the time to fail, understand the clay, understand the 3D printing machine and the whole process as much as I did? Not many, on this I can give you now a couple of names of artists that did even spend much more time than me..inspiring.. but then.. should we focus on my capabilities rather than the digital side of things? The machine is just a means to an end.” (C)

Hence, Participant C decided to run the Grid using the *constructs* ‘analog’ and ‘digital’. The *construct* ‘analog’ stands for those artefacts where, in Participant C’s opinion, the authors spent time understanding the material and developing the knowledge to use digital techniques in relation to that material. Whereas the *construct* ‘digital’ refers to those elements where manual intervention and hand-making abilities were not as heavily required as in the elements considered ‘analog’ by the Participant C.

When talking about materials, Participants C, J and K all focused on the importance of physical craft materials. Whereas, Participant D, owning a background in computer science, reflected the importance of material knowledge through a different lens, focusing on digital materials aspects. Participant D stressed how all *elements* in the repertoire inherently involve code in their making process. Thus, if in some cases practitioners use softwares to design 3D models, in other cases they write code directly and this happens especially when practitioners need to manage electronic components. Referring to the *elements* he claims that some “feel engineered” (D); whereas, in other ones, he perceives those practitioners “are making the most of some of the craft challenges… making the most of the process” (D). Considering this differentiation, Participant D decided that it would have been challenging to create the two opposite *constructs* of ‘coded’ and ‘not coded’.

Having analysed the meaning behind the *constructs* articulated by Participants C, D, J and K, the researcher will provide examples for each *construct* through the analysis of the corresponding Grids *c, d o* and *r* (the original Grids can be found in Section 5.2) and the support of the gathered conversational data describing and articulating the rating choices for the *elements* in relation to the *constructs.*

As shown In Figure 83, Participants C, D, J and K often chose similar *elements* for the triad but sometimes they would give them very opposite ratings. In the following, the researcher will describe some of the *elements* most discussed, trying to articulate the Participants’ observations made while mapping out the *elements* in the Grids.

Figure 83.

Cluster 1

Cluster 1																	
Participant C	c)	Analog (6)	5	4	1	3	5	6	3	5	4	5	2	5	1	5	2
		Digital (1)															
Participant D	d)	Not Coded (6)	5	4	5	2	3	1	6	1	5	2	6	2	2	5	5
		Coded (1)															
Participant J	o)	Non Digital (6)	4	3	1	5	4	6	3	3	4	5	2	3	2	4	1
		Digital (1)															
Participant K	r)	Tacit Human Expression (6)	4	2	2	3	5	4	4	4	3	3	6	5	5	6	1
		Explicit Commands (1)															

Both Practitioners C and J chose Edens' *Innovo Vase* (2016) as a representative *element* in the triad for their chosen *construct* 'digital' and Jorgensen's *Large Pin Bowl* for the opposite pole *construct* 'analog/non digital'. Both Participants stressed the importance materials had in their decisions.

For Participants C and J, in *Innovo Vase* material is not a central guiding factor in the making process. Therefore,due to its material properties and to the fabrication process used, Eden's work (in Figure 84) was considered the most 'digital' artefact in the repertoire. As seen in the contextual review (Section 3.1.1), *Innovo vase* is an artefact made out of Nylon and Participant C claims that that was one of the main reasons that made him position the artefact on the 'digital' end pole. Moreover, the artefact "it is made through a digital machine with almost no intervention within the actual making process. It is completely digitally made, you wouldn't even be able to make it by hand!" (C) which significantly influenced both his decision and Participant J's choice.

In contrast to Participants C and J viewpoint, Practitioner D, placed *Innovo Vase* by Michael *Eden* (2016) to the complete opposite rating pole. Practitioner D assigned 5 to the same *element* but relating it to the opposite *construct* of ‘not coded’. From his point of view, as the vase it is not directly made through coding language, it is much closer to the *crafting* side of things rather than the *digital* side of things:

> “we can say that that’s not coded [referring to Eden’s Innovo Vase] ...there is of course code involved in the process, but it's not actively coded... the code is happening in the background, the maker is not typing in code, he is perhaps drawing lines or using 3D modeling softwares” (D*).*

Figure 84.

Innovo vase by Michael Eden

Note. Adapted by the researcher from “Innovo Vase” by Michael E., 2016 [Nylon and soft mineral coating, 50x40.5x29.5cm, Los Angeles County Museum of Art, USA]. Copyright of the photo retained by © Michael Eden and © 2016 Museum Associates/LACMA. Retrieved from: http://www.michael-eden.com/new-gallery-1/9tlvskw1drk8tn2qywbqmv2rc95se6

In other words, differently from the first two participants, in Participant D's eyes, the fact Eden designed *Innovo Vase* through 3D modelling and hand- drawings, rather than actively using coding language, makes the artefact one of the least digital *elements* among the selected group.

Figure 85.

Campionissimo by Drummond Masterton

Note. Adapted by the researcher from "Campionissimo" by Masterton D., 2009 [Aluminium. –. National Museum of Scotland, Edinburgh, Scotland]. Copyright retained by © 2009 Drummond Masterton. Retrieved from: https://www.nms.ac.uk/explore-our-collections/stories/art-and-design/campionissimo-aluminium-bowl/

Also, Mastertons' *Campionissimo Bowl* (2009) (Figure 85), was selected by Participants J and K as an *element* holding a bigger 'digital' imprint rather than a 'non-digital' one. The bowl is seen as an artefact celebrating how difficult materials to manipulate become tamable, through *Explicit* digital commands. *Campionissimo Bowl,* which is made out of CNC milled aluminium, was considered one of the most digital elements like *Innovo Vase*. From the conversations with Participant K, it looked like metal in a way it is considered "..a much more kind of..fixed material, Yeah, I'd say it's not going to move, you know what your mark is going to be time after time... This leads itself to this idea of using digital processes that are repeatable and explicit.. whereas glass and clay are more malleable" (K). Hence, the view on metal as a fixed/tamable material, in association with the digital processes of CNC milling, rather than exalting what Participant K defined as 'tacit human expression', exalts the repetitiveness and precision of 'explicit commands. Being *Campionissimo Bowl* strictly dependent on digital fabrication processes rather than material knowledge and hand-making, moved the *element* away from *constructs* associated more with craftsmanship. On the other spectrum related to the *construct* 'tacit human expression', Participant K positioned *Set of Free Blown Vases* by Keep & Stern (2014) within the UNFOLD project.

The particularity of this *element* (Figure 86) is that it sees two very different materials coming into play within the same artefact. On one side you have the unpredictability concerning the 3D printed clay parts of the bowls, with all their possible making variables, on the other side, you have the glass blowing making process, which involves a very high degree of unpredictability as well. Moreover, blending these two very different materials in one *element* exponentially raises the possibilities for new, unexpected outcomes to happen.

Figure 86.

Set of Free Blown Vases by Jonathan Keep & Charles Stern

Note. Adapted by the researcher from “Set of Free Blown Vases” by Keep, J., & Stern, C., 2014 [Glass and clay. Various dimensions]. Copyright retained by the Authors and © UNFOLD. Retrieved from: http://unfold.be/pages/the-transaction-project.html

Like in the *element Set of Free Blown Vases*, Jorgensen’s *Large Pin Bowl* (Figure 87) was considered by Participants C and J a good example of a digital craft representing the *constructs* of ‘analog’ and ‘non digital’. The bowl, being made of glass which, as seen above, is a complex material adding to the process many unpredictable variables, inevitably puts into play the practitioners’ material knowledge. Participants C and J focus on the *element* considering Jorgensen’s ability in mastering crafting techniques through his material knowledge. This is what mostly captures the Participants when thinking about the *element* in relation to the *constructs*, underlining how the digital related parts in the making process are marginal, if compared to the human knowledge needed to produce the bowls.

Figure 87.

Large Pin Bowl by Tavs Jorgensen

Note. Adapted from "Large Pin Bowl" by Jorgensen, T., 2012 [Glass, 16x57cm, Vessel Gallery, London, United Kingdom]. Copyright retained by © Tavs Jorgensen. Retrieved from: https://www.vesselgallery.com/object-details/844493/0/tavs-j%C3%B8rgensen-pin-bowl-in-grey

Together with *Set of Free Blown Vases* and *Large Pin Bowl*, Marshall's *Hand Thought Series (2018),* in Figure 88, was attributed the *construct* pole of 'tacit human expression' by Participant K.

While comparing it to Masterton's piece, Participant K explained how "the wood differently from metal it moves over time. it is something that is more organic requiring more interventions" (K).

While realising that both elements were made through CNC milling techniques, the researcher realised how Participant K choice in contrasting those two specific *elements* and focusing on their material composition, stressed how, afterall, there is a hierarchy of materials that are generally being considered more or less 'digital'.[27]

Figure 88.

Hand Thought Series by Justin Marshall

Note. From "Hand Thought Series" by Marshall, J., 2018 [Oak. From left to right: Small bowl, 210x45mm; Japanese platter, 230x120x40mm; Oval dish, 370x260x60mm]. Copyright retained by © 2018 Justin Marshall. Image courtesy of the Artist.

For Participant K, when a digital practitioner uses a combination of materials and techniques able to challenge the making process, the practitioner needs to rely more on 'tacit human expression', moving closer to traditional craftsmanship: "someone could think that the digital processes are transferable across materials but materials

[27] This point will be further explored in the discussion (Chapter 6, subsections 6.1.1 and 6.1.2)

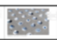
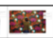
make a radical difference if you are using digital processes and some material choices become easier than others, depending on the digital choices you make" (K).

Participant D, reflecting on the making process rather than the materials used, stresses how, in *Hand Thought Series*, Marshall heavily relied on hand-drawings to create the traces that were then CNC milled on the bowls. For this very reason, when considering his *constructs* 'not coded 'and 'coded', Participant D positioned the *element* closest to the *construct* of 'non coded'. Marshall had not been writing lines of code to produce *Hand Thought Series,* rather, he relied on digital software. But even then, Marshall instead of drawing directly in the digital software used it to translate hand drawings into digital traces that could have then been milled on oak blocks through the CNC machine. In Participant D's opinion, the creativity used to work around the digital presence was considerably far from the *elements* that he considers as 'coded'.
Thus, differently from the perspectives of Participants K and D, Practitioners C and J did not consider Marshall's artefact as an *element* where manual intervention and hand-making abilities were explored enough to be considered 'analog' or 'non-digital'.
Differently from the element *Large Pin Bowl* by Jorgensen (2012), which they considered the *element* in the repertoire where material knowledge is best expressed, the participants considered *Hand Thought Series* by Marshall as being 'digital' due to CNC milling process which, in their opinion, requires almost no manual intervention by the practitioner which, as a result, cannot expose his material knowledge.

Despite the similarities and differences in the choices of Participants C, D, J and K discussed above, by calculating the median value of all the ratings assigned to the *elements* by the same participants, the researcher is able to assess which *elements* were, on one side, rated on average closely to the *construct* pole of 'analog', 'non coded', 'non digital', and 'tacit human expression' and, on the other side, which elements had been more related to *constructs* such as 'digital', 'coded', 'digital' and 'explicit commands'.

Figure 89.

Cluster 1– median values

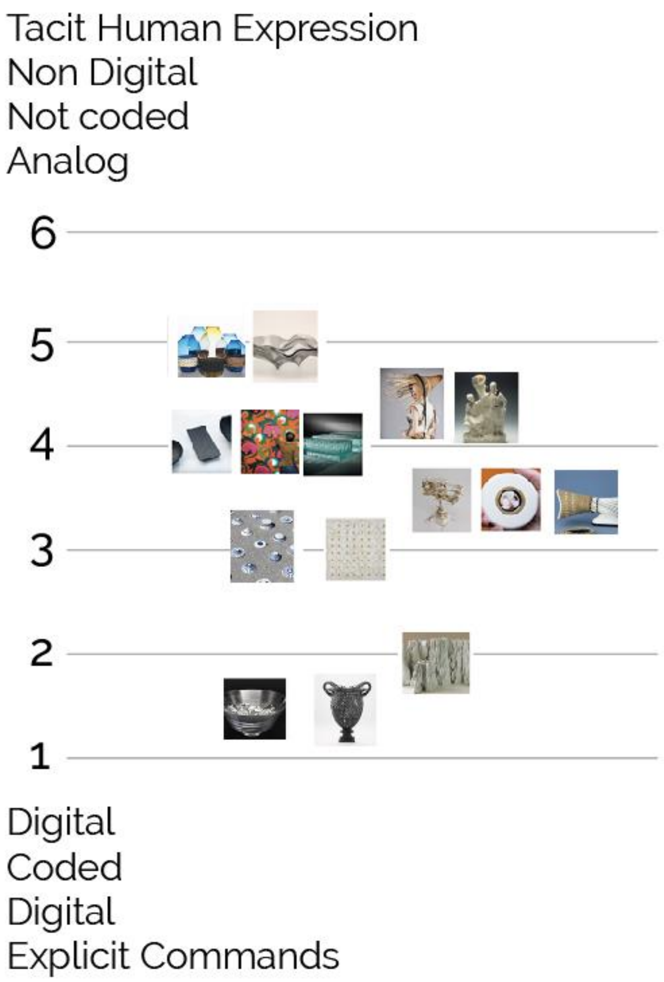
		Cluster 1															
Participant C	c)	Analog (6)	5	4	1	3	5	6	3	5	4	5	2	5	1	5	2
		Digital (1)															
Participant D	d)	Not Coded (6)	5	4	5	2	3	1	6	1	5	2	6	2	2	5	5
		Coded (1)															
Participant J	o)	Non Digital (6)	4	3	1	5	4	6	3	3	4	5	2	3	2	4	1
		Digital (1)															
Participant K	r)	Tacit Human Expression (6)	4	2	2	3	5	4	4	4	3	3	6	5	5	6	1
		Explicit Commands (1)															
		Median Value	4,5	3,5	1,5	3	4,5	5	3,5	3,5	4	3	4	4	2	5	1,5

In Figure 89 we can notice that *Innovo Vase* by Eden and *Campionissimo Bowl* by Masterton had been considered on average the *elements* most representative for the spectrum of *constructs* 'digital', 'coded', 'digital' and 'explicit commands'. Instead, for the other *construct* spectrum, together with *Large Pin Bowl* by Jorgensen, *Set of Free Blown Vases* by Keep & Stern had been considered the closer example to the representative *constructs* of 'analog', 'non coded', 'non digital' and 'tacit human expression'. What the median values show is also how Participants perceived the whole set of elements within the extremes of the *constructs* described.

As we can see in Figure 90, Participants C, D, J, K identified just a few examples as 'digital', 'coded' or made through mechanical processes requiring 'explicit commands', and those examples were clearly positioned towards the correspondent *constructs*.

Figure 90.

Mapping out of the elements based on their median values



At the same time, very few *elements* had been positioned towards the opposite *construct* extreme. Instead, the majority of the *elements* were on average assigned a position comprising the ratings 3 and 4, which is quite central in relation to the *constructs*.
Therefore, it is clear that, for the Participants interviewed, materials do not hold a hierarchy of importance when considered independently from the making process. Some materials are not considered closer to craft traditions than others if taken out from the making context: they are seen as different “ingredients” (C) that have all specific, different properties.

Thus, when combined with the specificities of a making process, they stopped being considered alike and they started acquiring different values. Through a balanced compromise between the material chosen and the technique carried out, whenever the technique allows some space to explore and create possible unexpected outcomes (see Cluster 2), the artefacts produced will lean towards the ‘analog’ side of things as ‘tacit human expression’ will be required in the process, at any time. When specific techniques or processes are chosen to be carried out to produce a specific outcome, and the materials chosen are not heavily challenging, the practitioners in the act of crafting will not need to recall their embodied, material knowledge. By doing so they give up, as a result, their analog and non-digital *Tacit Knowledge*. In the following, the researcher will describe and articulate a cluster of *constructs* to reflect and unpack this point further.

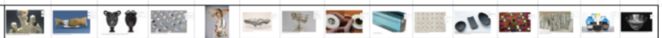
5.3.2 Cluster 2 – Control and fluidity in materials and making processes

As seen through Cluster 1, the participants interviewed seemed to agree that whenever the making process “is very controlled in its layers” (J), the craft practitioner is leading himself/herself towards a ‘closed’ execution in the making allowing, as a consequence, less potential for new, ‘serendipitous’ accidents to happen for the first time or to be repeated (i.e., repeating the same process again recognising the potential for a same variable to occur).

Therefore, when talking about the technical processes involved while using specific materials, Participants D, E, K and V differentiated between *elements* made through materials and processes that allow for more serendipity and *elements* made through materials and processes that instead have a closer, more predetermined end. As seen in the *Cluster* illustrated in Figure 100, Participant D articulated the *constructs* as ‘fluidity’ and ‘control’, Participant E as ‘chance, unpredictable, risk’ and ‘determined, prescribed, certainty’, Participant K as ‘open ended’ vs. ‘closed’ and Participant V as ‘serendipitous’ and ‘structural, predetermined’.

Figure 100.

Cluster 2



Cluster 2																	
Participant D	e)	Fluidity (6)	2	2	3	6	2	6	5	1	4	3	3	2	5	5	2
		Control (1)															
Participant E	l)	Chance, Unpredictable, Risk (6)	3	2	3	6	4	6	5	1	2	2	3	2	5	5	2
		Determined, Prescribed, Certainty (1)															
Participant K	q)	Open ended (6)	2	2	2	4	2	5	2	2	4	3	6	2	4	6	1
		Closed (1)															
Participant V	t)	Serendipetous (6)	2	3	3	6	4	3	5	2	3	1	4	1	4	4	2
		Strctural, Predetermined (1)															

On one side *constructs* such as ‘fluidity’, ‘chance, unpredictable, risk’ and ‘open ended’ refer to the condition where materials unexpectedly have more space “to be” (V) in the making process. In Participant’s opinions, this often happens when the

making process is tweaked to challenge the materials and explore something new; instead, the opposite *constructs* refer to those making processes and materials that do not allow unexpected variations from the initial planned design.
Participant K created the triad of *elements* reflecting on “where the hand is” (K) within their authors' making processes. Through discussing the *elements, Participant* K differentiated between processes that are more ‘open ended’ from those that are considered ‘closed’*.* As in Cluster 1, where Participant K chose as *elements* for the triad *Set of Free Blown Vases* by Keep & Stern (2014) and *Hand Though Series* by Marshall (2018) to represent the *construct* ‘tacit human expression’ and *Campionissimo* by Masterton to represent the *construct* ‘explicit commands’, in the new Grid with the new *constructs* the Participant chose the same *elements*. *Set of Free Blown Vases* by Keep & Stern (2014) and *Hand Though Series* by Marshall (2018) were chosen to represent the *construct* ‘open ended’, *Campionissimo* by Masterton instead was chosen to represent the *construct* ‘closed’.

Participant V as well created a distinction between those artefacts that, in her opinion, have a pre- ’determined’/ ‘prescribed’ structure and those that derive from processes and materials allowing for ‘serendipitous’ acts to happen. She describes the latter *construct* as an example where “the technology of the process and the material work together to create quite surprising results” (V). This is instead impossible to happen when a predetermined procedure to generate a predefined goal is set from the start.
To describe the differences between the two, Participant V takes Dripping *Bowls* by Studio Joachim-Morineau’s (2018) as an example for the *construct* ‘serendipitous’ . In *Dripping Clay* (Figure 101) paint, when combined with gravity, becomes completely unpredictable and there is no way to control it.

Figure 101.

Dripping Clay Bowls by Studio Joachim-Morineau

Note. Adapted from Dripping Clay by Studio Joachim-Morineau (2018). Ceramic. © Studio Joachim-Morineau, photo © Pierre Castignola. Retrieved from https://studiojoachimmorineau.com/projects/moca-2/graphics.html

Participant V reflected over the fact that the making process heavily contributed in rendering this *element* 'serendipitous'. The process depended on coding structures that allowed space for the material "to be" (V); *elements* that can be defined as being 'serendipitous' are those *elements* created through a making process where coded instances were designed from the start to allow and exalt variance of results, rather than prescribed outputs with no variation.

Similarly to Participant V, Participants D and E recognised *Dripping Clay* as the outcome of a process relying on 'fluidity' and 'chance' being based on 'unpredictable' opportunities which involve 'risk'. Participant E's reflections aligned with Participant V's views on the *element* being made of materials which, due to its physical properties, naturally "add more chance and unpredictability to the outcome" (E). Instead, Participant D's observations underline how, while it is true that the materials used to drip on molds (i.e., clay and paint) are unpredictable because of their physicalities, the code structures used for the making processes of those *elements* might also be considered as ‘serendipitous’: they allow unpredictable variances and elements of randomness that would otherwise be repeated with difficulties in other circumstances.

Therefore, Participant D, unlike the other Participants, started thinking about the *elements* through the idea of “code as material” (D) expanding from previous reflections solely based on the risk and uncertainty certain physical materials allow, more than others.

Participant D tried to unpack the *construct* of ‘fluidity’ chosen, reflecting on the relationship between two of the elements within his triad, namely: Wallace’s *ReFind* piece and *Dripping Clay* by Studio Joachim-Morineau. Participant D claimed:

> “Perhaps the design of the bowls [referring to Studio Joachim-Morineau’s *element*] came after the exploration of the combination of code and materials. With *ReFind* you're not dropping in the code with the material and see what happens. You are not dropping in the code to see where the code spreads out, because it just wouldn't work.. we are not talking about an algorithm here, but about a code that needs to calculate simple parameters in order to provide predetermined outputs. So ...the actual material of coding isn't quite the same here [referring to Wallace’s artefact] if compared with the fluidity and absence of control you can have over the dripping of the paint here [referring to Studio Joachim-Morineau’s *element*]. It would be different if we were to speak about algorithms, but this is not the case.. this is a quite simple code [referring to Wallace’s artefact]. It responds to predetermined choices you make, nothing as serendipitous in the making process as it could emerge from the dripping here [referring to Studio Joachim-Morineau’s *element*]” (D).

In these sentences, Participant D explains how in the *Dripping Clay* example, code is used to provide a making process which allows serendipitous acts to happen. The encounter of the code, the material ‘fluidity’ (paint, clay physical material properties) and the chosen making process, ultimately fuse resulting into the outcome where the central actor remains the physical material.

Instead, in Participant D’s opinion, the making process of an artefact as *ReFind*, similarly as *Living Wall* by Buechley, is defined by a collection of very controlled processes and materials for this reason, Participant D believes that both *elements* sit closer to the *construct* ‘control’.

In his opinion, aside from the actual making process, one could arguably say that the way in which potential users might interact with *ReFind* or *Living Wall* is serendipitous as it is not scripted and therefore unpredictable. Thus, Participant D firmly judges this a paradox:

> “When you create the conditions for something to happen, but you don't necessarily know what's going to happen, generally the concept is based on things in the environment. Sensors can detect that. It's based on very specific conditions that cause the code to do a particular thing. That's kind of unpredictable, but it's numerical, it's recognizable even to a micro level and it's’ ‘codable’, but this freedom, this serendipity happens because the variation happened within a particular constraint that you created as a maker. A paradox, isn’t it? Here [referring to Wallace’s, Buechley’s and Frankjaer elements] you need to create constraints in order for something serendipitous to happen, here instead [pointing at all the other elements] you need to work through a serendipitous approach in order to work against pre-existing constraints of the machine or the material” (D).

Working with what Participant D identifies as ‘fluidity’ is what can avoid predictable and pre-tailored repeatedness. But in order to do so: ”you must allow yourself to explore without thinking through code but through materials” (D), describing this as the higher challenge of crafting with electronics.

The researcher here recognised a tension as firstly code was being proposed *as* material (e.g.,”material of coding” (D)) and soon after was again distinguished *from* the material as separate entity by the same Participant. Trying to unpack this distinction, the researcher understood that Participant D made a fundamental distinction between the act of writing the code and the finalised code. While making the code the Participant recognises that even if the maker is trying to find the most functional way to write the code that will translate in what exactly he/she has in mind, serendipitous acts can happen while adjusting the code to reach the aimed result. Participant D makes an analogy of the act of throwing a bowl with the act of writing and compiling the code:

> “If we take a very hands-on process like working with clay or materials that you're constantly manipulating, where your hands are always on the material.. like throwing clay on a wheel, that’s the serendipity you could have in the process of creating the code. Write- compile, write-compile, equals code. The same with clay. Is it too thick? Put your hands like that [showing hand movement] and check if you are making it rounder. Is it too dry? You can make it more moisturous.. So essentially we've kind of made it.. there is a similarity here. Throwing a bowl is what I'm doing when coding at an early stage.” (D)

Participant D in this part of the conversation sees code as a material being shaped by the practitioners’ specific digital knowledge. When throwing a clay bowl, the practitioner engaging with the material is consciously tweaking his/her gestures and the material consistency, making sure that they are right to achieve a predetermined outcome. In the same way, the practitioner writing and compiling the code in its early stages is also adjusting the code to reach the aimed goal using his/her material knowledge. Thus, once the code is compiled successfully and it does what it was designed for, the code becomes the "the recipe and the result, all in one" (D). It is at this point that the Participant changes his perspective on code. Once the code is written down, "there is nothing serendipitous in the code itself" (D) and the code stops being a material becoming "a controlled set of parameters" (D).

Participant D at this point stresses out how, surely, some designers would want to believe there is space for serendipitous acts to happen when interacting with coded *elements* as potential users might interact with the result in unexpected ways, but he claims "there is no magic, no unexpected actions really, because you are constraining everything into numerical translation. The code is reliable, it is binary (...) with code you can control everything while giving the impression you are not" (D). Therefore, in order to use code and electronic components as materials, the maker knows from the start that in order to design a specific line of code freedom and possibilities must be shut down both within the making process and the outcome, limiting the openness of the coded variables and external inputs into a specific set of clear, binary, numerical instructions.

Therefore, while among Participants D, E, K and V only Participant D reflected on the *elements* explicitly from a code perspective, based on the *median value* of the ratings (below in Figure 102), *Dripping Clay* and *Large Pin Bowl* were considered by all Participants the elements where both materials and making processes successfully rely on chance and serendipity. Contrarily, the *element ReFind* had been considered on average as the most suitable example representing a digital craft where the *constructs* 'control/determined, prescribed, certainty/closed/structural, predetermined' are defining both the making process and materials used.

Figure 102.

Cluster 2 – median values

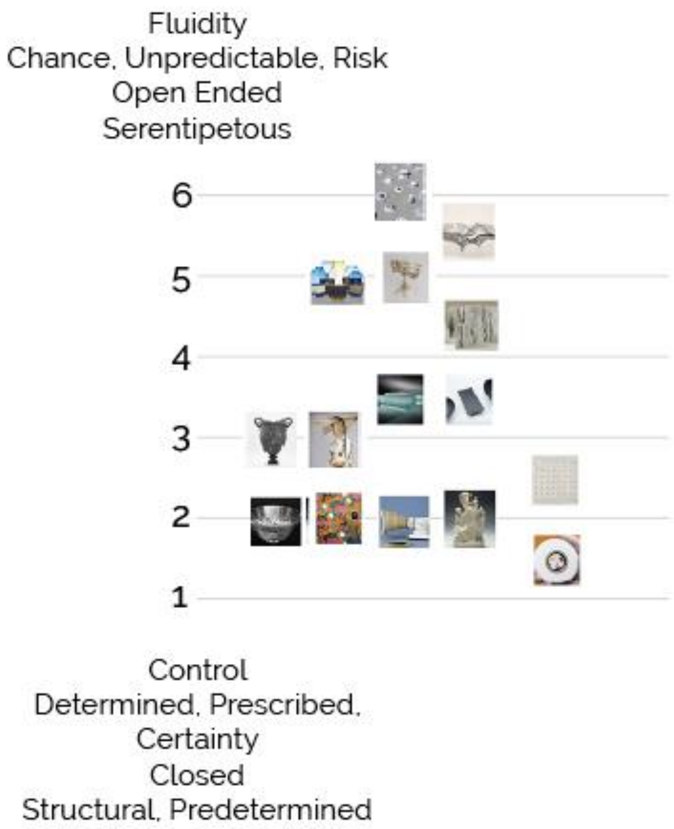
Cluster 2																	
Participant D	e)	Fluidity (6) / Control (1)	2	2	3	6	2	6	5	1	4	3	3	2	5	5	2
Participant E	l)	Chance, Unpredictable, Risk (6) / Determined, Prescribed, Certainty (1)	3	2	3	6	4	6	5	1	2	2	3	2	5	5	2
Participant K	q)	Open ended (6) / Closed (1)	2	2	2	4	2	5	2	2	4	3	6	2	4	6	1
Participant V	t)	Serendipetous (6) / Strctural, Predetermined (1)	2	3	3	6	4	3	5	2	3	1	4	1	4	4	2
		Median value	2	2	3	6	3	5,5	5	1,5	3,5	2,5	3,5	2	4,5	5	2

Moreover, based on the *median value* results shown in Figure 102, participants D, E, K and J identified many *elements* together with *ReFInd* as closer to materials and making processes being 'controlled, determined, prescribed, certain, close, structural and predetermined'. Instead, fewer elements reached the other *construct* pole and while sometimes this choice strictly depended on the way in which the making process was carried out or coded, other times it depended on the material physicality or a combination of both.

In Cluster 1, many examples were positioned in a neutral rating zone (i.e., between 3 and 4) when the *construct* poles 'digital/coded/digital/explicit commands' and analog/non coded/non digital/tacit human expression' applied, whereas now, as shown in the illustration below, many of those *elements* moved towards the 'control' (determined, prescribed, certainty, closed, structural, predetermined) end.

Figure 104.

Mapping out of the elements based on their median values



The researcher recognises that the Participants positions over the *elements* radically changed while talking through their perspectives on materials and making processes[28].

In the following, the researcher will continue to analyse the gathered data, trying to unpick other similarities or discrepancies between the Participants Grids and the participant's insightful observations.

[28] This point will be explored later in the discussion Chapter 6 (Section 6.1.1).

5.3.3 Cluster 3 – Experiential and Contemplative Values

To most participants in the study, certain artefacts proposed in the selection of the 15 *elements* belonged to a different, separate, grouping. Participants D, E, K and J made this evident in the ongoing conversation with the researcher and tried to unpack and articulate the reasons behind this view articulating new *constructs.*

In the figure below (x), an overview into the *constructs* articulated by the Participants is presented[29]. On one side of the spectrum, we find the *constructs* 'experiential value', 'objects to experience', 'volatile', 'artefacts as facilitators. On the other side of the spectrum, we find the *constructs* 'contemplative value', 'objects of contemplation', 'concrete' and 'artefact as self-expression'.

Figure 105.

Cluster 3

Cluster 3																	
Participant D	g)	Experiential Value (6)	5	1	2	3	6	3	-	6	2	1	2	4	2	3	-
		Contemplative Value (1)															
Participant E	h)	Objects to experience (6)	4	2	2	1	5	1	2	6	2	4	2	5	2	2	2
		Objects of contemplation (1)															
Participant K	s)	Volatile (6)	5	2	1	2	5	2	1	5	2	3	2	6	2	2	2
		Concrete (1)															
Participant J	m)	Artifact as facilitators (6)	1	2	2	5	5	2	1	6	1	2	3	5	2	4	1
		Artifact as self expression (1)															

Practitioner D, a technologist working with craft-based approaches and with an experienced background in digital materials (i.e., code), tried to explain from his perspective the nature of the differentiation among the *elements*. Reflecting through

[29]As noticeable from the overview, the *elements Shine* by Mann and *Campionissimo Bowl* by Masterton are assigned the symbol '-' as they were not rated by Participant D. Participant D during the mapping process found it difficult to assess these *elements* at a fixed value as he believed that both pieces comprised characteristics of both the *constructs* chosen. The repetition of the *elements* is noticeable in Grid 'g' by Participant D (Section 5.2).

the theme of code he explored the way in which code had been differently used in the *elements* presented. He says: “distinction works quite well when you are thinking about coding, because some [artefacts] are made with the intention of creating a particular experience for a user., which is a very product-thing. Whereas in others [artefacts] code is used with the intention of creating a piece of craft as a piece of art to contemplate” (D).

On one hand, he identifies artefacts where code is used to control and facilitate the digital fabrication processes. In his opinion, in those cases once the artefacts are produced, the uneducated user could potentially forget that digital literacy was needed to conceive or produce the artefact in the first place. On the other hand, there are artefacts where code is actively experienced by the user when interacting with them. In these *elements*, code becomes the essence of the artefact itself and physical materials (both craft materials and computational elements) facilitate the experience with code enabling the designed interaction. The artefacts, “are defined craft elements, but it feels like they’re from a speculative kind of world..even though they are identified as craft pieces, they are engineered craft pieces”(D).

Following his line of thought, Participant D defined a first group of artefacts as artefacts having what he articulates as ‘contemplative value’ while, the second group, as artefacts with an ‘experiential value’.

When describing the positioning of the elements in relation to the *constructs*, Participant D explained that while mapping each *element* out, he would ask himself whether the final outcome explicitly reflected the “presence of code” (D). In some cases, Participant D claimed he would immediately perceive the presence of code in some artefacts, while, at other times, he needed instead to take a closer and longer look to identify it.

Figure 106.

Embroidered Computer by Ebru Kurbak & Irene Posch

Note. Adapted by the researcher from "Embroidered Computer" by Kurbak, E., & Posch, I., 2018 [Glass beads, golden threads, copper coil, magnets etc.]. Copyright retained by the Authors, photo © Elodie Grethen. Retrieved from: http://www.ireneposch.net/the-embroidered-computer/

Participant D positioned towards the 'contemplative value' *construct* examples such as *Hybrid Craft* by Zoran or *Embroidered Computer* by Posch & Kurbak (in Figure 106) which, in his opinion, well express the practitioners' desire to hide the presence of code or to strategically blend it with craft techniques and materials. Rather than making the code visible, the practitioners Posch & Kurbak seem, in his opinion, preoccupied in "making the most of some of the problems with the engineering (...) making the most of the process" (D). In these *elements* Participant D believes that code is used with a 'contemplative' value.

Instead, towards the opposite *construct*, Participant D positioned elements where code is immediately perceivable and a very dominant presence. In these pieces, where code is explicitly expressed, the authors are "working very closely with people to evoke a particular experience" (D). In *Bamboo Whisper* by Frankjear and *ReFind* by Wallace, Participant D finds code present in obvious ways (through computational elements) and users do not just have a contemplative role, but they are fundamental as they are needed to wear or flick the artefacts in order to *experience* them and put in practice the purpose for which they were made in the first place (i.e., to provide certain experiences). The same happens in artefacts such as *A Day at the Hunt* by Murphy (Figure 107), where, despite there are no explicit computational elements, the QR code positioned on the piece explicitly evokes *code*, underlying a digital experience that the QR code gives access to. Practitioner D believes that those elements defined as *contemplative*, are less user-dependent and they do not need a user to get fulfilled and enact an experience they had been loaded with, from the start; “they are created to be, not to provide experiences” (D).

Participant D struggled to place *Shine* by Mann in the Grid as it appears several times in the mapping in different positions of the rating scale system (6,4 and 2). Participant D found it a difficult artefact to think of through the chosen *constructs* because, in his opinion, it embedded both ‘contemplative’ and ‘experiential’ qualities. One side Participant D found the *element* intrinsic to ‘contemplative’ value as it was not created to provide an experience through the help of technology as other *elements*. Thus, differently from other ‘contemplative’ valued pieces, *Shine* resembling a traditional candelabra with unconventional spikes, had aesthetic qualities that could potentially suggest the use of digital technologies in its making.

Figure 107.

A day at the Hunt by Ingrid Murphey

Note. Adapted by the researcher from “A day at the Hunt” by Murphy, I., 2016 [Porcelain. Hunt Museum, Limerick, Scotland]. Copyright retained by © Ingrid Murphy. Retrieved from: https://www.inGridmurphy.com/fullscreen-page/comp-ixrh9rc3/8769c30d-8a6d-4bc5-b302-43afe02bc72a/3/%3Fi%3D3%26p%3Dc1tfw%26s%3Dstyle-jebflc5k

In Participant D’s opinion in *Shine* code is as present and obvious as it is in artefacts where computational *elements* are embedded. The spikes capture the viewer as the QR code on the piece *A day at the Hunt* by Murphy, engaging the viewer in a deeper reading of the artefact enabling an experience going beyond the value of contemplation.

Similarly, from Participant D, other participants differentiated the repertoire of *elements* based on *constructs* similar to the ones expressed by Participant D. As an example, Participant E, mapped the elements over the chosen *constructs* of ‘object to experience’ and ‘object to contemplate’.

As seen in Figure 108, he positioned elements such as *Refind* by Wallace, *Bamboo Whisper* by Frankjaer and *Living Wall* by Buechely are closest to the concept of ‘objects to experience’. Practitioner E claimed: “they're not just objects of contemplation. They're not objects that you would sit on a coffee table, but they involve interaction, they involve an experience, the user gains an experience through designed interactions” (E).

In between the two polar *constructs*, the Participant positioned *Embroidered Computer* by Posch & Kurbak and *A Day at the Hunt* by Murphey. Specifically in Murphey’s artefact, he argued that with the QR code, “the physicality of the object is sort of liberated by enabling it to have a virtual experience of virtual accompaniment. So, through the use of the QR code and the link to a video, the practitioner is giving the viewer an additional experience which can help to inform, which can help to add meaning to the piece explaining the rationale behind it”(E).

On the other side of the spectrum, closer to the *construct* pole of ‘objects of contemplation’, the participant placed the vast majority of the other elements stating that if he could have positioned all the elements together on the extreme pole (6) without differentiating with the *elements* composing the triad, he would have.

Similarly, Participant K reinforces this point of view saying that: “any increased communication or expression that comes out of electronics, it has more to do with the concept than.. artistic expression” (K). Moreover, Participant K differentiates between elements that are relatable to the *construct volatile* and others that are more relatable to the *construct concrete*. Thinking about an experience as something that is rapidly consumed, that is invisible and abstract, Participant K chose as *constructs* the terms *volatile* and *concrete*. As shown in *Grid s* (Figure 75, Subsection 5.2.5), closer to the pole ‘volatile’ we find artefacts such as *Living Wall* by Buechley, *ReFind* by Wallace, *Bamboo Whisper* by Frankjaer and *A day at the Hunt* by Murphy.

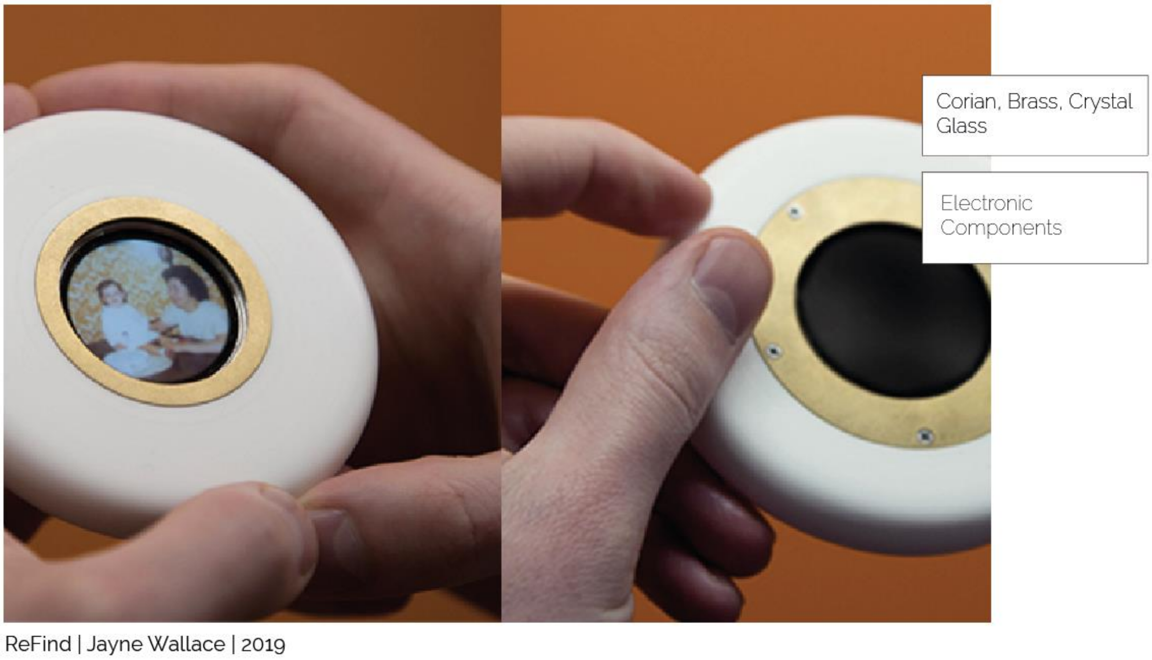
Moreover, Participant J analysed the repertoire of *elements* through the *constructs* of ‘artefact as facilitator’ and ‘artefact as self-expression’.
In his opinion, certain artefacts had in common that if they were to be made differently, with different materials and different making processes, they would remain unaltered in their concepts. In his perspective the richness of these specific artefacts relied on the experience they would facilitate instead of relying on their material nature and composition.
Articulating the ‘artefact as facilitator’ *construct* pole and its related chosen *elements*, Participant J claimed: “The production method in these examples is not really critical to the concept. That’s not to say it is a bad thing, they are lovely pieces. I just think that in terms of the general concept, the material and process for the actual production of the pieces are kind of subservient to the core idea behind them” (J).

Specifically talking about *ReFind* by Wallace (Figure 108), *element* chosen in the triad as representative of the *construct* of ‘artefact as facilitator’, Participant J says:

> “If you were.. let’s say.. to take out the concept of remembering a beloved and feeling connected again with someone that you have lost [referring to Wallace’s artefact] this whole piece would melt away. The piece is a facilitator of an experience, it is beautifully executed, don't take me wrong... and it may help that it is lovely, it's obviously tactile and you want to flick it, but essentially, it is about a specific abstract concept and a specific user” (J).

Figure 108.

ReFind by Jayne Wallace



Note. Adapted from "Refind" by Wallace, J., 2019 [Corian, brass and electronic components]. Retrieved from "ReFind: design, lived experience and ongoingness in bereavement" by Wallace, J., Montague, K., Duncan, T., Carvalho, L. P., Koulidou, N., Mahoney, J., ... & Fisher, H., 2020, *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, p.1 (https://doi.org/10.1145/3313831.3376531). Copyright retained by © 2019 Jayne Wallace.

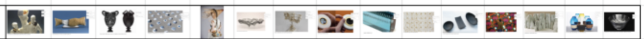
Differently, in the *elements* closer to the *construct* 'artefact as self-expression', their whole concept lies within the authors' specific making process choices where "the material [is] a central actor all along" (J). In these *elements*, if you were to change the material or making processes used, the whole concept behind the piece would instantly change.

Previously, Participants E and D positioned the *element A Day at the Hunt* by Murphey closer to the other two *elements* just mentioned, mainly because of the QR code present in Murphey's piece. Instead, Participant J, focused on the pieces' traditional techniques and skills used and found the concept of the piece heavily relying on the author's personal experience of a day with her father at the Hunt Museum, rather than being an experiential concept built for other users. While a day at the Hunt Museum was video recorded and made accessible to viewers through the QR code, in his opinion, "the experience is already consumed by the author of the piece and her dad and this makes us viewers, not users" (J). In Participant J rating choices, this positions the piece on the opposite *construct* of 'artefact as self-expression'.

In Figure 109, the researcher clustered the Grid's results from Participants D, E, K and J KRG's processes and calculated through the *median value* the average rating assigned to each *element* by the Participants.

Figure 109.

Cluster 3 – median values



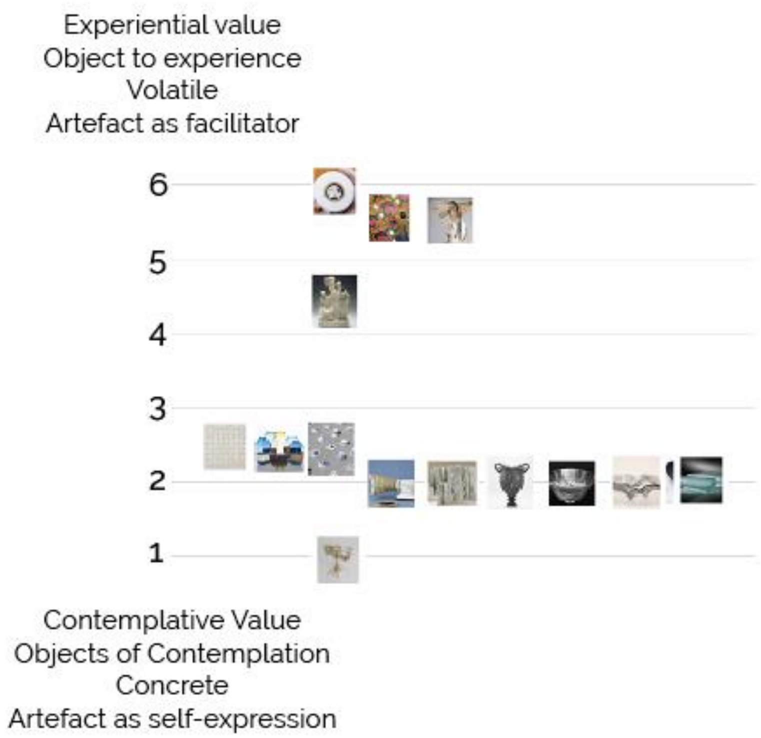
Cluster 3																	
Participant D	g)	Experiential Value (6)	5	1	2	3	6	3	-	6	2	1	2	4	2	3	-
		Contemplative Value (1)															
Participant E	h)	Objecs to experience (6)	4	2	2	1	5	1	2	6	2	4	2	5	2	2	2
		Objects of contemplation (1)															
Participant K	s)	Volatile (6)	5	2	1	2	5	2	1	5	2	3	2	6	2	2	2
		Concrete (1)															
Participant J	m)	Artifact as facilitators (6)	1	2	2	5	5	2	1	6	1	2	3	5	2	4	1
		Artifact as self expression (1)															
		Median value	4,5	2	2	2,5	5	2	1	6	2	2,5	2	5	2	2,5	2

Elements such as *ReFind, Bamboo Whisper* and *Living Wall* were closely related to the *constructs* 'experiential value, objects to experience, volatile, artefact as facilitators. Often grouped with these three *elements,* A *Day at the Hunt* by Murphy it is found, thus, while in the first three *elements* the Participants' rating choice was nearly unanimous, in Murphy's piece Participant J positioned the *element* in a distinctive opposite way than the other Participants which, as a result, moved down the *element*'s *median value*.

As seen in the illustration below derived from the *median value* calculated, the repertoire of *elements* seems divided into two main groupings with no *elements* assigned to more neutral rating numbers (i.e., 3 and 4). This means that the Participants clearly distinguished certain *elements* from others, assigning them ratings very close to the *construct* poles rather than choosing in-between positionings.

Figure 110.

Mapping out of the elements based on their median values



If on the one hand we can clearly see the mentioned grouping led by the *element* ReFind by Wallace (6), on the other hand we can see that almost all the other *elements* are sitting on the rating scale numbers 2 and 2.5 except *Shine* by Mann (1). were considered closely related to the opposite *constructs* ‘contemplative value, objects of contemplation, concrete, artefact as self-expression’. Moreover, over 60 rating positions (15 *elements* rated 4 times by each Participant), excluding the times stronger polar rating numbers were assigned (i.e., 6 ,1and 5, 2), only 9 single *elements* were rated in a more neutral area of the scale system (i.e., 4, 3). This heavily underlines that for the Participants was quite infrequent to assign middle values in the scale. In other words, while there were some uncertainties in the Participants rating choices such as for the *elements Shine* by Mann or *Campionissimo Bowl* by Masterton, for all the other *elements* the Participants had a clear view on where the *elements* belonged between the *constructs*.

Moreover, while in this Cluster the researcher focuses on Participants D,E,K and J – as they were the only ones that built a Grid based on *constructs* with similar meanings– every participant in the study referred to certain artefacts proposed in the selection of the repertoire, as “*elements* belonging to a different, separate, grouping” (K), judging them as the only *elements* holding an “experiential layer”(V). In the figure below the researcher brought together in an illustration all the frameworks obtained from the gathered data and highlighted through red rectangles the *elements*: *ReFind* by Wallace (2019), *Bamboo Whisper* by Frankjaer (2011), *Living Wall* by Buechley (2010) and *A Day at the Hunt* by Murphy (20).
It is immediately noticeable how the *elements* have been repeatedly clustered together by each participant, independently from the *constructs* articulated or their assigned positioning within the rating scale system.

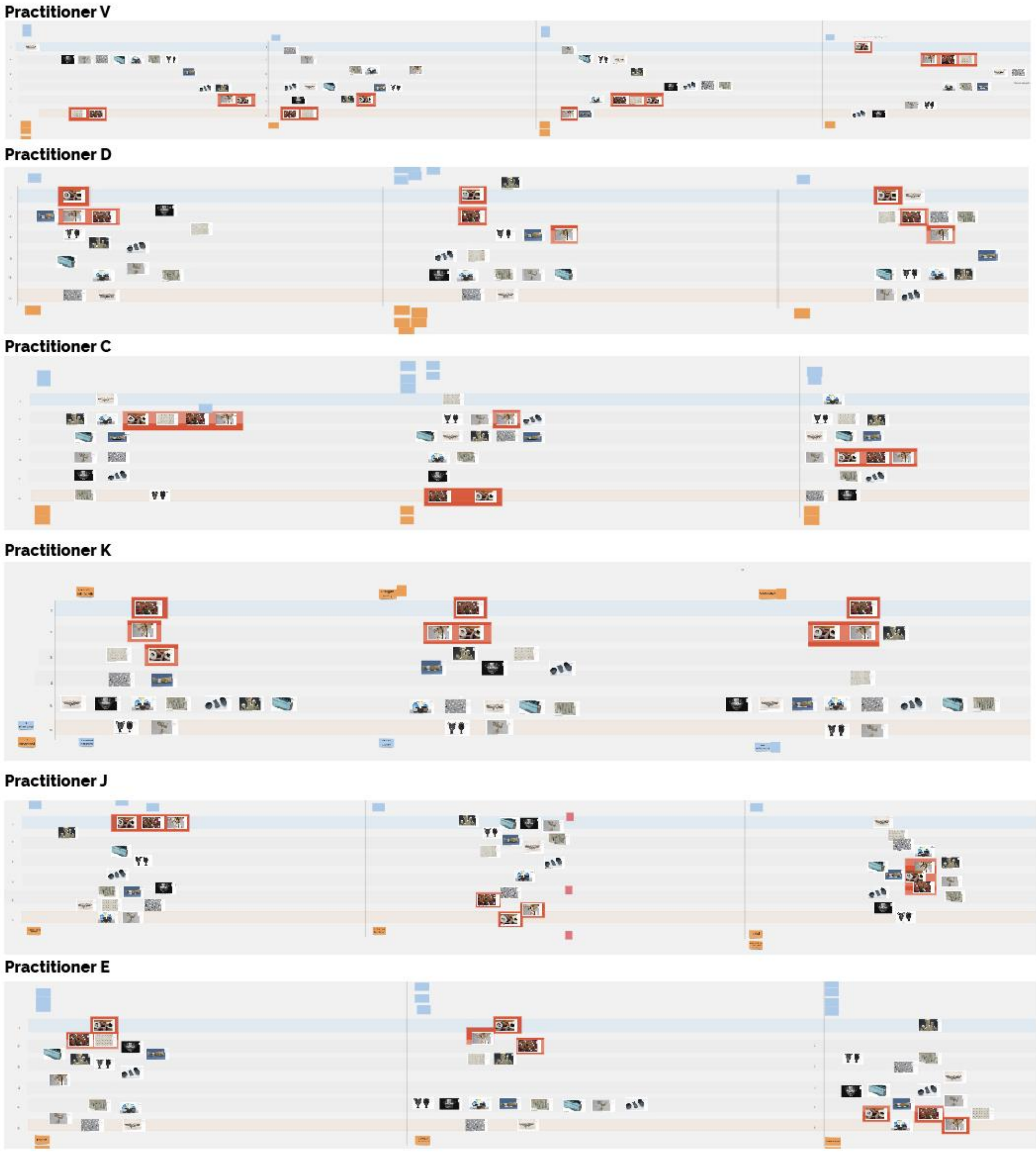
The researcher recognises that, differently from all other artefacts in the repertoire, the selected *elements* embed computational elements in the final outcomes[30]. Moreover, the researcher also recognises how, through the participants' reflections on materials articulated through Clusters 1, embedded electronics were initially never discussed as determinant differentiators from the rest of the materials used: this point will be further addresses in the discussion (Chapter 6 subsections 6.1.1 and 6.1.2).

In the following, the researcher will continue to analyse the gathered data, trying to unpick other insightful observations.

[30] these *elements* are presented extensively in the Critical Contextual Review (Chapter 3, Section 3.1)

Figure 111.

Highlighting the elements considered as separate grouping



Note. All iterations of Kelly's Repertory Grid run with Practitioners V ,D C,K,J, E (top to bottom). The author highlighted in red the elements that were considered as a separate category.

5.3.4 Cluster 4 – Culturally Digital

When talking about digital craft pieces, the words ‘traditional’ and ‘modern’ often came up in the Participants’ reflections.

As seen in the illustration below, Participant C decided to articulate the‘controversial’ with, as a polar opposite, the *construct* ‘traditional’ that he then re-articulated as ‘modern looking’ and ‘reflecting the past*’.*

Figure 112.

Cluster 4

Cluster 4																	
Practitioner V	**v)**	Initial stage of the tradition of the digital (6)	-	4	5	3	2	3	5	1	-	2	6	2	4	4	6
		Last stage of the tradition of the digital (1)															
Practitioner C	**a)**	Traditional, Reflecting the past (6)	4	4	5	4	5	3	5	1	4	6	5	1	3	3	2
		Controversial, Modern looking (1)															

Participant C chose Wallace’s (2019) and Buechley’s (2010) artefacts as the ‘most controversial’ and ‘modern looking’ among the 15 *elements*. The practitioner pointed out how embedded computational elements as screens or LED lights “scream modern!”(C). Continuing his mapping, Participant C chose, as an opposite *element* to *ReFind* and *Living Wall*, the *Embroidered Computer* by Posch & Kurbak (in Figure 103). The practitioner claimed:

> *“..looking at it I honestly couldn't have told it was electronical [i.e.,digital], it could have been made, you know, like 500 years ago as we were using beads and glass and things like that…like the Queen could have worn something made out of this. I would say that the digitality of it doesn't necessarily translate to it. it doesn't look like it's made out of like, circuits and things like that. It's very sort of clever. And this is something that I quite admire”* (C).

He then expands his argument commenting on other pieces such as Marshall's Hand Thought Bowls*:* "Also this one, I was surprised when I saw that it was machine made. Honestly it seemed like a set of... Japanese sort of handmade bowls.. with all the engravings and that.. but no, he [Marshall] used a CNC for that. I wouldn't have guessed" (C) *.*

Participant C stressed how those *elements* where it is more difficult to guess whether they are made with digital processes/materials/machines are those *elements* that have what he considers a 'traditional' appearance. Even pieces such as *Innovo Vase* by Eden, which"it's made out of plastic basically" and, therefore, for Participant C it should be more related to contemporary days and how we now use plastic instead of being perceived by the participant as 'controversial' or 'modern looking' "it's symmetry, the design chosen, it has this very strong traditional vibe"(C).

This reflection on the traits he recognised as most traditional culminates with an observation on Murphy's artefact: *"* this piece is very tricky...It is culturally digital to my eyes, because we know it has digital properties to the QR code.. but if I show it to my grandma'.. she would see weird black 2-dimensional dots on a traditional sculpture, nothing more" (C).

Therefore, while acknowledging that some *elements* tend to sometimes refer to traditional aesthetic values specific to a culture (e.g., *Hand Thought Series a*esthetically referring to Japanese platters, *Innovo Vase* referring to an ancient Roman vase) the Participant C stresses how this is "probably dependent on my idea of tradition now as a young, white, male, european. Something that looks traditional to my eyes might not look traditional to someone coming from the other side of the world or with a different age" (C).

Figure 113.

Embroidered Computer by Ebru Kurbak & Irene Posch

Note. Adapted by the researcher from “Embroidered Computer” by Kurbak, E., & Posch, I., 2018 [Glass beads, golden threads, copper coil, magnets etc.]. Copyright retained by the Authors, photo © Elodie Grethen. Retrieved from: http://www.ireneposch.net/the-embroidered-computer/

Similarly, to Participant C, Participant V pointed out how, from her perspective, the difference between the *elements’* material choices and technical processes is severely influenced by the period during which the artefacts were made. Participant V defined the clusters ‘initial stage of the tradition of the digital’ and as a polar *construct* ‘last stage of the tradition of the digital’. She then defined three questions referring to different research moments of digital craftsmanship (see Grid t, Section 7.2). Moving clockwise from the ‘initial stage of the tradition of the digital’ she adds the question“how can we push the [making] processes beyond?”, around the neutral scale numbers she articulated the question “how can we push the digital beyond?” and finally, closer to the *construct* ‘last stage of the tradition of the digital’ she articulates the question “how can we push materiality beyond?”.

Participant V started making distinctions between different ways in which digital craft asks questions throughout the work produced she says:

> "If I think about the tradition of the digital, then I think these ones down here [ReImage and Living Wall] are quite at the beginning of a new tradition. What we recognise as traditional in the digital is more like these ones [referring to Marshall's, Masterton's, Mann's, Eden's and Keep's artefacts]. I mean, if you were looking at it just from a… I suppose.. an historical perspective, these would be at an earlier point... I think that the kinds of questions that people were asking then, have changed. And I think these artefacts answer different questions and, you know, I mean, this is not just about chronology.. It's more about what question is that the object is asking. And then I would see this one here, you know, as explorations of the question 'how can we push processes and materials?' and these instead [referring to Wallace's and Beuchley's pieces again] would be asking something different, something directed to the user as it is meant to be for and designed for the user" (V).

Participant V challenged the idea of one coherent vision of digital crafts by stressing out how different *elements* are asking different questions throughout the produced work which, in her opinion, relates back to different stages in the evolution of the digital craft practice.

While in their discussions, Participants C and V both address the implication of cultural influences in the perception of *digital crafts*, underlining different point of views, Participant C underlines this aspect through a reflection focused on the aesthetical characteristics of digital crafts and on how they might or might not remind possible viewers about tradition– in relation to their specific cultural background. The researcher recognises that in a similar way their perspective stresses out how, in the *Repertoire,* different *elements* express their practitioners' different motivations and goals while making.

Participant J as well differentiates the artefacts into two main categories, based on what he believed were the practitioners' motivations while crafting. On the one hand, he claims that practitioners producing 'artefacts as self-expression' craft just for themselves, in order to challenge their material knowledge or process competence. On the other hand, in his opinion, practitioners that craft 'artefacts as facilitators' have in mind a selected user. This, in his opinion, makes them designers rather than craft practitioners. The researcher recognizes that more than one participant found motivations and goals fundamental to relate their making process to the one of craftsmanship. This point will be further discussed in Chapter 6 (Section 6.1.2).

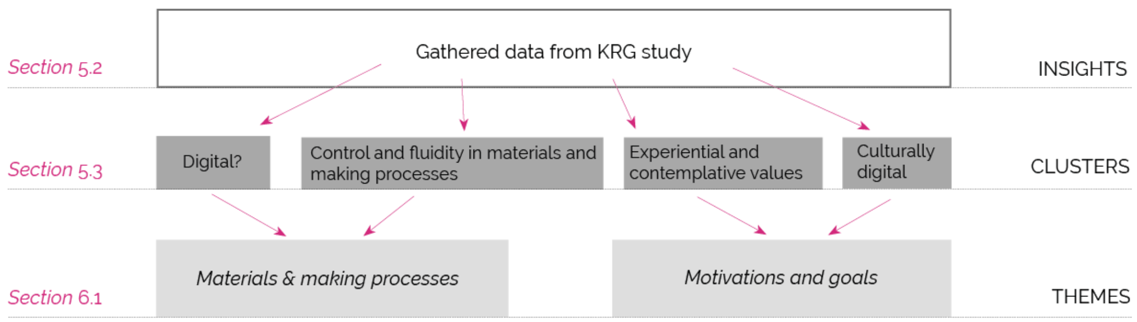
5.4 Concluding remarks on data analysis

From the data organised and described through the Clusters, the researcher identified two main themes that were of importance to the participants' reflective focus. As illustrated in Figure 114, *Clusters* 1 & 3 related discussion mostly focussed on participants' positions over the *elements* which radically changed while talking through their perspectives related to **materials and making processes**. Through the insights articulated in *Clusters* 3 & 4, participants seemed instead more focused on the intrinsic participant's **motivations and goals** when producing an element.

To organise a discussion over the *Clusters*, the researcher decided to address these as two separate themes. In the following Chapter, the author will discuss the gathered data.

Figure 114.

Themes deriving from the Clusters



To organise a discussion over the *Clusters*, the researcher decided to address these as two separate themes. In the following Chapter, the author will discuss the gathered data.

CHAPTER 6. Discussion and main findings

In this Chapter the researcher will discuss the data analysed in Chapter 5 (Section 5.3) providing theoretical background to the insights obtained from the KRG study. To structure the discussion, the researcher will situate the practitioners' reflections with the wider theoretical debates explored and articulated in the Critical Contextual Review (Chapter 3) and with the insights obtained from the researcher's *auto-ethnographic* and *ethnographic* experiences (Chapter 4).

In the first part of the Chapter (Section 6.1), the researcher organises the discussion through the identification of two main *themes* that were extensively discussed by participants and that, through the Clusters, became evident through their analysis. The researcher considered the themes significant as starting points to advance theoretical reflections. Through theorizing and discussing over the themes and, therefore, over the insights previously exposed in the Clusters, the researcher articulates three emerging *principles* defining the community of digital craft practitioners. The emergent *principles* are summarised in Section 6.2.

Lastly, the researcher discusses other remarks she believes are characterising the studied community (Section 6.3) providing further food for thought.

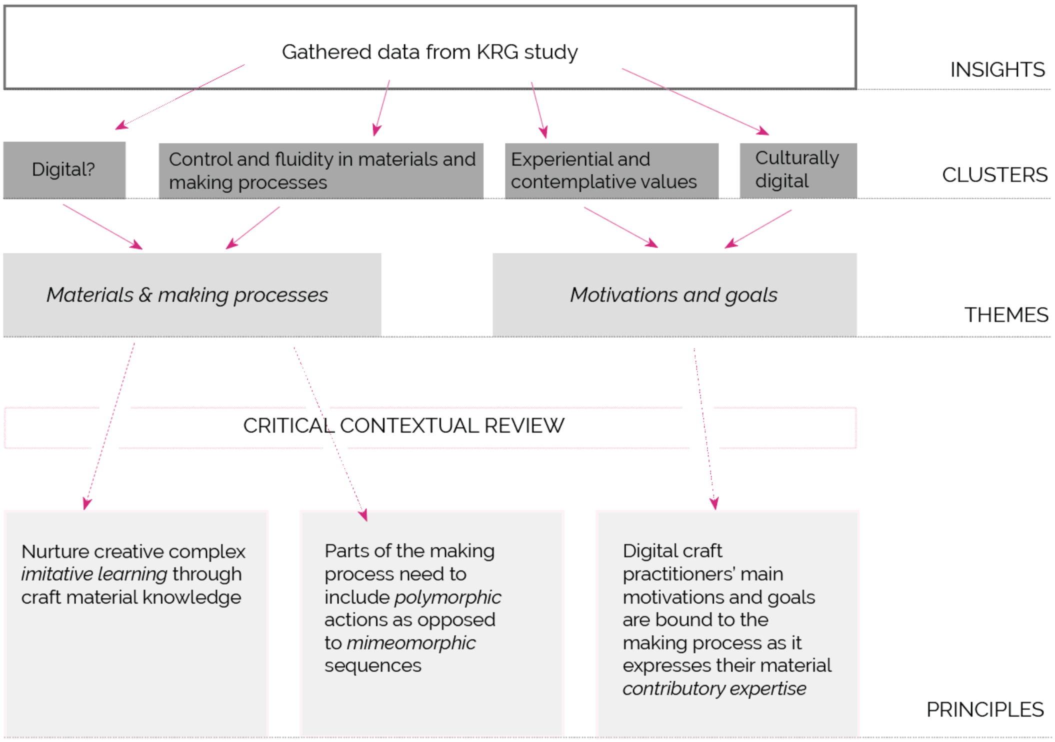
6.1 Emerging themes

Having organised and analysed the participant's insights through four *Clusters* based on the akin meaning of the *constructs* articulated by the participants, the researcher was able to better organise the analysis of the gathered data. Insights can be drawn out through a general inductive approach that allows research findings to emerge from the frequent, dominant, or significant *themes* inherent in the data

(Thomas, 2006; Turner 2010). As illustrated in Figure 115, through the analysis the researcher identified two main *themes* of interest that had extensively been discussed within the *Clusters*, and that the researcher articulated as: *Materials and making processes* and *Motivations and goals.* Through this frame, the researcher was able to anchor the themes to theoretical debates that helped in the identification and articulation of the participants' *principles*.

Figure 115.

From insights, to clusters, to themes, to principles



6.1.1 Materials and making processes

Due to the variety of digital tools and new techniques used to engage with craft materials, a new spectrum of technical processes have arisen (e.g., 3D printed clay, CNC milled wood etc.), shifting the focus from materials to making processes. As described in the Critical Contextual Review (Chapter 3, Section 3.1), outside of the design research field, numerous scholars (e.g., McCullough, 1998; Sennett, 2008, Pallasmaa, 2009), whether practitioners or not, have pointed out the theoretical controversies arising from the new frontier between hand-making and digital tools / techniques. The focus of these controversies often emphasises the differences rather than similarities between the two. Within the wider craft sector, a smaller part of the community has increasingly shifted their skills towards the mastery of the digital interface. In general, digital making has a reputation as being analogous to the ethos and practices of industrial design rather than to those of craft, suggesting a comparison between digital craftsmanship and industrial / automatized processes – working with almost no direct human involvement in the making (Pye, 1968; Latour, 2008; Pallasmaa, 2009).

Craft practitioners moving towards digital making, in the design / craft research field and beyond (i.e., HCI community), have been addressing the importance of acquiring craft material sensibilities and have been promoting hand-making processes in digital practices (Wallace & Press, 2004; Niedderer & Townsend, 2014). On the other hand, digital communities have been advocating for a *material turn* (Robles & Wiberg, 2010) and started engaging with craft approaches. They have been promoting craft values within the community (Bardzell et al., 2012) drawing analogies between: digital making & traditional craftsmanship, digital & craft materials and digital & hand-making processes (Bdeir, 2009; Buechley & Perner-Wilson, 2012; Lindell, 2013).

While materials have always been fundamental in craft practices, participants involved in the KRG study had a shared understanding that the viewers' judgement should not be solely bound to either the nature of the materials (digital or physical) or to the making processes used while crafting. Rather, scholars should be focusing on both the techniques adopted and the materials used. The digital craft practitioners engaged in the study revealed that it is not relevant if the material knowledge used in the making processes includes digital materials or craft materials. This is because practitioners tend to work with different digital or physical materials over the course of their careers, tending to blend multiple materials within the production of one piece. Instead, what was heavily emphasised by the participants was how important it is that the final artefact should show that the practitioners' material choice was made with the conscious intention of being challenged by the crafting process. Practitioner C made a very clear statement about this point:

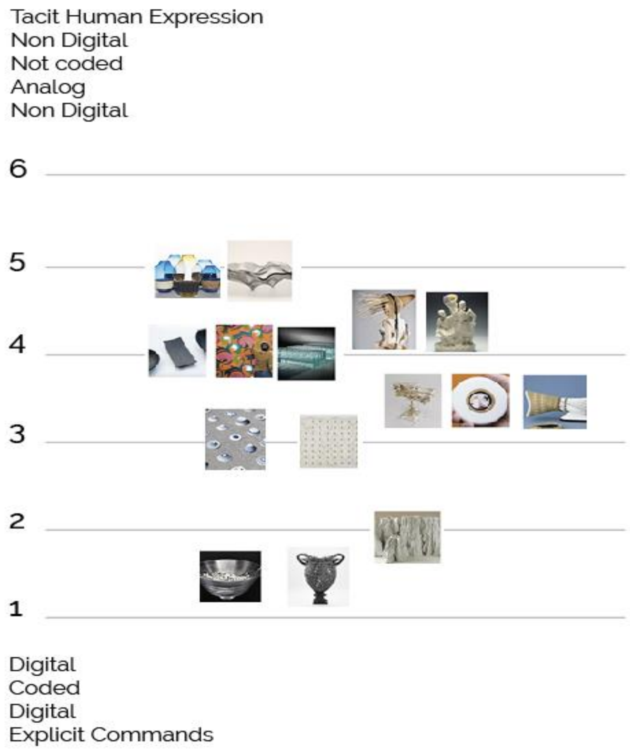
> " It's 2020 we are digital, everything is digital, so nothing is digital [laughs] let's focus on the core here, which is all about materials and skills, really. Everyone might have a 3D printer at home, few tweak it and make new, complex, statement pieces with it. A small percentage surely. And if you look closer, in that small percentage there is even a smaller one which is using craft materials demonstrating a deep understanding of both materials and technologies. Then.. aren't those few makers as crafty as any traditional maker?" (C)

Drawing on a study of the materials used in interaction design, Wiberg (2013) argues that while material studies generally try to deconstruct material structures in order to analyse their aspects separately, the ability to focus on the '*wholeness'* of an artefact has a central importance – both in order to make sense of and analyse any artefact (Wiberg, 2013, para.4). Wiberg's concept of *wholeness* encapsulates, in a single word, the participants' widely shared propensity to shift their analytical perspective on the digital crafts presented in the study. Their perspective shifted from the artefact's materials treated in isolation (i.e., the individual materials an artefact is made of), to the analysis of their specific combination as parts of a *whole,* together with the making process.

When talking about the artefacts in the study (data analysis Section 5.3), digital craft practitioners would place digital and craft materials at the same level of importance in terms of their material properties. At the outset of the conversation with the researcher, the participants mostly judged the example artefacts as displaying a balance between a combination of 'digital' and 'analog' aspects. Figure 116 illustrates the median values calculated through the data analysis of Cluster 1.; here the participants were only considering the material composition of the artefacts presented.

Figure 116.

Cluster 1 – median values



As discussed in Cluster 1 (Chapter 5, subsection 5.3.1), most artefacts had been initially placed between the rating numbers 3 and 4, sitting midway between the chosen *constructs*. Thus Figure 116 shows only few *elements* were considered closer to the 'digital' side of the spectrum by the participants. Specifically, participants chose to place the artefacts which they considered to be "impossible to do by hand" (C) towards the pole labelled 'digital', 'coded', 'digital explicit commands'. Those artefacts were considered closer to the 'digital' *construct* rather than 'analog' because they were perceived as predominantly made by digital machines and with little to no engagement of the practitioners' material knowledge within the making processes (subsection 5.3.1). The researcher acknowledges that there is a greater complexity to this debate. Therefore, further articulation on this point will be developed as the subsection expands.

Participants proposed that the possibility to tap into one's material knowledge strictly depends on the making techniques which the practitioners decide to adopt in relation to specific materials. They seemed to agree that certain material choices, if considered in relation to the same making process, would allow practitioners to engage with their material knowledge in different ways.

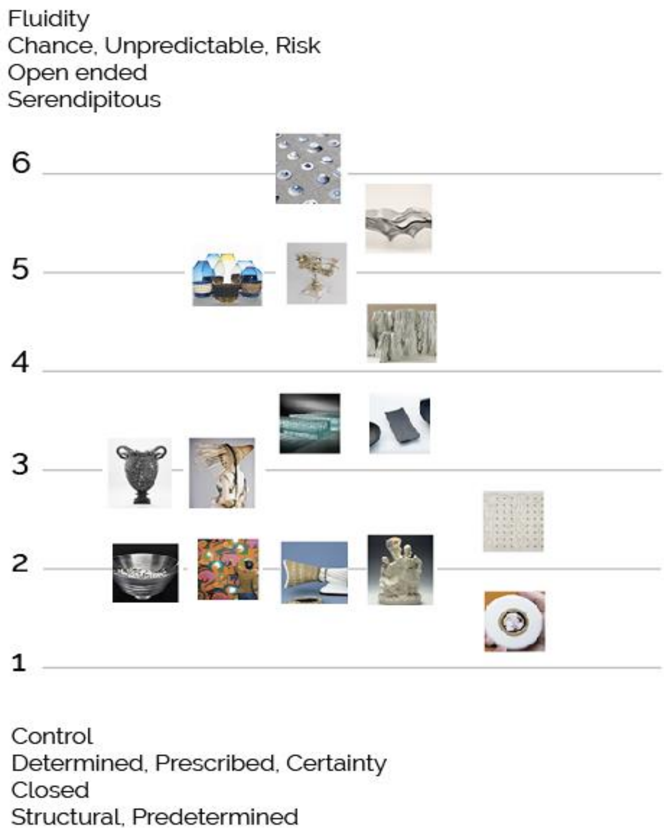
In those artefacts considered to be more 'digital' participants believed that the practitioners' ability to express their digital craft expertise was limited – relative to artefacts considered to be towards the 'analog' pole. This viewpoint stemmed from their beliefs towards the nature of the materials chosen when considered together with the techniques adopted by the craftsperson. The researcher stresses that, while there is certainly a lot of skill embodied in the works mapped in Figure 116, this perception towards digital crafting has been given by practitioners who themselves work within that same field.

Traditionally, the act of making has always been identified as a process in which the craft practitioner reflects aspects of their technical abilities and aesthetic judgement through material choices and their manipulations (i.e., making processes). Therefore, to be able to produce an expected form or to determine the functional qualities of a handmade artefact, materials need to be chosen together with the tools and techniques needed to tackle the specific material. These qualities have been always considered a fundamental and central part of the practitioner's ability to design a problem rather than a marginal decision to be underestimated (Sennett, 2008). Therefore, when artefacts were taken into consideration in their *wholeness* (i.e., the materials would be analysed together with the making processes), the participant's judgements on the *elements* mapping in the KRG radically changed and they started revealing more definite hierarchical judgements over the artefacts. The discussion on the concept of *wholeness* is partially articulated here and will be extended more later in subsection 6.1.2. Figure 117 shows the calculation of the median values deriving from Cluster 2 (Chapter 5, subsection 5.3.2) from data gathered when participants considered the material alongside the making process. When comparing Figure 116 with Figure 117, it is noticeable how in Figure 117 the spread of artefact placement is more polarised; practitioners that had previously been placing some *elements* centrally (i.e., ratings 3&4), have now placed them toward the extremes (i.e., ratings 1,2 & 5,6).

In the mapping process some artefacts were argued to be closer to a 'determined' and 'prescribed' making process, due to both the materials and the making processes chosen. Certain combinations (e.g., CNC milling with metal) were judged as more *controlled* than others and were therefore considered further away from traditional craft. Whilst, on the opposite *construct* pole, the artefacts were argued to be made under conditions that would allow for more 'serendipitous' and 'unpredictable' acts. This is in spite of them having been made via digital fabrication processes, positioning them further away from the idea of 'control' and closer to fluidity.

Figure 117.

Cluster 2 – median values



When considering materials in relation to digital fabrication making processes, certain craft materials such as glass, clay, and wood, were considered by participants as materials that allowed for a higher degree of unpredictability leading to unforeseen risks due to their material properties. On the contrary other materials (e.g., metal, computational elements) were judged as being more "fixed" (K). In their opinion, there is a relationship between materials considered more unpredictable and items considered to lead towards serendipity. This creates the conditions for practitioners to be challenged, intervening in the making process while drawing on their material knowledge, even if the techniques used to carry out the process are digital. Every single participant stressed how **serendipity** is a quality that, in their opinion, aligns more with craftsmanship characteristics as opposed to **control**. These qualities were mentioned and discussed differently in the workshop conducted with craft practitioners at the beginning of the research project [Appendix E]. In the workshop held with craft practitioners, *control* over the process of making was defined by the ability to produce a preconceived outcome. This appeared to play a significant part in validating an artefact for the participants. Differently, digital craft practitioners would stress the importance of framing a making process allowing for *serendipitous* possibilities. The idea of *control* would be subservient to the idea of *serendipitousness.*

As discussed in the contextual review (Chapter 3, subsection 3.1.1), as early as 1968 Pye (a woodworker and teacher) was comparing craftsmanship to industrial/automatized processes, describing their differences through the terms *workmanship of risk* and *workmanship of certainty.* Pye was referring to technologies and mass production processes as agents delivering a final piece without encountering any risk as they enabled practitioners to fully *control* the process. In contrast, Pye believed that the same does not happen in craftsmanship where “the quality of the result” was considered “continually at *risk* during the process of making” (Pye, 1968, p.20).

Again, concepts such as *control* and *serendipity* came out in the workshop carried out at the beginning of the research project [Appendix E] which have been extensively articulated in Chapter 4 (subsection 4.1.1.2) as from the workshop, the researcher together with her co-authors, was able to extrapolate some significant insights. Specifically, one insight that emerged was that the practitioners in the workshop believed the statement “Control as a measure of competence and competence as a measure of skill” (Vannucci et al., 2019, p.10), to be descriptive of craft practitioners’ ethos. In the reflections raised by the participants involved in the workshop, there was a disinclination to recognise the impacts and values attendant to technology use beyond its ability to carry out predefined tasks (goals/intentions). This is because to them digital fabrication technologies were considered passive *means* to get to a predetermined *end*. Moreover, participants believed that makers have little *control* over materials involved in the digital fabrication process as the tools themselves take over (Ibid.). This understanding of digital technologies is the opposite to the beliefs held by the participants in the KRG study. These participants described the natural ability of digital craft practitioners in recognising and controlling serendipitous events within the making process. Through the insights obtained from the group of craft practitioners involved in the workshop conducted at the beginning of the research project (Vannucci *et al*., 2019) some analogies can be drawn between their views and Pye’s (1968) standpoint. They both associated the idea of *control* and *certainty* to production processes involving digital fabrication machines, and the idea of risk and serendipity to hand making processes.

Instead, the digital craft practitioners involved in the KRG study, while also stressing the importance of *serendipity* and *control* in defining making processes, developed a more nuanced understanding of these qualities. Participants in the KRG study, similarly to craft practitioners involved in the workshop, believed that the digital craft practitioners’ abilities in determining the level of *control* or *serendipity* used in the making process of an artefact (be it digital or analogue) demonstrates their expertise. Thus, they made it clear how these qualities do not depend solely on the digital nature of materials or processes used to produce a craft. In other words, digital craft practitioners believe that actively choosing a combination of materials and making processes that enable serendipitous events expresses the practitioners' expertise. Accordingly, they also maintain that there are combinations of materials and tools which might inhibit that same expertise. Hence, in their view (i) the choice made by digital craft practitioners expresses their ability to recognise combinations that might allow for *serendipitous* craft opportunities, and (ii) the level of *control* used over those *serendipitous* situations is what ultimately determines the practitioners' expertise and material knowledge.

Drawing on more recent theoretical literature explored in the Critical Contextual Review (Chapter 3), many scholars focus on the shift of the practitioners' agency over making processes through the advent of digital technologies and how this has had an impact on their active engagement on materials – often referring to Pye's work (e.g., McCullough, 1998; Sennett, 2008; Latour, 2008; Pallasmaa, 2009). While such a shift may be not universally described negatively, the suggestion of a comparison between digital craftsmanship and industrial/automatized processes, working with almost no direct human involvement in the making (Pye, 1968; Latour, 2008; Pallasmaa, 2009) suggests a polarising role of hand-making and digital technologies. Treating them as entirely separate processes and analysing practitioner's *control* over materials, through the agency practitioners have on the making processes, underlines a common tendency in "assuming every action to be pragmatic" (Luscombe, 2017; p.9). From that perspective cognition and *control* over the material and making process is prioritised over actions. Luscombe (2017) carries out a critique over Pye's theory on this point suggesting that his overview on making is *pragmatic.* He argues that it refers to making processes as actions carried out to advance towards a predefined goal. By doing so, Luscombe believes that Pye is ignoring the role of *epistemic actions* (Kirsh & Maglio, 1994), which are those actions carried out in the attempt of working things out “to simplify the problem-solving task” (Ibid., p.513). Moreover, Luscombe posits that “there is a more fundamental distinction than that of risk and certainty: between *processes through which things emerge step-by-step*, and *processes through which things are planned in advance of their execution*” (Ibid., p.2010). Luscombe stresses that while tools allow for certain outputs to be conceived, they also provide sensorial feedback to the practitioner using them, and therefore they should not be contemplated “only by the degree of certainty with which they may achieve pre-conceived ends, but the ways in which they support epistemic action” (Luscombe, 2017, p. 11). Luscombe defines as *epistemic character* the intrinsic property of certain techniques which “structures the process of working things out whilst using the technique” (Luscombe, 2017, p.40). He suggests that the concept of ‘risk’, which is heavily valued by Pye as a dominant characteristic in hand-making processes, could instead be interpreted as the *consequence* of those making processes. Which allow for frequent serendipitous acts because of the way they distribute decision-making in the process. Interacting with materials and / or techniques considered more serendipitous ultimately forces practitioners to tap into their *tacit* human knowledge which is what was ultimately valued by digital craft practitioners themselves. For this reason, the attention provided in the selection phase of materials and the techniques used in the processes, cannot be discussed solely on the grounds of how well they will help the practitioner achieving a predetermined result in a pragmatic way and “by the degree of certainty with which they may achieve pre-conceived ends” (Luscombe, 2017, p.11).

If we consider again the insight obtained from the workshop carried out with craft practitioners, “control as a measure of competence” (Vannucci et. al, 2019) appeared to be recognised as an important measure to establish expertise by the participants. The themes of *control* and *serendipity* were separately raised by digital craft participants involved in the KRG study. In each of the two cases both groups shared views on their practices equating to what Luscombe defines as "*epistemic character"* (Luscombe, 2017, p.40). The researcher recognises that Luscombes' discussion on the *epistemic character* relies on practical examples, mostly adopting traditional crafting techniques. Yet Luscombe does not include processes driven by digital fabrication technologies, therefore he does not explicitly align the terminology *epistemic character* to digital production. Throughout his work Luscombe makes clear that Pye's (1968) concept on '*the workmanship of certainty'* is based on the assumption that practitioners engaging with technologies mostly draw on their cognitive knowledge rather than their embodied knowledge.

Similarly digital craft practitioners involved in the KRG study, when mapping artefacts on the 'digital' or 'control' spectrum of the Grids seemed to agree that a large use of digital materials and fabrication technologies –in combination with materials considered more fixed and tameable–, requires a greater endeavour of practitioners to show their expertise beyond characteristics relatable to the control of the digital process. Digital craft practitioners stressed how materials, again in combination with techniques and tools, need to be selected by also taking into account how they aid the decision-making opportunities offered to the practitioner during the making process. Differently from the craft practitioners involved in the workshop (Vannucci et al., 2018), digital craft practitioners tended not to have a negative value judgement of digital fabrication technologies. Indeed, the same fabrication technologies were considered by craft practitioners involved in the workshop as instruments supporting solely *pragmatic actions*. Just like craft practitioners, digital craft practitioners assessing digital craft outcomes tended to judge the value of the artefacts based on the following considerations concerning their making process: (i) whether or not it supported ‘serendipitous’ opportunities and (ii) how well the practitioner was able to respond to those opportunities.

When digital craft practitioners describe their ability in dealing with making processes which have ‘serendipity’, ‘risk’, ‘unpredictability’ and ‘chance’ as a quality, they can truly express their expertise and material knowledge. The researcher posits that they are implicitly sharing the belief that some digital technologies and processes when combined with certain materials have an *epistemic character* (Luscombe, 2017). This is so because they better support *epistemic actions* (Kirsh & Maglio, 1994) in the same way as hand tools do for craft practitioners. In Figure 117 we can see combinations of tools, materials and techniques that were considered to potentially have *epistemic character* (Ibid.) (e.g., in *Dripping Clay* by Studio Joachim-Morineau). Conversely, other combinations were not pointed out for this specific characteristic (e.g., *ReFind* by Jayne Wallace).

Making connections with the notions articulated in the Critical Contextual Review (Chapter 3, subsection 3.3) related to *complex imitative learning* (Tomasello et al., 1993; Sterenly, 2012) and *Tacit Knowledge* (Polanyi, 1966; Collins, 2010), humans can distinguish the final goal of a certain behavior from the actions or means that bring it about. Further, they could be broken down into a finite sequence of simpler acts to be carefully *imitated* (Tomasello et al., 1993) one by one. In craft practices, when a practitioner faces numerous points in which variations are possible along the making process, decisions need to be made promptly to provide adequate feedback to the material in order to move towards an end goal. Through the high number of repetitions of similar acts and, more specifically, through the understanding of the relationships between these episodes (i.e., cause and effect understanding), *experience* is acquired through the embodiment of actions, of both a *pragmatic* and *epistemic* nature. The way in which humans can acquire experiential knowledge (i.e., *Tacit Knowledge*) is through *imitative learning processes* (Tomasello et al., 1993). Embodied knowledge in action (Eastop, 2014), as shown in the Critical Contextual Review, is largely *Tacit* and although the majority is strongly resistant to being made explicit, certain elements are easily articulable but not fully articulable (Collins, 2010).

Therefore, it is proposed that while in digital craftsmanship the materials and tools used to make an artefact are important, the interrelation between *Tacit-Explicit Knowledge* and *expertise* (i.e., the making processes and techniques a practitioner has access to), is considered of greater relevance (see Chapter 3, section 3.2). This point will be returned to later in the subsection to discuss one of the principles articulated by the researcher.

As pointed out by Collins (2010), to understand *expertise* and *Tacit/Explicit Knowledge* many researchers have been directing their attention and focus on the role that bodies play in the acquisition of knowledge. As a consequence, scholars have been focusing specifically on the nature of human bodies, rather than on the nature of the knowledge to be acquired.

In light of the Critical Contextual Review (Chapter 3, subsection 3.1) and as mentioned at the beginning of this section, the researcher believes that the debates in existing literature (e.g.,McCullough, 1998; Sennett, 2008; Latour, 2008; Pallasmaa, 2009) have enforced a polarisation of hand-making and digital making. This polarisation ultimately prevented more recent research from focusing on the nature of the acquired / transmitted knowledge in digital craftsmanship. The focus on the nature of knowledge is important as it helps in trying to make a distinction between different aspects of digital craft practitioner's knowledge. Certain aspects of their knowledge are intrinsically *Tacit* and therefore human, while other aspects are instead *Explicit* and therefore digital. In the following paragraphs the researcher will discuss this point further explaining how craft materials, more than digital materials, were considered by digital craft practitioners as the gateway par excellence to the access of *Tacit knowledge.* Moreover, it will also be stressed how these materials nurture human learning capabilities.

As seen at the beginning of this subsection, the participants involved in the KRG study initially did not distinguish digital materials from craft materials. When approaching the theme of *coding* participants started differentiating between two main types: coding where the practitioner is actively writing lines of codes (i.e., programming) and coding where the practitioner is using code indirectly through the use of a software. Participant D underlined how code not only can be considered as a digital material bound to the making process ("a recipe" (D)), but it can also be considered as a product itself ("the result" (D)).

Code seemed to be considered at its purest when expressed through active coding by participants who frequently coded in their own making processes (e.g., participants D, J and K). Whereas other forms of access to code was somehow considered limiting for the practitioner of digital literacy's expression. Participants seemed to be differentiating between processes where, on the one hand the practitioners' direct mediation with code is assumed to be reflecting the practitioners' expertise over digital materials – expertise gained through the direct experience of writing the code. On the other hand, the use of the functionalities brought about by code[31] (rather than stemming from code written by the practitioner themself) was considered by the digital craftspeople questioned to be less dependent on a practitioners' digital material knowledge.

[31] For example, the use of specific lines of code selected by the practitioner, from pre-developed software, in order to realise their overall design aim - rather than writing the coding elements themselves.

Consequently, artefacts which were not a result of active coding were considered leaning more towards ‘digital’ related concepts rather than towards ‘craftsmanship’ traditions. The researcher acknowledges that there are more nuances in this spectrum: from using code embodied in commercial software (e.g., CAD) to the scripting of one’s own original code. For example, ‘block coding’ environments, such as Grasshopper that is linked to RhinoCAD software, sits somewhere in between these extremes. However, it is argued that the basic claim is still valid, as it speaks to the way in which the code can be recognised as a craft material, and on how coding can be recognised as crafting.

In Cluster 1 of the KRG study (subsection 5.3.1), code was recognised by participants as a digital material that, as much as physical materials, requires practitioners’ *Tacit Knowledge* in its creation. Therefore, the coding process was recognised as akin to any other embodied making process and considered closer to traditional crafting processes in that it draws on humans' *Tacit Knowledge*. Thus, the peculiarity of code is that once the practitioners write a line of code participants stop recognising code as a digital material and start recognising code as a product. Once written down code becomes an *Explicit* piece of knowledge (i.e., a function to be tested) even though this digital material was formed from the *Tacit Knowledge* of the individual encoding. As claimed by Participant D: “There is nothing serendipitous in the code itself once it is written down, it becomes just a controlled set of parameters. It becomes the recipe and the result, all in one” (D).

The approach of letting the materials take the lead in the making process reflects the theoretical notion of crafting as being “an approach, an attitude or a habit of action” (Adamson, 2003, p.4). As seen in the Critical Contextual Review (Chapter 3, subsection 3.1.3), the idea of materials taking the lead in making processes is an approach that "can also be noted in constructive design research and RtD practices in HCI" (Frankjaer & Dalsgaard, 2020, p.14). Specifically, in HCI, craft-based approaches started rapidly permeating within the community as a consequence of the *material turn* (Robles & Wiberg, 2010) where making with embedded electronic components and coding had been compared to the experience of carving, sewing or painting (Buechley & Perner-Wilson, 2012). Thus, such coders, engaging with problem-setting and problem-solving tasks, started calling for analogies with craftsmanship (Bdeir, 2009; Satomi & Perner-Wilson,2011; Buechley & Perner-Wilson, 2012; Lindell, 2012, 2013, 2014). Their abilities to explore, identify and understand a design situation, and to select the tools and techniques needed to provide a solution to a specific material situation, had been often underlined as problem-setting and problem-solving qualities – extensively used to describe craft practitioners (Sennett, 2008). When actively crafting with code as a digital material (Lindell, 2012, 2014), scholars in the HCI community started identifying "programmers as craftsmen of code" (Lindell, 2013, p.622), describing them as both capable of involving "human skills and judgement" (Satomi & Perner-Wilson,2011, p.2) in their making process. Hence, while many different scholars from the HCI community made analogies between the act of coding and the act of crafting, and between craft materials and the materiality of code, digital craft practitioners involved in the KRG study seemed to differentiate the two.

Arguably, by closely following technical directions on a *know-how* instruction book we would be able to write the right lines of code to activate chosen electronic components and we would be able to calculate the correct electric capacity needed to have the components working. Thus, as long as we could possibly also have an instruction-based book on how to manipulate thread as *Somatic tacit knowledge* can be articulated, we would still need to practice through a *know-that* (Ryle, 1945) approach in order to acquire what ultimately is *Tacit Knowledge* (see Chapter 3, section 3.2). Collins (2010) thoroughly articulates why *strings* of code are an example of *Explicit Knowledge* (see subsection 3.2.2) and while the act of writing code cannot be made *Explicit* as it is done through embodied actions, once coding functions are written down, code becomes *Explicit*. Having these theoretical notions in mind it is therefore easily understandable why participants in the study tended to remark on the paradox of the dual facade of code.

The techniques used to engage with any physical or digital materials in active making processes are embodied, complex and ultimately *Tacit*. As seen in section 3.2.1.3 on *Somatic tacit Knowledge*, articulating and communicating information through spoken or written language alone is not an efficient way to reach *Tacit Knowledge*. Code once finalised acquires fixed qualities and is replicable in every detail, as such it sits further away from the idea of craftsmanship which aligns with the concept of knowledge as being *tacit* (at different degrees of resistance to be made explicit) and not *Explicit*. Digital craft practitioners pointed out that the material knowledge used in coding is limited because, while the act of writing code is embodied and it initially allows a degree of serendipity within its creation, on completion it turns from *material* to *result,* which is determined by explicit rules. As Participant D claimed:

> "The thrown vase needs to go through many unreliable and therefore serendipitous phases, even the best scientist would perhaps not be able to control everything...they could potentially explain it... I mean... They might be able to describe it, create optimal systems and environments for the desired outcome... but with code... you can control everything" (D)

This means that code allows easier access to replication and, as code is strictly related to electronic components, they are in turn perceived as closer to the idea of 'control' (Figure 117). In making processes where strings of code are involved, code itself provides a visual trace of conditions which are written down. Such conditions are not fluidly changing without the makers' *control*, at least not without the addition of specific morphic algorithms. In other words, whenever a mistake occurs a clear sequence of coded functions can be displayed and the practitioner can clearly analyse what went wrong, and when and where it went wrong. Being able to point out where the mistake was carried out leads to a greater *control* over the material on the practitioner's side. Instead, with craft materials the practitioner is not always able to capture the exact issue whenever an error occurs and fixing the error is not as easy as deleting and rewriting pieces of code.

These premises underline why, ultimately, the act of making through the digital material of code and the act of making through craft materials were not considered the same by the digital craft practitioners involved in the study. Thus, the researcher stresses that, like physical craft processes, the act of programming and / or indirect uses of code rely on the practitioners' human embodied capabilities of typing or drawing with a mouse, while at the same time accessing personal cognitive knowledge (McCullough, 1998; Sennett, 2008; Adamson, 2007). Like cycling or driving a car, writing code is an embodied action which consequently has some characteristics that are resistant to being fully made explicit. Take for example the case of touch-typing which is a time saving and beneficial sub-skill involved in coding. With touch-typing, it is not possible for us to explain how our fingers move quickly between keys without visual stimulus. This sub-skill is experience driven, improving our ability to smoothly translate the code from thoughts in the mind into written code onto a computer. Considering the act of *writing* code as an embodied action, as many other human embodied actions, it would be impossible to differentiate the two as they rely on the successful acquisition and transmission of *Tacit Knowledge*. On the contrary, if we are to focus on the result of a making process involving digital materials or a making process involving craft materials, it is possible to delineate important differences between the outcomes. Their differences rely on the fact that code is constituted by explicit strings of information (Collins, 2010). Participant C in the study stresses this point very clearly:

> "When I try to code, I always need to simplify reality and material properties... I use fabrication technologies to 3D print, I know the language.. I am not able to look at a digitally made artefact and see literally the code behind it in my head... but I understand the main properties of the code which basically come down to binomial variables: extrude/non extrude, higher speed/lower speed, left/right, up/down, more material/less material. I am also simplifying now but it is just to make my point. You see, when I am making a pot with my hands, and if you look at me, you will not be able to simplify my movements in the variables I just expressed.. Material Intelligence is much more complex, it is what makes us humans.. Can you tell the difference?" (C)

As seen in the discussion of the concept of *Somatic tacit knowledge* (subsection 3.2.1.3), a precise set of instructions and descriptions on how to handle craft materials would not be enough to transmit all knowledge to another practitioner. Code on the other hand, being explicit, allows for an exchange of information with no loss of data. Instead, craft materials do not explicitly display the process needed to achieve that same result. As a consequence, code can be easily *replicated*. Therefore, it would be more likely for a machine to be able to master some of the skills practitioners are able to break down into explicit and discrete steps – if the goal was to produce repeatable examples rather than one-offs. These points are subtle but important to address differences in the nature of knowledge transmission and acquisition in digital craft practices. The following paragraphs will expand on interrogate this point further drawing on the concepts of *mimeomorphic* and *polymorphic actions* (Ribeiro & Collins, 2007) .

In the Critical Contextual Review was previously articulated (Chapter 3, subsection 3.2) how *mimeomorphic* actions (Collins & Ribeiro, 2007) can be reproduced by machines and technologies as they do not rely on social understandings, and therefore they can be translated into simplified sets of machine-like actions. No matter how complicated the actions are, they can be simplified, standardised, automated and reproduced in a more precise manner than humans ever could. *Mimeomorphic* actions rely on a fixed set of instructions (i.e., strings of code) that do not admit a plurality of interpretations and are always decoded in the same manner. Differently, *polymorphic* actions live in *Tacit Knowledge* and "no available instructions on how to vary the behavior associated with the action in order to carry it out successfully" (Collins & Ribeiro, 2007, p.1419) can be described or made explicit. Any human action is *polymorphic* but as seen in Nonaka & Takeuchi's (1997) example, (see subsection 3.3.2), certain actions are more easily transformable into *mimeomorphic* actions with a limited loss of information. Moreover, if the material used in the making process happens to be more fixed in its nature (e.g., a block of aluminium) machines will have to deal with fewer variables.

Through *complex imitative learning* (Tommasello, 1999; Sterenly, 2012) discussed previously, humans can rely on their ability to imitate sequences of actions. They can also distinguish the final goal of a certain behavior from the actions or means that bring said goal about. Finally, the human mind is also possibly able to break down the actions into a finite number of simpler acts, which themselves can be carefully imitated step by step. If the making process used involved materials considered as more “fixed” (D) (e.g., highly processed textile threads or electronic components), which might provide visual or coding traces of action – to learn from when there is a mistake–, the ability to then deconstruct the making process into simplified actions would be easier than if the materials used were organic, changing form under many different conditions / circumstances. While it would be possible for digital production technologies to master some of the human skills involved in textile making to a closer degree of perfection, it would be more difficult for a digital machine to interact with materials that are organic and can change over time their conditions. This does not mean that machines would not be able to manipulate organic materials like glass or clay through a semi-automated process. Rather, it means that the actions the machine would be reproducing would be even less representative of embodied actions, simplifying them in an incoherent interpreted version of hand skills.

This point was thoroughly explored by the scholars Ribeiro & Collins in their critique of Nonaka & Takeuchi’s (1995) study. Nonaka & Takeuchi were claiming to have programmed a bread making machine through explication of *Tacit Knowledge* so that the machine could produce loafs of bread exactly as humans would (see Chapter 3, subsection 3.2.2). Ribeiro & Collins (2007) severely criticized the study emphasizing how the set of functions programmed for the machine were based on the explicitation of humans *mimeomorphic* actions without including humans’ *polymorphic* actions (see subsection 3.3.2). The scholars identified several actions in bread making considered *polymorphic* and that, as such, cannot be simplified. Examples of the *polymorphic* actions identified are: the setting up of the production scene, choosing the recipe, defining the size and crust colour, dealing with the variability of ingredients and brands available and choosing the level of tolerance of acceptance of the final product. Ribeiro and Collins claim that if these actions were to be omitted or simplified, their variances would also be excluded. Consequently, *Tacit Knowledge* would also be excluded. Hence, *Tacit Knowledge* is not made *Explicit* in Nonaka and Tekeuchi's (1995) study, rather, they were able to programme machines to reproduce heavily simplified versions of human *polymorphic* actions that are impossible to fully translate into *Explicit Knowledge*. Ribeiro & Collis claim that in the case of the kneading machine, the pieces of *Explicit Knowledge* are comparable to *how-to* manuals and books and "are deceptive" (Ribeiro & Collins, 2007, p.1430). In other words, while meaning seems to be carried within them, meaning it is actually provided by humans; "their potential lies in the tacit knowledge and social understanding brought to their use by both their producers and their users" (Ibid.). Machines would not be able to reproduce human actions as much as humans would not be able to relearn *mimeomorphic* actions from a machine nor to reproduce a set of fixed instructions as precisely as a machine would. This is so because the qualities and capacities of human bodies are based especially on the limitations that bodies naturally hold. Conversely, machines do not have those physical limitations (Collins, 2010).

The researcher posits that the examples where digital craft practitioners noticed a limited human intervention, both in the making process and in the craft material knowledge, were those examples that, using Collins's notions on *mimeomorphic* and *polymorphic* actions, leaned towards *mimeomorphism*. When through unexpected variations materials and processes create a challenge, finding a way to turn that challenge into a skillful making process requires the practitioners to largely engage with their *Tacit Knowledge* together with smaller aspects of *Explicit Knowledge.* While this might be true for any craftsperson, through the premises explored it can definitely be considered a characteristic of digital craft practitioners. As experienced through the workshop carried out with craft practitioners mentioned at the beginning of the thesis (Vannucci et al., 2019) and through the reviewing of the literature (Pye, 1968; Pallasmaa, 2009; Shiner, 2012), more often craft practitioners using technologies tend to be thought of as carrying out highly structured and controlled making processes. By digital craft practitioners this is believed to be true whenever in the making process practitioners do not make an effort to use their human *Tacit Knowledge*, giving greater space to technologies and associated *Explicit Knowledge*. In those cases, participants in the KRG study tended to not recognise the output as digitally crafted but as solely digital. Instead, when technologies and their intrinsic qualities of ‘control’ are balanced out with human knowledge and *polymorphic actions*, digital craft practitioners see digital machines as an opportunity to create ‘serendipitous’ opportunities to be managed, rather than a way to avoid *risks* (Pye, 1968) or as a way to control every detail of the making process (Johnston, 2015) . Therefore, an artefact to be considered crafted should be shaped predominantly by means of *polymorphic* actions using a mix of materials (both digital and craft materials).

In conclusion, for digital craft practitioners craft materials provide easier access to the practitioner's *Tacit Knowledge,* if compared to the material of code. This characteristic was perceived by the researcher as a fundamental shared ***principle*** uniting digital craft practitioners: **(1) the importance of nurturing creative complex imitative learning through craft material knowledge.**

Moreover, if the goal of a making process is to create accurately replicable pieces, then materials considered by participants as more “fixed” (D), and an instrumentalist use of technology to enact *pragmatic actions* (Kirsh & Maglio, 1994), would be successful in achieving the aim. In contrast, if the goal of the making process was to produce one-off pieces, interacting with craft materials considered by participants as “fluid” (D) in that they easily change their properties (i.e., glass, clay, wood) would increase the opportunities for serendipitous and unexpected events. This would require the practitioners engaged in the process to tap into their *Tacit Knowledge* in order to skillfully respond to unexpected events. For this reason, it would be more difficult for a machine to interact with materials that are organic and can change their conditions over time: to programme those machines, we would need to make explicit parts of the knowledge practitioners use when engaging with said unexpected events.

The researcher recognises this point as a second characteristic that appeared significant for digital craft practitioners in the study, despite their varying and different backgrounds. The researcher believes digital craft practitioners were united by a second common ***principle***: **(2) aspects of the making process need to include *polymorphic* actions, as opposed to solely *mimeomorphic* sequences**.

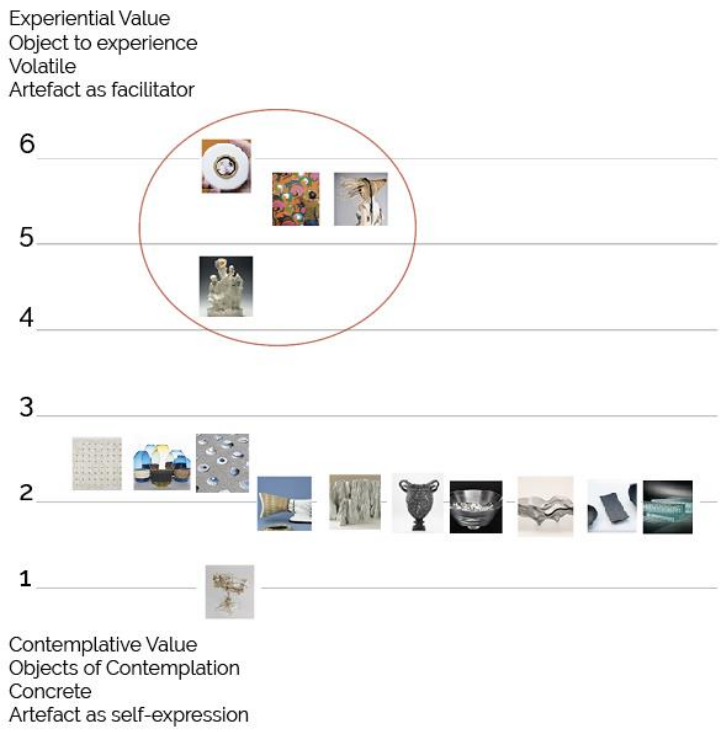
6.1.2 Motivations and goals

Materials and making processes are important factors in digital craftsmanship, and they are considered fundamental in order to refer back to the term *craft* as an approach (subsection 6.1.1). Thus, all participants in the KRG study stressed how the practitioners’ motivations and goals are other two fundamental themes to be considered in order to assess whether a making process can be regarded as a genuine craft process.

With a focus on code, the previous subsection discussed how a string of code becomes an example of *Explicit Knowledge* once it is written down, though the act of code-writing has analogies with a crafting activity. Through the data analysis in Cluster 3 (subsection 5.3.3), and from the calculated median values illustrated in Figure 118, it is shown that participants in the KRG study recognised most *elements* as sitting closer to the *constructs* articulated as ‘contemplative value’ , ‘object of contemplation’, ‘concrete’ and ‘artefact as self-expression’. Distinctively, four artefacts (in the red circle) were differentiated as a very distinct group due to their “experiential value” (D). In these *grouped artefacts* (thoroughly articulated in Cluster 3, subsection 5.3.3), code was perceived as a product even before being perceived as a digital material.

Figure 118.

Cluster 3 – median values



The following subsection will focus on the ‘experiential value’ *construct* after firstly discussing a common trait identified among the *grouped elements*: three out of four of the *elements* considered by the participants as a separate grouping all have electronic components embedded within them. The fourth artefact, placed in a lower rating position than the other three, while it has no embedded electronic components in it, displays a QR code. Though, the QR code was considered by participants as a characteristic comparable to the artefacts including electronic components in that it explicitly reflects the digital culture –alongside clearly exemplifying ceramic processes and traditional ceramic forms.

As seen through some of the participants' very first reflections on the *elements* (e.g., C), electronic components were never identified and discussed as key features that would radically distinguish artefacts. However, the experience the artefacts provide once their electronic components are programmed, was believed to go beyond materials and their physicality. Participants involved in the KRG study mainly believed that when coding is not used for fabrication purposes (i.e., to programme digital fabrication machines) but it is written to programme electronic components, as a consequence, physical materials in the artefact become subservient to the interaction the code facilitates. In their opinion, practitioners engaging with physical/digital materials with the aim of designing an experience tend to put the coded experience at the very core of the making process, focusing on the interaction as the central concept of the whole piece. Consequently, the artefacts become “facilitators of the experience” (J), acquiring an “experiential value” (D). Trying to elicit an interaction with the user appeared to gain importance over the craft materials and techniques used to produce the artefact itself. Therefore, the participants believed that while the artefacts might be produced through material sensibilities, these become additional features of the piece as they are no longer it’s central focus. The same reflection was made about the QR code displayed on *A Day at the Hunt* by Murphey (2016). The artefact was produced entirely using traditional ceramic techniques thus, the digital reference obtained through the application of a QR code was considered “an additional experience”, where “the physicality of the object is sort of liberated, by enabling it to have a virtual experience of virtual accompaniment to a viewer” (E). This characteristic placed the artefact closer to the ‘experiential layer’ *construct* rather than the opposite pole.

Drawing on arguments previously considered in the Critical Contextual Review (Section 3.2) and the previous discussion on code as material (subsection 6.1.1), while not ignoring analogies with craft-approaches scholars Satomi & Perner-Wilson in the HCI community claimed: “the researcher, the engineer, the educator, the artist and the designer are all capable of creating work in their field with attention to the craft quality of their work” (Satomi & Perner-Wilson, 2011, p.2). Specifically, Satomi & Perner-Wilson when talking about the diverse set of practitioners producing e-textiles write: “while their motivations and goals may be different, craftsmanship is exercised throughout all of these disciplines” (Ibid., p.2). While many scholars previously suggested that the crafting ethos can be found in various fields (Adamson, 2007; Sennett, 2008), digital craft practitioners seemed not to share this view stressing that there are specific motivations behind the crafting making process that are distinctive.

As owning a 3D printer does not automatically make the owner a maker (Barba, 2015), utilizing craft materials and techniques does not immediately transform a technologist into a craft practitioner. Indeed, making a vegetarian meal does not make someone a vegetarian but might suggest that someone appreciates vegetables, or that someone decided to experiment with a different type of diet for their meal or, again, might suggest that, valuing sustainability, someone is trying to introduce more vegetarian meals in their cuisine to have a greater control on their consumes and choices etc. The listed motivations and / or goals are still not enough to identify somebody as a vegetarian.

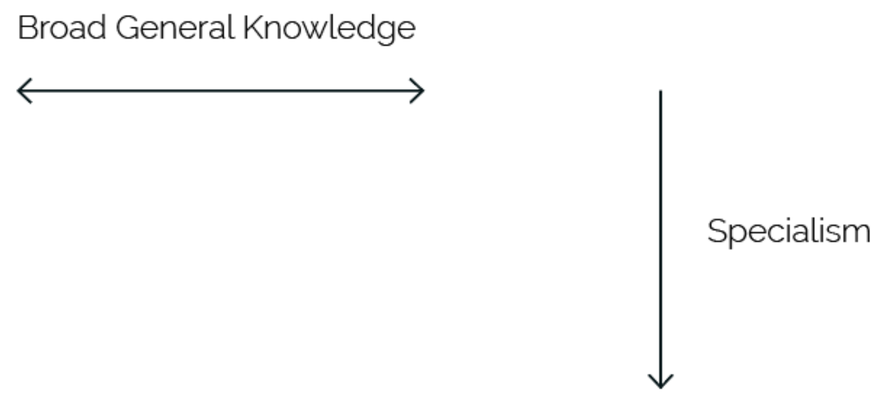
Similarly, digital craft practitioners showed to take into account the motivations and goals behind a craft as much as the materials and the techniques used in the artefact itself.

Thus, according to Adamsons' (2013) theoretical notion of crafting as being "an approach, an attitude or a habit of action" (Adamson, 2013, p.4), we should consider craft as the general process of making and we would have to reject the idea of craft as being a movement or a field. Rather, we would be defining "the craft process at a level so generic that it means nothing more than skill" (Shiner, 2012, p.233). Instead, based on the reflections made by practitioners involved in the KRG study, motivations and goals are central characteristics considered necessary to identify someone as a digital *craft* practitioner and a making process as a *crafting* process without diluting the terminology of *craft*. Therefore, craft was considered more often as what Shiner argues being "a process into the concept of a practice" where "a set of shared assumptions inform a way of doing" (Ibid., p.233).

Referring to the Critical Contextual Review (Chapter 3), the researcher believes that the differences described by practitioners around motivations and goals complement, and sometimes overlap with, the approaches identified and articulated by Shorter (2015) as described in Chapter 3 (Section 3.2). Shorter in his t-shaped diagrams defines distinct types of making practices, with particular attention to practitioners defined as *craft practitioners* and *craft technologists*. The t-shape model, as illustrated in Figure 119, helps evidencing the breadth of the b*road general knowledge* practitioners depart from, and the depth of specific *specialism* they bring into their making processes.

Figure 119.

T-shape Model

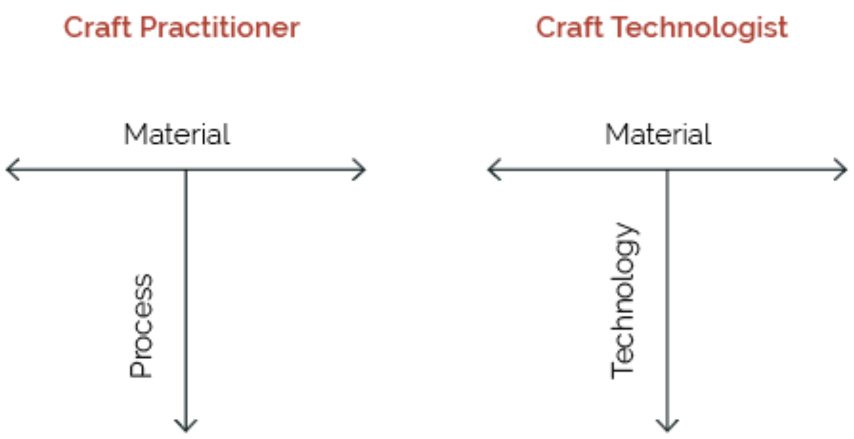


Shorter (2015) writes extensively about the *craft practitioner* who “has a reflective and personal process concerning the physicality of a material” and “has a deep understanding of not just a material, but a material's history” (Shorter, 2017, para.2). *Craft practitioners*’ try to solve questions related to materials and processes, using technology as a tool to support their making.

He then describes the *craft technologist* as a practitioner whose focus relies on technology as a material to evoke emotions and create connections with a user. Moreover, Shorter posits that technology is used by *craft technologists* to raise issues and, eventually, to try and answer open-ended questions (Shorter, 2015). Identifying himself as a *craft technologist*, Shorter writes: “just as a potter crafts clay, I was crafting interactions” (Shorter, 2015).

Figure 120.

Shorter's t-shaped practitioner's diagram



Note. Adapted by the researcher from "The Craft Technologist" by Shorter, M., 2015, *Studies in Material Thinking*, *13*, p.8. Copyright retained by © 2015 Studies in Material Thinking and © Michael Shorter.

As illustrated in Figure 120, Shorter counterposes *craft technologists* to *craft practitioners* who "predominantly focus on technologies as a tool" and "regard technology in a pragmatic sense" (Shorter, 2015, para. 4). In both cases practitioners in their making process depart from a general broad knowledge on *materials* to be combined with their different specialism, namely: process and technology.

Shorters' interpretation on the way different practitioners operate, has analogies with the differences the researcher identified throughout her interactions with the craft practitioners involved in the workshop at the beginning of the study, and the digital craft practitioners involved in the KRG study. In the workshop (Vannucci et al., 2019), and as previously discussed in subsection 8.1.1, the participants –craft practitioners– inclined towards a pragmatic and instrumentalist view of technologies.

In contrast, participants involved in the KRG study reflected on technologies as possible creative tools allowing for serendipity and providing unexpected creative opportunities for the practitioner (discussed in subsection 8.1.1).

Thus, when describing more thoroughly *craft technologists* Shorter writes:

> “Aside from practicalities concerning technology as a material and the tangibility of physical crafting, it is this magical and intriguing quality that can differentiate between a craft technologist's practice and other practices. The familiar artefacts of craft blended with the mystery— and, arguably, inaccessibility—of technology creates an enthralling and engaging user experience” (Shorter, 2015, para.3)

While most characteristics align with the reflections made by KRG participants, all practitioners involved in the KRG study categorized as different *grouping* from the repertoire (subsection 6.1.1) the only artefacts with embedded electrical components and which allowed for a digital interactive experience with potential users.

In fact, all participants in the KRG study believed that the motivations and goals behind the artefacts identified as a grouping were not reflecting the notion of craft in the same way as other artefacts shown in the study. In participants' opinion (e.g., C, J, V) , the practitioner's attention to the challenge of the making process was not commensurate with the attention given to the design of the code providing the related interactive experience. Participants (e.g., J, V) tentatively underlined how the driving motivation to craft can be distinguished between practitioners crafting mainly to provide a specific designed interactive experience to their future users’ and practitioners crafting to challenge their material knowledge and competence. This does not imply that there is no intention of the latter to craft material characteristics that could support some form of interaction and experience with the users. The distinction is rather made between artefacts including programmed electronic components providing a designed experience as mediums, and artefacts that do not. Drawing analogies with Shorter t-shaped illustrations, it appears to the researcher that the differentiation made by the participants in the KRG study redirects to the definitions of the *craft practitioner* and the *craft technologist.* While participants agreed that in the four grouped artefacts (see Figure 118) practitioners demonstrated material sensibilities, participants claimed that the practitioners' skills and expertise related to their craft material knowledge were not involved to a significant extent into the grouped artefacts.

The researcher recognises that there is an inconsistency with the previous judgement participants made on code, which was argued to be considered as any craft material at the point of creation and during initial stages of the making process. While based on this view there should be no distinction between code and craft materials within the definition of material knowledge, when it comes to judging the interactions coding facilitates, participants distinctively group and exclude a set of artefacts from the repertoire.

This point can be further explained drawing on the study carried out by the researchers Nitsche and Weisling (2019) who defined when an artefact or a making process should or should not be considered as *craft* in the HCI domain, specifically in relation to the tangible interaction design field. The researchers argue that in the digital age the "focus on materials invites craft as a reference point, but it does not mean that tangible interfaces practice craft by definition" (Nitsche & Weisling, 2019, p.683). Nitsche and Weisling (2019) provide an important distinction between a design project that *is craft* and others that should be instead analysed *as craft*. A tangible interaction *is craft* "when it includes actual craft practice in the direct encounter of the material and the computer as a tool" (Ibid., p.683). Instead, when craft-related theories are used to explore and critically analyse and advance tangible interaction designs we should analyse a tangible interaction design *as craft.* In this case, crafts' history and methods provide the basis to be counterposed to interaction ones and, through their differences, they are able to provide new perspectives. The researcher posits that the articulated theories support the understanding of the clear participants' distinction between the artefacts in the repertoire.

Drawing on the theoretical notions addressed in Section 4.3 concerning *contributory expertise* (Collins & Evans, 2007), the ability to contribute through practical examples of valuable outputs in one's community is sometimes addressed as ones' expertise in the field. Digital craft practitioners work at the intersection of hand-making and digital making and tend not to hold a pragmatic view of technologies (as previously described in subsection 8.1.1). Compared to the instrumentalist view on technologies craft practitioners shared throughout the workshop at the beginning of the research project, digital craft practitioners can be considered closer to the definition of the *craft practitioners* described by Shorter (2015) –where technology is seen as a tool to support making.

The researcher argues that while many *craft practitioners* working solely with traditional craft materials might have an instrumentalist view on digital technologies, *digital craft practitioners* think the opposite. Thus, while they do not align with a pragmatic view on digital technologies and rather they describe digital technologies as any other making tool, they still maintained at their core part of the *craft practitioners'* ethos in that they try to preserve and nourish aspects related to *Tacit* human knowledge. They do so by promoting serendipity and validating crafts based on the craft material knowledge expressed in them. Hence, the digital craft practitioners involved in the KRG study seemed not to recognise as *contributory* (Collins & Evans, 2007) to their field those skills related to the role of the *craft* *technologist* – focusing on “enthralling and engaging user experience“ (Shorter, 2015, para.2).

Recall that in Shorter’s description, *craft practitioners* tend to recognise material competencies and skills in the way serendipitous and unexpected creative opportunities –challenging of materials and processes– are recognised and successfully repeated by practitioners in their making process (2017). Shorter writes about *craft practitioners* the following:

> “ A craft practitioner has a deep understanding of not just a material, but a material's history. In addition to crafting a material they are also able to alter and advance materials through reflective and playful processes. With such focus on the materiality of craft, questions arise that are becoming increasingly relevant in our technology driven society: What if the material of choice is the Internet, electrical components, electricity, digital signals or code? Can we use the same rhetoric? How would the use of these ‘materials’ fit into the practice, discourse and final outcomes associated with standard craft methodology?” (Shorter, 2015, para.3)

Digital craft practitioners participating in the KRG study stressed how (i) physical materials have a very important role in that they facilitate the practitioners’ engagement with their *Tacit* human knowledge (subsection 6.1.1), and that (ii) code used to provide interactive experiences to possible users changes the significance of the motivations and goal behind the artefact. Therefore, the researcher posits that participants in the KRG study seemed to differentiate between those artefacts demonstrating that the practitioners’ goal was bound to challenging the material or making process and, on the other hand, those artefacts showing the specific practitioners’ interest in programming and designing interactive systems providing experiences to users. In the first case participants in the KRG study acknowledged practitioners as *contributory experts* in their use of craft materials. Instead, in the case of artefacts with a significant interactive component, practitioners were acknowledged as *contributory experts* in the use of digital materials (i.e., programming).

Relating Evans & Collins (2007) studies on *contributory expertise* to Shorters' (2015) t-shaped descriptions, the researcher posits that *digital craft practitioner's* ethos aligns more to Shorter's description of the *craft practitioner* rather than the *craft technologist.* To the *craft technologists,* the expertise in dealing with craft materials is described as important as the crafting of intriguing and magical experiences created for the user (Shorter, 2015). By contrast, the digital craftsperson does not recognise this as a dominant motivation and goal in the making process and rather, in completed artefacts with a designed interaction, digital craft practitioners did not recognise the artefacts as similar to the others in the repertoire. For this reason, the researcher believes that attributing to digital craft practitioners the same rhetoric used by Shorter to describe *craft practitioners* is possible, despite their use of digital processes and materials –which is not originally contemplated in Shorter description.

Therefore, the researcher argues that when considering the *wholeness* of an artefact, digital craft practitioners, while interpreting its material and making processes, also consider aspects encompassing the authors' motivations and goals in its creation. The researcher argues that understanding the nature of the material knowledge valued by digital craft practitioners' as *contributory experts* helped in articulating a third ***principle***: **(3) the main motivation and goal bound to the making process should be the expression of a digital craftsperson's material c*ontributory expertise*, rather than the reaction or experience their work could elicit in viewers/users.**

Among the participants engaging in the study, it seemed clear that *contributory experts* are the ones that tend to define and express with their works the shared motivations and goals of their community of practice.

6.2 Summary of identified *principles*

Building upon the knowledge acquired in the review of literature and contextual sources (Chapter 3), through the researcher's own lived experience (Chapter 4) and the KRG study (Chapter 5), the researcher was able to identify and articulate the underlying *principles* that characterise a digital craft practitioner's ethos. The participation and insights of experienced digital craft practitioners involved in the KRG study were fundamental to meet the aim of delineating and articulating some shared *principles* that could unify the practitioners into a community. From the range of the Participants' backgrounds involved in the study, the researcher was expecting very different viewpoints and was therefore surprised to assess –through the analysis of the *constructs* and the Grids– that the practitioners' beliefs were more often shared by the larger group of practitioners involved in the study. Throughout the research process this realisation stressed even more the necessity and the relevance of understanding existing, yet unarticulated, underlying commonality of *principles* pertaining to the digital craft practitioners' community.

While it is recognised that these *principles* are partially rooted in the historical/political background of the wider craft sector and are partially shared within the digital craft discipline, the researcher decided to focus on the nature of knowledge transmission and acquisition in digital craft practices as she believes it to be most useful in terms of progressing the status and definition of digital craftsmanship as a community. Four principles associated with premises of *Tacit and Explicit Knowledge* need to be recognised and valued by the community of digital craft practitioners in order to ensure future transmission of human knowledge. These can be summarised as:

1) Nurture creative complex imitative learning through craft material knowledge

From the studies carried out within this research project, it emerged that digital craft practitioners tend not to have a negative value judgement on digital technologies which, instead, were considered by craft practitioners participating in the workshop at the beginning of the research project as instruments supporting solely pragmatic actions.

Moreover, it emerged that like for craft practitioners, digital craft practitioners looking at digital craft outcomes tend to judge the value of the artefact based on at least two considerations over the process: (1) if it supported 'serendipitous' opportunities and (2) how well the practitioner was able to respond to those opportunities. While these might not be the only criteria to be used to rate a piece of work, they seemed of relevance to the practitioners involved in the KRG study.

The researcher posits that when digital craft practitioners describe their ability in dealing with making processes that in their nature hold a higher degree of 'serendipity', 'risk', 'unpredictability' and 'chance' and describe these qualities as truly expressive of the practitioners' expertise and material knowledge, they are implicitly sharing the belief that some tools and techniques when combined with certain materials have an *epistemic character* (Luscombe, 2017) in that they better support *epistemic actions* (Kirsh & Maglio, 1994). Adamnson (2013) in his book *The*

Invention of Craft shows the links between craft and industry, stressing how the hand and the practitioner's material knowledge still remain central in the making processes, despite mechanical execution. The researcher posits that, similarly, craftspeople using digital machines heavily rely on their bodies in their making activity. Moreover, it is worth emphasizing here that embodied knowledge, being highly *Tacit*, is intrinsic to human specific ability of acquiring and transmitting knowledge through complex *imitative learning* (Tomasello et al., 1993), which ultimately distinguishes humans from other primates, and living beings from machines. Until bodies are relied upon in the making process. Therefore, while the craft sector, like much of the creative industries, might become more and more permeated with digital alongside analog processes, the fact that digital craft practitioners' minds and bodies will remain anchored to the physical world through *Tacit* material knowledge will preserve parts of human knowledge that distinguishes human making from automated making processes.

2) Parts of the making process need to include *polymorphic* actions as opposed to *mimeomorphic* sequences

In digital craftsmanship related literature, researchers (e.g., McCullough, 1998; Sennett, 2008; Latour, 2008; Pallasmaa, 2009), have often focused on the redistribution of agency between machines and practitioners within making processes, rather than studying the nature of knowledge acquired and transmitted by practitioners while using digital technologies. Through the participants' observations, the researcher was able to underline how in their opinion certain artefacts and making processes heavily rely on the concept of *Tacit Knowledge* if compared to others. Digital craft practitioners, reflecting on their own practice, emphasised the importance of drawing on material knowledge, balancing between digital and hand processes. Participants claimed that material knowledge is fundamental to consider examples of digital crafts as digitally *crafted* artefacts.

The researcher posits that digital craft practitioners draw on / promote *polymorphic actions* (Ribeiro & Collins, 2007) in their making processes as through these types of actions they are able to attain their *Tacit Knowledge*. Therefore, making sure that polymorphic actions are included in parts of the making process ultimately ensures a balanced distribution between the use of Tacit and *Explicit Knowledge* in digital craftsmanship.

3) Digital craft practitioners' main motivations and goals are bound to the making process as it expresses their material *contributory expertise*

All digital craft practitioners involved in the KRG study firmly differentiated a particular set of *elements* from the full repertoire, defining them as different from the rest because of the motivations and goals their practitioners had when made. Throughout the study they evidenced how these *elements* provided a designed embedded interaction for users/viewers to experience, differently from the others. For these digital craft practitioners, this information becomes the core and essence of the *elements* themselves, while physical materials (both craft materials and computational elements) take a subservient role in the outcome, turning into facilitators of the *experience* that the code was conceived and written for. In other words, in the KRG participant's opinion, the coded experience obscures the craft becoming a central actor of the piece as materials and techniques should always be central in digital crafts.

Drawing on the Critical Contextual Review the researcher was able to address how the *contributory expertise* (Collins & Evans, 2008) acknowledged and recognised by digital craft practitioners seemed to be linked to the practitioner's abilities to craft artefacts through making processes involving both digital and craft materials. Instead, the participants tended to identify the ability of certain practitioners crafting interactive experiences for possible viewers / users of the artefact[32] as a different kind of *contributory expertise.* Through Shorter's (2015) definitions of the *craft technologist* and *craft practitioner*, the researcher posits that digital craft practitioners align more with Shorter description of the craft *practitioner* rather than of the *craft technologist.* Although digital craft practitioners use digital technologies, similarly to *craft practitioners* craft materials are central in their making process.

6.3 Locating authoritative evaluators: other remarks on the community of digital craft practitioners

While facilitating the KRG study and through the analysis of the related gathered data, the researcher observed that the interviewed digital craft practitioners had in common a characteristic: the identification of certain artefacts as being –or not being– actual digital crafts, was strongly held to be bound to the judgement of *contributory experts* (Collins & Evans, 2007). While participants did not express this thought explicitly, the researcher perceived this underlying belief to be quite dominant in the way participants would assess a digital craft as being a digital craft or not and, as a consequence, in the way participant would recognise its author as a practitioner with affinity and analogies to the participant itself in their *contributory expertise* or not. This characteristic might not be unique to digital craft practitioners in that it might be a shared attitude in different practice-based fields. In particular, there is no evidence that it plays a key role in *defining* the community for its

[32] through the use of programmed functions of code and electric components

members as the *principles* described above. However, the researcher believes that it also contributes to a better understanding of the community in a wider comparative setting by describing one of its interesting features.

In the following the researcher will articulate further the underlying characteristic she identified as being tacitly shared among digital craft practitioners from an observer point of view.

6.3.1 The specific judgement and interpretation of contributory experts

A number of the Digital craft practitioners involved in the KRG study (e.g., J, V, C) argued that practitioners' different motivations and goals (discussed in subsection 6.1.2) are strictly dependent on the cultural background and premises (i.e., cultural values) of a community and how that relates to different moments in the developmental timeline of digital crafts as an area of research and practice. As articulated in Cluster 4 (subsection 5.3.4) , Participant V defined three questions referring to the motivations different practitioners might have pursued at different moments in the development of digital crafts as a field of practice (see section 5.2, Participant V, Grid t), namely:

1. "how can we push the [making] processes beyond?
2. how can we push the digital beyond?"
3. how can we push materiality beyond?".

Participant V defined the first one as the question posed at the "initial stage of the tradition of the digital" and referred to the second one as "a middle stage" and the third and last as the question practitioners posed more recently, in the "last stage of the tradition of the digital".

The researcher contends that while different motivations and goals followed by practitioners at different moments in time might be partially related to questions arising from technological changes in different periods (e.g., after the rapid development of cheap desktop 3D printers), it also heavily depends on the cultural context and the background of a specific practitioner and, consequently, the community he/she identifies him/herself with (e.g., in traditional crafts, in craft research, in computer sciences etc.).

As articulated in the contextual review and the *auto-ethnographic* and *ethnographic* chapters (3 & 4), *skills* play a big part in defining the specialism of practitioners which is then reflected in the artefacts they produce. The holistic nature of the process of crafting is complex and to become a specialised practitioner it takes more than learning a set of specific techniques or skills (Sennett, 2008; Crawford, 2009). As a matter of fact, practitioners need to be recognised as such by the cultural community to which they belong or aspire to belong. Therefore, skills are fundamental in marking practitioners' access to the community. Practitioners are able to enter communities with similar beliefs only once they are highly specialised and considered experts by other experts (Kuijpers, 2017). This ultimately generates an elitarian community of practitioners holding the same status of *contributory experts* (Collins & Evans, 2007). This was argued to be a characteristic of the general craft community thus the researcher argues that it is also characteristic of the community of digital craft practitioners.

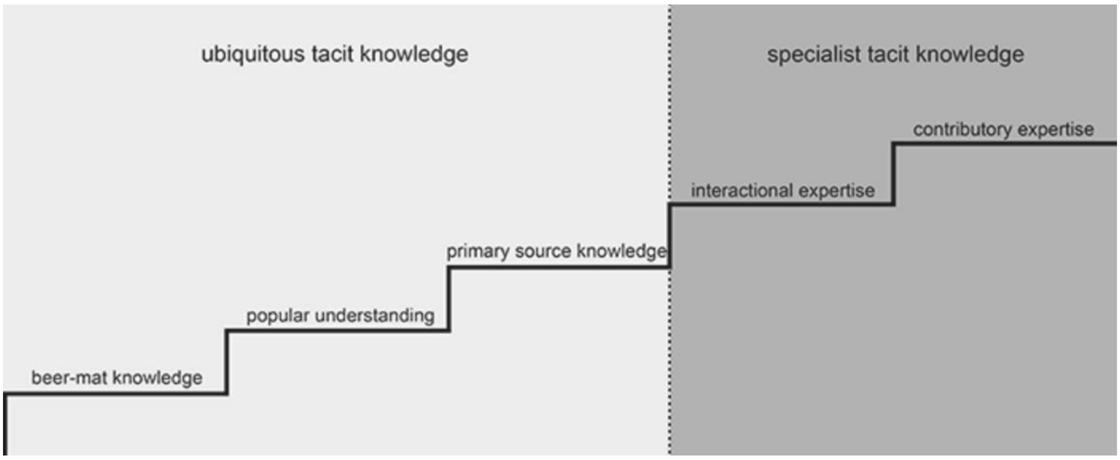
In their extensive work on expertise, Collins & Evans describe different practices where the "locus of legitimate interpretation" (Ibid., p. 120) lies. They refer to the latter, as the place where the judgement and interpretation of the outcome is legitimate when made by different actors (e.g., the author himself, peers of the community, a connoisseur, or the general public). This strictly depends on the community concerned with the judgement and interpretation of a piece and the culture in which the work is displayed. It must also be stressed that in certain fields the *contributory experts'* judgement on someone's work does not define the legitimacy of their inclusion in the community. In some fields more than others self-expression is one of the highest *principles* valued and, consequently, the *locus of legitimate interpretation* (Ibid.) might vary between the critics or the public. For example, in some cases a connoisseur of the specific field of practice (Nimkulrat et al., 2015) has more legitimacy in the judgement of a piece than a *contributory expert*. Instead, in other instances, non-experts (i.e., the general public) acquire importance in the judgement of a piece, especially if the viewers are also the consumers of the artefact displayed. This has strong implications over who ought to express judgement, develop opinions and define a meaning on a piece and on the legitimacy of the author of that piece in the access of a community; these interpretations might promote the artists' work or disregard it (Collins & Evans, 2007).

At the opposite end of the spectrum where contributory experts are fundamental to define the *locus of legitimate interpretation,* Collins & Evans place scientific communities. For scientific achievements, *contributory experts* accept or dismiss the results of one of the members within the community (i.e., a rigorous peer review process). Non-experts might acquire *interactional expertise* (Collins, 2004) over time and, therefore, they might be able to discuss results and to have a conversation about results and theoretical debates without being recognised as non-experts. Collins after years spent studying the sociology of gravitational wave scientists (Collins, 2017), and having immersed himself for decades among communities of gravitational wave scientists, demonstrated this point through a test: the *Imitation Game for Gravitational Waves*. The test involved a group of wave scientists and Collins himself. All participants had to answer a set of open-ended questions on the topic of gravitational waves created by *contributory experts* in the field. After completing the test anonymously and independently, a group of judges, all *contributory experts* in the field analysed the answers and asked to point out the non-expert. Collins iterated the test many times demonstrating how, by relying solely on his *interactional expertise*, he was able to successfully answer questions without the experts figuring out that he was the non-scientist within the group (Collins, 2017). This point showed how *contributory experts* might not be able to distinguish an *interactional expert* from a *contributory expert* through a test, or even through a dialogue. If a person with *interactive expertise* was immersed for long enough in a community of interest, he/she not only acquires knowledge of the matters discussed, but he/she also attains tacit understanding of the way *contributory experts* act in the world, the way they talk about things, including the details that should be omitted or stressed to acquire credibility. These characteristics cannot be learnt without being in direct contact with the community. However, when it comes to validating results that analyse technical knowledge or that require new knowledge generation, it soon becomes evident that only *contributory experts* can put their technical abilities into practice and can, therefore, truly *contribute* to new knowledge generation. That is why, within the scientific community, while theories and ideas might be discussed with the wider public, only *contributory experts* can contribute to knowledge generation.

Collins & Evans (2007) describe how these two types of knowledge (i.e., *interactional* and *contributory expertise*) are regarded as 'specialist tacit knowledge', which is distinct from what they define as 'ubiquitous tacit knowledge'. The latter consists of 'primary source knowledge', 'popular understanding' and 'beer-mat knowledge' which are considered to be the first kinds of knowledge to be acquired and that should be distinguished from specialist learnings. *Beer-mat knowledge* is the knowledge that can be acquired by simply reading a coaster at the bar. This kind of knowledge can be used to play games (e.g., Trivial Pursuit) but does not make the person holding *beer-mat knowledge* an expert in a certain topic. Instead, *popular understanding* is the kind of knowledge acquired through the reading of books or popular articles. *Primary source knowledge* derives from the understanding of research papers and theoretical readings (i.e., primary research). As illustrated in Figure 121, climbing the ladder we then find two main categories of expertises in the acquisition of *Tacit Knowledge*: *interactional* and *contributory expertise*.

Figure 121.

Different acquisition steps of expertise according to Collins & Evans (2008)



Note. From “On understanding expertise, connoisseurship, and experiential knowledge in professional practice” by Nimkulrat, N., Niedderer, K., & Evans, M., 2015, *Journal of Research Practice*, *11*(2), E1. Adapted from “*Rethinking expertise*” by Collins, H. & Evans, R., 2008, p.14. Copyright retained by the Authors.

Contributory expertise and *interactional knowledge* are very much dependent on *Collective knowledge* (Collins, 2010). These types of knowledge sit at the core of *Tacit Knowledge*, as they are at their strongest power of resistance to be transmitted because they derive from the recurrent involvement of humans in interactions and activities, both communicative and practical, with other humans. Two scenarios will now be articulated to explain through a practical example this point further. In the first scenario, the researcher will consider two learners that want to replicate for the first time an e-textile made by an instructor. Let's assume that one learner holds *contributory expertise* in textile making and coding while the second learner does not hold crafting or coding expertise (i.e., he/she is a novice). The instructor decides to demonstrate to the two learners the making process of the artefact in order to facilitate its production.

Starting with the coding process, if the instructor was to dictate every detail and both learners knew how to type and spoke the same language as the instructor, they would be able to replicate the exact same sample of code made by the instructor – assuming that between the instructor and the learner conditions related to the impediments of transmission of *Relational tacit knowledge* are not verified (subsection 3.2.1.2).

This is not to say that the *contributory expert* knowledge can be compared to that of a *novice* (Dreyfus & Dreyfus, 1986) or an *amateur* (Kuijpers, 2017). In fact, if the two were asked to explain the reasoning behind the coding or to reproduce the code a second time without the instructor's dictation, it is unlikely that, in contrast to the *contributory expert*, the novice would be able to succeed. It is important to stress that being code an example of *Explicit Knowledge*, strings of code afford the exact same interpretation for those that have the same linguistic understanding of the speaker, limiting any information loss and providing the means to be easily replicated by anyone.

Thus, let us imagine the instructor asking both the *contributory expert* and the novice to reproduce the physical qualities of the artefact. The instructor would give a demonstration while carefully describing each step of the making process.

Drawing on the Critical Contextual Review (Chapter 3) and the learning process articulated by Tomasello et al. (in subsection 3.2.2), in this scenario the *contributory expert* would possibly establish a *collaborative learning process* (Tomasello et al., 1993) from the start, ultimately achieving a result close enough to the instructors. As Tomasello et al. write, in *collaborative learning,* knowledge transmission does not happen from "mature to immature organism in the classic sense because, by definition, the situation consists of peers collaborating" (Ibid., p. 510). Thus, to collaborate over a process both practitioners need to be *contributory experts* (Collins & Evans, 2007) and this would be the case between the learner and the instructor. In contrast, the novice would not be able to reproduce the output for some time, due to his/her lack of expertise in the field. *Relational* and *Somatic tacit knowledge* (Collins, 2010) would be more difficult to overcome in order to successfully put into practice the instructions and acquire *Tacit Knowledge*. As seen throughout the Critical Contextual Review (Chapter 3) detailed descriptions on embodied actions cannot help accessing *Somatic tacit knowledge*. Only through an *imitative* or an *instructing* learning process (Tomasello et al., 1993) , through trial and error, and only through time and through embodied practice, the learner would gather the *Tacit Knowledge* needed to achieve a result close enough to the instructor's output without relevant information loss.

Making analogies with the researcher's lived experience as a novice in the setting up of the software for CNC milling settings, repeated attempts supervised by the *contributory expert* Justin Marshall were needed before the researcher as a novice was able to set up the machine alone. Drawing on Tomasello et al.'s (1993) cultural learning processes, the researcher was able to ultimately repeat the *instructed learning* experience provided by Justin Marshall. Justin Marshall, as the *instructor,* was able to break down different parts of the process in simpler acts for the researcher to emulate with his supervision. Then, thanks to the breaking down of the setting instructions, the researcher was able to take exhaustive notes on the explicit numerical settings necessary in the settings for the CNC milling production process. The interiorisation of those sets of values never happened in the short practical experience had-. Thus, the researcher started acquiring knowledge on how determined values related to the mechanics of the machine and sometimes, engaging with the machine alone. She was able to put into practice *imitative learning* strategies where, through trial and error, the researcher would attempt at setting up different values in the setting options in order to produce the designated output.

In this sense, experience helps in accessing more rapidly skills that are achieved through processes that are *Tacit* and certainly, through collaborative learning, contributory experts can collaborate and rapidly share experiences and absorb *Tacit* information from each other. As Ingold writes: “if knowledge is shared it is because people work together, through their joint immersion in the settings of activity, in the process of its formation” (Ingold, 2013, p.162-163). As discussed in subsection 3.2.1.4, collaborating and closely interacting with other practitioners is the only gateway that provides access to *Collective tacit knowledge* (Collins, 2010). Face to face communication with other practitioners from the same discipline is the most fruitful medium of exchange: sharing knowledge and the complexities of the discipline through workshops, meetings or demonstrations and exposure of one's artefacts to others, creates the basis to construct a solid identity of the community (Keller & Keller, 1996).

Drawing on Collins & Evans (2008) studies an analogy between the scientific community and the digital craft community can be drawn. While being a very different field of research from the one of gravitational wave scientists, the researcher herself experienced early in the research process the importance of *contributory expertise* for communities working within craftsmanship. In the first workshop conducted with craft practitioners, the researcher produced and introduced her own imperfect artefacts to experts in the field (see Chapter 4) and the artefacts were judged by a participant as “scrap bin pieces" (Vannucci et.al, 2019, p. 14) and were immediately disregarded. These examples were interpreted as pieces expressing poor technical abilities and material knowledge and, while the researcher knew that if compared to other examples that was indeed the case, it was clear that the novice attempt was immediately disregarded rather than encouraged and that the experts did not even consider the piece as being crafted. The researcher soon realised that in the community of craft practitioners, demonstrating expertise in craft material knowledge is fundamental to define an artefact as *crafted*, and to validate a *craft practitioner* as such. Therefore, a practitioner wishing to identify him/herself with the community, would have likely had to produce an artefact showing his/her *contributory knowledge* in that specific area. Throughout the data analysis and discussion of the KRG study, digital craft practitioners, like craft practitioners, also tended to have very specific *principles* on what should or should not be considered as a digital craft and who should or should not be considered a digital craft practitioner.

Therefore, the researcher posits that within the community of digital craft practitioners, as in the wider community of craft practitioners, *skill* is a culturally laden term strictly depending “on the cultural reference of what is considered ‘quality’ ” (Kuijpers, 2017, p.140) within a specific community. In craft communities, as expressed through the insights gained from the workshop (Vannucci et al., 2019 [Appendix E]), and later from the KRG study with digital craft practitioners, as the *control* of specific materials and techniques grows throughout their serendipitous opportunities, arguably the *value* of the outcome also grows alongside. As a consequence of the increased quality of a piece, prestige, rank and status are reinforced in the practitioner as long as his/her *skills* improve and continue to contribute in the field.

As seen in the Critical Contextual Review (Chapter 3), people have the need to identify themselves as part of a social group and members of a group tend to construct and idealize some form of unity of experience that reinforces the social group (Mead, 1913). These *principles,* especially in a community of practice like the one of digital craft practitioners, need to be reflected in the outputs produced by its members. As seen through the KRG study (subsection 6.1.2 & section 6.2), all six participants in the study identified four *elements* as a different grouping if compared to the others. In the reflections that followed these decisions, participants stressed how the artefacts, rather than leaning towards the self-expression of their authors, were designed to provide an experience for a user which, consequently, positioned the possible user at the center of the crafting process. The researcher posits that the reason why those artefacts were differentiated from the repertoire is also that, within those artefacts, the users' interpretation on the output has a wider relevance than on the other pieces in order for them to be successfully interpreted. Instead, in the other *elements* the interpretation of the pieces is left to *contributory experts*. Like in the case of scientists, when the results, or creation of new theoretical problems, are interpreted by *contributory experts* who will determine their validity and quality, a digital crafts' quality is strictly dependent on the judgement of expert digital craft practitioners. When it comes to identifying whether a specific practitioner's digital craft expresses his/her *Tacit Knowledge*, and whether the motivations and goals bound to the production of the artefact are aligned with motivations and goals in the field, the relevance of *contributory expertise* acquires a regulatory bar strictly dependent on the few *principles* identified and possibly on more. *Contributory experts* are the ones providing –or not providing– access to the community to newcomers.

The researcher stresses that taking into account other communities widely using digital fabrication technologies such as the Maker Movement (Morozov, 2014), as briefly described in the Critical Contextual Review (Chapter 3) there are no regulatory processes determined by *contributory experts* that include or exclude participation. In the *Maker Movement Manifesto* (Hatch, 2013), the key *principles* of the movements are *to make, share, give, learn, tool up, play, participate* and *support*. Within the Manifesto itself, Hatch writes: "In the spirit of making, I strongly suggest that you take this manifesto, make changes to it, and make it your own. That is the point of making." (Hatch, 2013, p.1). The spirit of the Maker Movement is largely encapsulated in this sentence as it represents well the values of open creativity, self-expression and inclusivity which are considered more important than in depth *material knowleldge*, skilled demonstration of *technique* or the *quality* of final outcomes. While there are people in the maker community certainly considered *contributory experts* in one area or another, their judgments do not weigh more than other makers in the field and, specifically, they are not gate keepers, accepting or declining the entry of novice makers wishing to be part of the community.

Therefore, the researcher believes that a characteristic of digital craft practitioners as a community is that **the identification of certain artefacts as being, or not being digital crafts, is bound to the judgement of *contributory experts***.

Regulating the entrance of novice practitioners in the community of digital craft practitioners, on the one hand results in a very small community of experts, producing very refined artefacts that can be distinguished by other communities for their excellent technical and aesthetical qualities, showing padronance of craft and digital materials. On the other hand, the researcher posits that the closure of the community among dislocated *contributory experts* has a very relevant negative impact on the transmission of *Collective tacit knowledge*. This point will be further discussed in the conclusions (Section 7.1).

CHAPTER 7. Conclusion

Digital crafts that in their constitutive features show diversity of practice, cross-fertilisation, and interdisciplinarity, were recently considered as artefacts belonging to a “fuzzy area”, with little to no delineation of a *distinct area of research* (Frankjær & Dalsgaard, 2018; Nitsche & Weisling, 2019). From the first steps within the project, based on the evidence of the Critical Contextual Review (Chapter 3), the researcher understood that in the researched context, practitioners producing digital crafts are, as a consequence, not clearly defined as *one* community of practice with a shared and defined set of values or *principles*.

While practitioners working in the field all acquired to a certain extent competences in both material knowledge and digital technologies, the researcher at the beginning of her research process recognised the community as a non-homogenous community of practice constituted of:

- technologists working with craft- processes;
- craftspeople adopting digital production tools;
- craftspeople adopting digital interaction tools;
- digital natives who have only ever used digital tools in their making processes.

To help in the initial framing of the community of interest to focus on, the researcher tentatively concluded that a general and inclusive interpretation of the term *digital craft practitioner*, combining Risner's (2012) *technepractice* and Shorters’ (2015) description of the *craft practitioner* and *craft technologist,* could be used as starting points (see Section 3.1).

Thus, the researcher soon realised that the few works aiming at describing digital crafting characteristics in the field of design research (e.g., Risner, 2012; Shorter, 2015), were authored by practice-based researchers using digital craft approaches. Hence, they tended to rely heavily on their author's own experiences and their personal views of the world as practitioners. These gaps evidenced that there was space to pose the research question:

- **What are the underlying *principles* that characterise a digital craft practitioner's ethos?**

Moreover, through the literature reviewing process, the researcher noticed that only few practitioners suggested connections between *craftsmanship* and *tacit knowledge* in design research (e.g., Niedderer, 2007a; Nimkulrat et al., 2015), but without expanding on digital craftsmanship specifically, or on *explicit knowledge* and its possible subsidiary role in establishing distinctions within the body of *tacit knowledge* (Collins, 2010). Therefore, the overarching question later evolved and the research frame was expanded through two sub-questions, namely:

- **What is their significance in relation to understanding forms of knowledge acquisition and transmission in the field of digital craft?**
- **What are the implications of this new understanding for the field of digital craft?**

In the following sections the researcher will describe how the aims and objectives of the research were met (Section 7.1), address the value of the articulation of the *principles* (Section 7.2), and speculate on future research opportunities deriving from the articulation of the *principles* (Section 7.3). Moreover, the researcher will point out the limitations and advantages of the methodologies used (Section 7.4).

7.1 Meeting the aims and objectives

The notion of *principles* refers to a research study produced in 1996 by Keller & Keller, where the scholars were able to articulate some shared values (i.e., *principles*), describing the situated learning behind the practice of blacksmithing. Through their attentive analysis of conversations between smiths, and the observations made by Charles Keller during his apprenticeship with a blacksmith, Keller & Keller articulated qualities “expressed implicitly in their [the blacksmiths’] products, performances and literature” (Keller & Keller, 1996 p.52).

The researcher, to address the research questions achieving similar goals to the ones achieved by Keller & Keller, initially adopted an *auto-ethnographic* and *ethnographic* research processes. Thanks to practice-based experiences and observations carried out with expert digital craft practitioners (see Chapter 4), the researcher was able to gradually develop her *interactional expertise* (Ibid.) in the field, meeting the objectives of:

- exploring the nature of craft practices through extended observation and discussion with a range of craft practitioners.
- undertaking a series of making projects within the context of a digital crafts practice.

However, over time, the discussions held with practitioners while using the *ethnographic* methodology were not evolving in breadth and depth hoped for. Hence, the researcher realised the need of a change in the methodology. It is therefore through the adoption of a *para-ethnographic* methodology (Chapter 2, Section 2.4) that the researcher managed to better support her research aims. Using *heterophenomenology* (Dennett, 2003) as a method to articulate the characteristic features and beliefs shared by practitioners with very different backgrounds and working within the broad spectrum of digital craftsmanship, the researcher was finally able to identify three *principles* characterising digital craft practitioners as a community. The researcher recognizes that this was possible not only for the *para-ethnographic* approach used, but also thank to the *interactional expertise* previously acquired through the adoption of the *ethnographic* methodology. Through this study, the researcher was able to confirm the value of *interactional expertise* in a different field of practice than the one of gravitational wave physics that was used originally by Collins to develop this concept (Collins, 2017).

Moreover, the aim of better understanding and articulating digital craft practitioners as a community, was achieved through the central role of Kelly's Repertory Grid (KRG) framework, in its readapted version. While KRG had been previously used by different researchers in the field (Chapter 2, Section 2.4.1), the researcher readapted the method specifically to the research needs. Hence, through a readaptation of Kelly's Repertory Grid method and with the necessity of readapting the framework to run the grid fully in remote, the researcher was able to meet the objective of:

- facilitating a series of structured activities and interviews with expert digital craft practitioners that could inform a theoretical and contextual understanding of digital craftsmanship (Chapter 5, Section 5.1).

Through the analysis of the gathered data from the KRG study, while drawing on theoretical concepts from a number of authors and fields of study that had not been used for the understanding of digital craftsmanship before, the researcher was able to address the research questions providing:

- an examination on the types of knowing within digital craft practices, with a specific focus on the ways in which knowledge is acquired and transmitted (Chapter 6, Section 6.1);
- the identification and articulation of three *principles* describing digital craft practitioners' ethos (Chapter 6, Section 6.2).

Namely, digital craft practitioners: **(1)** nurture creative complex imitative learning through craft material knowledge and (**2)** strongly believe that at least some aspects of the making process must include "polymorphic" actions (tacit forms of doing things) as opposed to "mimeomorphic" sequences (following a precisely defined sequence of actions). Moreover, **(3)** digital craft practitioners' main motivations and goals are bound to the making process as it expresses their material *contributory expertise.* Furthermore, by observing the participants and reflecting on the discussions undertaken while running the KRG, the researcher realised that the identification of certain artefacts as being, or not being, digital crafts is strictly bound to the judgement of *contributory experts* in the field.

While this is not an exhaustive list of *principles*, it has value in that it gives nuances to what, over time, became a "fuzzy area" (Frankjaer & Dalsgaard, 2019) and gives a clearer overview over a community whose outcomes as *digital crafts* were sometimes described as "an unspecific amalgamation" (Nitshe & Weisling, 2019, p.684) of neither craft traditions nor digital technologies. The *principles* can be a starting point for further articulation and description of the community and can be used to drive recommendations that would be useful to the sector (Section 7.3).
By identifying certain parts of the making process that, being *Tacit*, have a higher degree of resistance to being made explicit, the researcher was able to:

- Underline the importance of scaffolding the transmission of tacit human knowledge between expert digital craft practitioners and novices (Section 7.2);
- Articulate and further contextualise the relevance and value that the identification of digital craftsmanship *principles* provides for the future development of the craft sector (Section 7.2);
- Define *four* strategies to further develop and establish sustainable ways to ensure effective future transmission and acquisition of *tacit knowledge* in digital craft practices (Section 7.3).

7.2 The relevance and value of the identification of digital craft principles for the development of the broader craft sector

In digital craftsmanship the nature of the making processes allows for very skilled and expert makers to engage with digital machines and use hand-making techniques. While these processes are entangled and intertwined, it becomes counterproductive both to polarize and differentiate the two, or to create analogies between aspects of material knowledge of very different nature (i.e., craft materials and digital materials). As discussed in section 6.1, the outcome of a digital craftsmanship process is dependent on the practitioners' expertise in both choosing materials / making processes allowing for serendipitous acts and in promptly making decisions and acting on them when facing some unpredictable occurrences. This suggests that as with any other crafting tools, machines might also hold an *epistemic character* (Luscombe, 2017) (see subsection 6.1.1). Hence, the researcher posits that treating craftsmanship and digital craftsmanship as separate making processes is counterproductive since digital craft practitioners themselves heavily rely on *Tacit* aspects of knowledge. Under these premises the nomenclature 'digital' might be obsolete in crafts deriving from making processes heavily reliant on *polymorphic* actions and *Tacit Knowledge.*

Examples of outcomes deriving from making processes heavily reliant on *polymorphic* actions and *Tacit Knowledge* could be considered simply as 'crafts' as they are fundamental in promoting and preserving human dexterity and future *Tacit Knowledge* transmission and acquisition, as much as any traditional craft produced with other sorts of technologies (e.g., a hammer, a saw).

As previously underlined by Niedderer and Townsend (2014) "recognizing experiential and emotional knowledge as agents for intrinsic understanding, interpretation and judgement and articulating them is key" (Niedderer & Townsend, 2014, p.641). The same researchers also write that "it is essential to make these values and judgements explicit as part of any research" (Ibid.). In connection with this, it is worth recalling the concept of *Relational tacit knowledge* (Collins, 2010) previously articulated in the Critical Contextual Review (Chapter 3, subsection 3.2.1.2); these layers of *Tacit Knowledge* have a lower degree of resistance to be made explicit. These cases are identified by Collins as: *Concealed knowledge, Ostensive knowledge, Logistically demanding knowledge, Mismatched saliences, Unrecognised knowledge* (Collins, 2010) (thoroughly described in section 3.2). Only if these cases of resistance do *not* apply to aspects of practitioners' knowledge of their making process, they would be able to easily articulate (i.e., describe) the making processes through their understanding, their values and their judgements. Practitioners can also express their embodied practices through the analysis and articulation of their *Somatic tacit knowledge* (Collins, 2010), as described in Leach's (1945) example in the Critical Contextual Review (subsection 3.2.1.3). However, this would still not be enough to transmit the entire body of relevant *Tacit Knowledge* but would give access to those *tacit* parts that are, with some effort, articulable. Only collaboration with others ultimately gives access to the deeper layer of *Tacit Knowledge* which is *Collective* (Collins, 2010) and transmissible through interactions with others and practice in the field with others. Therefore, it is important to remind ourselves that while being able to verbally explicate aspects of *Tacit Knowledge*, we will never be able to transform *Tacit Knowledge* into *Explicit Knowledge* (Ibid.). Consequently, it is incorrect to claim that *Tacit Knowledge* can be explicated without also mentioning the different degrees of tacitness and their relation with the notion of *Explicit Knowledg*e.

Through the analysis of digital crafting making processes in relation to knowledge theories, the researcher could point out how, while some parts of the digital crafting process are communicable and easily made *Explicit* (parts related to coded *strings* and *mimeomorphic* actions (Collins, 2010)), other parts (the ones related to *polymorphic* actions) are *Tacit* and, as such, cannot be made *Explicit* in any circumstance while there are levels (and types) of *Tacit Knowledge* than can be communicated and amenable to at least partial effective transmission. For this reason, when knowledge cannot apparently be transmitted, or when "the tacit knowledge that sustains expertise" is not "made explicit nor is it easily articulated" (Nimkulrat et al., 2015, para.2), it should be first ascertained whether the knowledge to be transmitted pertains to *Relational tacit knowledge* with the associated possible knowledge transmission activities (thoroughly articulated in Chapter 3, Section 3.3.1.2) or *Somatic knowledge*. Otherwise, it is never a matter of "explaining better" (Collins, 2010): the *Tacit Knowledge* involved cannot actually be made *Explicit* but it could potentially become explicit, in the sense of *explicable* (i.e., you might be able to explain it partially but never fully).

Moreover, while acknowledging that there might be a number of different reasons for limiting the effective explication of certain aspects of *Tacit Knowledge,* also the *interactional ability* of *contributory experts* should be taken into consideration as a facilitator of such transmission. If *contributory experts* have a *latent* and, therefore, underdeveloped *interactional expertise* (Collins, 2004; Collins & Evans, 2008), most probably they will not be able to recognise in their making processes parts of *Tacit Knowledge* at their lower degree of explicitation. Hence, parts of their making processes might never be better explained and articulated until their *interactional expertise* is developed.

It has been already argued that while digital technologies have until now relied on an "instruction-based construction model" (Menges, 2015, p.32), where they follow precise codable instructions (i.e., "do action A, do action B") they could soon jump to "behaviour-based" (Ibid.,p.32) construction models. As Menges (2015) articulates:

> "production machines no longer remain dependent on a clear set of instructions cast in determinate control code, they are increasingly capable of sensing, searching, processing and interacting with each other and the material world in real time, opening up the possibility of truly explorative processes of computational construction that merge design and making" (Menges, 2015, p.12).

This means that machines will slowly acquire capabilities to adapt to circumstances that might happen in real time while they are operating (i.e., if X happens then do action A, if Y condition occurs then do action B). To make this possible, the conditions under which the machine can operate must be all collected in a vast programmed library. Moreover, with the advent of new materials, algorithms, and machine learning (i.e., Artificial Intelligence):

> "Gone is the idea of dump machines that simply execute static and predetermined tasks, replaced with that of production environments that allow the processes of fabrication, assembly and construction to have a say in the forms we create. Materialisation thus becomes an active driver of design, not only through the anticipation of its affordances and constraints in the domain of virtual design computation, but also by extending this towards the physical computing of form, structure and space during ongoing material unfolding" (Ibid., p.32).

The researcher maintains that while machines to some extents have gained the ability of sensing and reacting to unexpected occurrences, based on the studies on *Tacit* human knowledge undertaken by numerous scholars (Ryle, 1945; Polanyi, 1966; Tsoukas, 2005a; Collins, 2010), future digital machines will not be able to access, acquire or develop *Tacit Knowledge* unless the will be able to fully interact in a human community. This is because through socialisation and human activities it is possible to access those layers of *Tacit Knowledge* with the highest degree of resistance to *Explicit* transmission: *Collective tacit knowledge* (Collins, 2010). Thanks to Collins expansion on the concept of *Tacit Knowledge* and his previous studies made on *polymorphic* and *mimeomorphic* actions (Ribeiro & Collins, 2007), it appears clear how embodied skills acquisition, in combination with social skills, are, and will always remain, *Tacit Knowledge*. *Polymorphic* actions have "no available instructions on how to vary the behavior associated with the action in order to carry it out successfully" (Collins., p.1419) and this is because they are based on *Tacit Knowledge*. For this same reason while humans rely on *tacit* human knowledge when making, what they do will never be able to become entirely *Explicit* and translatable into *strings* (i.e., language and ultimately code) (Collins, 2010). Hence, while our culture might become more digital than analogue, our human brains and bodies will remain anchored to the physical world. If digital craft processes were to rely on *mimeomorphic* actions, which are generally redundant and carried out always in “the same way” (Collins & Kusch, 1998, p.47), these actions would be more easily translatable into codable instructions. In fact, digital machines are able to mimic simplified human movements or processes, not considering, or needing further consideration or understanding of the surrounding actions. Machines will still be set on a library of knowledge-based routines to rely on in case of necessity. Thus, these information will be *mimeomorphic actions* and not *Tacit, polymorphic* actions which means that they will never require the human intrinsic ability of *complex thinking* (Crawford, 2009) which is ultimately crafts practitioner’s and digital craft practitioner’s power. While AI has already successfully been used even for complex physical and cognitive tasks (e.g., automation in driving, manufacturing, and decision-making systems), taking part in social exchanges and being able to naturally select and absorb *Tacit* information in the way humans do, is arguably the only way for machines to significantly become competent in human activities.

In this thesis it is proposed that the identification of the *principles* suggests that more research on the topic of digital craft-based approaches in relation to knowledge and knowledge-transmission issues should be undertaken in order to increase clarity and validate the importance and value of human knowledge over and above the *mimeomorphic actions* embodied in digital technologies’ making processes.

The value of the articulation of these characteristics is twofold: on one hand it contributes to developing some theoretical clarity to debates on the nature of digital craftsmanship in the design research field and beyond. On the other hand, by framing digital craft practices through the notions of *Tacit* and *Explicit Knowledge* it also helps to focus on, and address, key issues concerning their acquisition and transmission.

7.3 Future research

The researcher concludes that to ensure the transmission and acquisition of those aspects of *tacit* human knowledge identified in digital craft practices, future research should focus on four main aspects. These aspects will be articulated below together with *four* suggestions of possible future research activities that could be conducted in the area.

1. **Testing and further articulating the *principles* with the help of the community identified**

In this research much effort was spent in the articulation of *principles* describing the community of practice producing *digital crafts*. While three *principles* were articulated, the researcher believes these should be considered as being in their initial framing stage rather than their final one. Indeed, the principles could be tested and further explored within the community addressed. Therefore, the researcher argues that future research should include a revision of the three proposed *principles*.

The revision process could be carried out in two ways:

a) *Facilitating a workshop with all the Participants engaged in this KRG study with the aim of discussing the three principles and their definition.*
   Understanding whether the same Participants involved in the study feel that these *principles* confidently reflect their role as craft practitioners would bring

this research forward through the revision and potential rearticulation of the three *principles*.

b) *Facilitating a workshop involving new participants with the aim of uncovering new principles defining the community.* A continuous refinement of the *principles* is possible as the presented outcomes should represent a solid basis from which new *principles* of the community could be further explored. The same revised method of the KRG used in this project could be used, but the range of participants involved in the process and/or the set of *elements* chosen to run the KRG method should vary.

2. **Creating tools and frameworks that can help *contributory experts* in the practice to further develop their reflective ability and *interactional knowledge***

The researcher proposes that educational systems and future studies on digital craftsmanship should focus on further developing ways to support *contributory experts* in the development of their *interactional knowledge* whenever that is *latent* (Collins & Evans, 2007). As discussed throughout the thesis, while *interactional experts* don't necessarily hold *contributory expertise*, *contributory experts* always hold *interactional knowledge* at least to some extent (Collins, 2004). However, often, their practical skills are more nuanced and expressed than their reflective and *interactional* abilities.

As discussed extensively throughout the thesis, properly articulated *interactional* skills are difficult to acquire unless one has a natural disposition to self-reflect, discuss, converse, and write about one's work and making processes. Therefore, *contributory experts* that do not extensively reflect and express their thoughts on specific making processes, while they might either just not want to do so (e.g., *concealed / ostensive knowledge*), they may not know how to do so or where to start from. Therefore, the researcher suggests that more studies and attention should be placed on the development of frameworks and tools that could support their reflective abilities and the development of practitioners' interactional *skills* further. Frankjaer and Dalsgaard (2020) recently published a framework with the aim of helping practitioners working with craft-based approaches in the HCI domain to understand the new forms of knowledge and the creation of new artefacts generated within the field. They write:

> "Our intended audience is researchers engaging with crafts-based approaches to inquiry in HCI and design, for whom the proposed framework may be of epistemic value to understand their own work or that of others, as well as researchers engaged within the ongoing discussions about knowledge creation in HCI and design" (Frankjaer & Dalsgaard, 2020, p.2).

While methods and frameworks used in other disciplines could also work in the facilitation of such reflective processes (e.g., Kelly's Repertory Grid), creating new frameworks specifically tailored for the wider sector of craft practitioners, or more specifically for digital craft practitioners, could support researchers using craft-based approaches to express qualities of their work that could help to position their work in the wider field of design research. The researcher argues that conducting further *para-ethnographic* or *participatory* (Simonsen, 2012) research with the community of digital craft practitioners would help in structuring exercises framed to support practitioners' reflective skills.

3. **Providing actionable means to promote encounters between digital craft practitioners in order for practitioners (and novice practitioners) to access and transmit Collective layers of tacit knowledge**

Following the discussion in Section 6.3, the researcher posits that the regulatory authoritative evaluative process adopted by digital craft practitioners is based on the importance given by participants to *contributory expertise*.

On the one side this approach allows for an attentive selection of practitioners reflecting precise *principles* (1,2,3) and, consequently, producing digital crafts demonstrating highly technical and specialised skills. On the other hand, it strongly limits a wider influence of the community on potential novices, limiting the transmission and acquisition of *tacit* forms of human knowledge.

Such issue is stressed more often in the wider craft sector where traditional craftsmanship making processes and techniques are often valued based on the likelihood they would survive to the next generation based on intangible cultural heritage safeguarding principles (see HCA Red List of Endangered Crafts[33]).

Accordingly, the researcher believes that as much as in traditional craftsmanship, if collaborations among *contributory experts* or between *contributory experts* and novices remain exceptional rather than routinary, they will have no significant positive effect on *Tacit Knowledge* transmission and acquisition in the digital craft sector. Not being exposed to other *contributory experts* or novices, digital craft practitioners are not frequently expressing their *interactional expertise* (Collins, 2010) which consequently might "become *latent* rather than expressed" (Collins & Evans, 2007, p.37). In turn, this would limit their ability to expose even that part of knowledge at its lower degree of resistance to being made explicit: *Relational* and *Somatic tacit knowledge* (Collins, 2010).

Despite a non-collaborative approach might at first sight seem to the detriment of only novices in the acquisition of new techniques, it is also counterproductive for expert practitioners as well; not explaining or sharing their *contributory expertise*

[33] https://heritagecrafts.org.uk/redlist/

with others, and not being pushed to reflect or speak about techniques or one's practice, naturally leads *contributory experts* to keep their *interactional expertise* at an underdeveloped level. In other words, unless practitioners have ways to reflect and talk about their own practical experience, motivations and goals, they will not be able to ultimately interact with others fluently about their own field and expertise. Hence, others, both *interactional experts* with *contributory expertise* and *interactional experts* without *contributory expertise*, would gain from more space to discuss within the field. This has often happened in the craft field, where sociologists or anthropologists have been contributing theoretically to the field often without holding any *contributory expertise* in it (e.g., Ingold, Sennett). As it happened in the wider craft sector this could also happen in the field of digital craftsmanship, unless *contributory experts* in the field continue to express and develop further their *interactional expertise* alongside their practical skills.

The researcher believes that helping practitioners to develop or express their, sometimes latent, *interactional expertise*, could generate new *interactional* opportunities with other practitioners in the field or with the broader community of researchers and practitioners. The site *The Grymsdyke Farm*[34] in Lacey Green, Buckinghamshire, United Kingdom, that was established by Dr. Guan Lee is an example of a space that was created to promote encounters among practitioners and students to experiment with materials and design. Encouraging *social exchanges* (Tsoukas, 1996) is fundamental as it would force *contributory experts* to express aspects of their practice in different ways than if they were to write a manual or a set of instructions for others or themselves. More opportunities of exchange and spaces such as *The Grymsdyke Farm* could promote apprenticeships and cross

[34] http://www.grymsdykefarm.com/

collaborations through residencies, conferences and workshops among practitioners working with different materials and techniques. While this to a certain degree happens in educational and research realms and while the UK Craft Council often facilitates events among makers[35], the researcher argues that it would be beneficial if public funds would be allocated regularly to activities and research projects focusing on:

(i) promoting cross-disciplinary, practice-based activities / workshops among craft practitioners and digital craft practitioners.

(ii) promoting cross-disciplinary, practice-based activities / workshops among digital craft practitioners working with different materials and / or techniques.

(iii) promoting apprenticeships among digital craft practitioners that are aimed at contributory experts and novices.

The researcher believes that the Crafts Council in the UK and local craft councils in other territories could facilitate further these processes in order to make sure that digital craft practitioners' encounters would not solely involve practice-based researchers using craft-approaches but would also include independent practitioners willing to share their thoughts with a community. Such events should include moments of *collective* practice where digital and craft skills are shared, and *Tacit Knowledge* could be potentially transmitted or acquired, together with *interactional knowledge*.

Whereas, in the educational system and specifically within the craft research field the researcher proposes that there could be further ways to promote the objectives mentioned above. As an example, one might consider introducing specific merit

[35]The most recent event that the researcher participated in was *"Touch: Reflections on making",* a collaborative event produced by the Crafts Council and the Centre for Fine Print Research at the University of the West of England (10-11 December 2020). The event was conducted online due to COVID-19.

points in the UK's annual Research Excellence Framework[36] (REF) to those researchers who successfully train novices through apprenticeships in their field (including other academics willing to learn specific skills). More generally, improving the status of communicating knowledge in ways beyond text-based publications should be further promoted, incentivised, and rewarded as a specific merit value.
As discussed, establishing *Collective experiences* as a frequent shared and valued habit of practice would be beneficial to the aim of opening practitioners to new *collaborative learning* (Tomasello et al., 1993) processes. Such encounters would lead to the training of practitioners' *interactional expertise* and the access to the deepest level of *Tacit Knowledge: Collective knowledge* (Collins, 2010).
Collective knowledge, which cannot be articulated and explicitated, can be accessed just through practice and interactional exchanges within the community. Hence, the researcher stresses that while regulating the entrance to the community of digital craft practitioners through principles defined by *contributory experts* in the field, the importance of discussing and articulating these principles through *interactional expertise* (Collins & Evans, 2007) should be the highest priority for the community of digital craft practitioners, researchers, and educational systems in general.

4. **Identifying those processes within specific making processes that, being tacit, require more dedication in the acquisition and transmission of knowledge**

Through this research into digital craftsmanship, the nuanced nature and scope of *Tacit Knowledge* and *Explicit Knowledge* have proven to be key aspects in understanding and articulating *principles* that underlie the digital craft practice. Taking a much broader perspective and on conclusive note, the researcher stresses

[36] https://www.ref.ac.uk/

that in order to innovate and contribute to future making, investing in the preservation and transmission of the human intrinsic abilities of complex thinking is fundamental.

As seen at the very beginning of this research, the ability of the craft practitioner is to simultaneously comprehend, think openly and engage with the world around them, which is an ability that is strictly subjective, *tacit,* and human. While any making technique that involves embodied actions is valuable, the term *craftsmanship* is rightly appropriated when it refers to making processes that heavily rely on *Tacit Knowledge*. Studying the community of digital craft practitioners, the theme of *Tacit Knowledge* and its association with *craft* materials and techniques appeared to be fundamental for these practitioners as well. The researcher posits that those processes heavily relying on *Tacit Knowledge* are the ones in need for more dedication in their acquisition and transmission in that they depend on community exchanges and collaborations over an extended period.

Therefore, the researcher suggests that future research on the identification of the nature of knowledge related to specific digital craft making processes would greatly impact future preservation of craftsmanship knowledge as human intangible cultural heritage[37]. Indeed, future research focusing on the attentive analysis of crafting processes would contribute to highlight those parts of the process heavily relying on *Tacit Knowledge* and those that are rather *Explicit*. Any bit of *Tacit Knowledge* that is not effectively transmitted and that 'dies' with its practitioners (i.e., without being first acquired by others), is effectively a human skill that will no longer be able to characterise and testify human's manual dexterity (i.e., *polymorphic actions*). *Tacit knowledge* is what differentiates –and perhaps will always differentiate– humans from machines. Therefore, the researcher argues that theoretical research on the

[37] https://ich.unesco.org/en/lists

identification of the nature of knowledge in different bits of digital crafts making processes it is crucial in this moment of time.

While embracing technological innovation, digital craft practitioners should provide or be provided with ways to further express, transmit and ultimately preserve every bit of *Tacit Knowledge.* As for traditional craft practices, this should be a priority not only for the community of digital craft practitioners but for the whole design research community, worldwide educational system, and humankind.

7.4 Limitations of the study

Within the time period the research was carried out, the researcher had to face the changing circumstances imposed by the COVID-19 pandemic. Due to the restrictions experienced during the pandemic, proximity with participants or proximity among participants in the research had to be reduced and avoided. The changing nature of restrictions and recommendations related to COVID required the researcher to re-adapt the case study design a number of times, in an attempt to find the best structure within the available possibilities.

The researcher speculates that proximity within the facilitation of Kelly's Repertory Grid process would have perhaps enriched the insights and the discussions with the participants. The ability to select a repertoire of artefacts that could have been collected by the researcher and exposed to each participant while running the KRG in person might have addressed different or more nuanced debates related to the physical qualities of the artefacts. Although participants often already knew the pieces shown in the repertoire, the researcher acknowledges that the ability to experience the artefacts directly might have changed the perspectives of the participants. This must be taken into account as a limitation of their judgement on the artefacts.

Moreover, the researcher believes that a second study bringing all participants together in a collective workshop with each participant bringing along one of their pieces, could have been a valuable addition to the methods deployed and resulted in further developments of the *principles*. From a wider perspective of defining a community and helping practitioners expressing their *interactional expertise* with other *contributory experts* in the field, meeting together as a group rather than solely with the researcher, would have been insightful and enriched the research. However, while this kind of encounter would have provided further debates and insights on the subjects under discussion, participants might have not talked as freely while discussing pieces created by other participants as they did with the researcher.

A positive aspect of the way in which the study was re-designed and conducted due to the circumstances was that it gave the researcher the chance to access practitioners dispersed geographically with a very limited budget. The researcher was able to address diverse practitioners from the community living in Europe, rather than practitioners solely based in the UK.

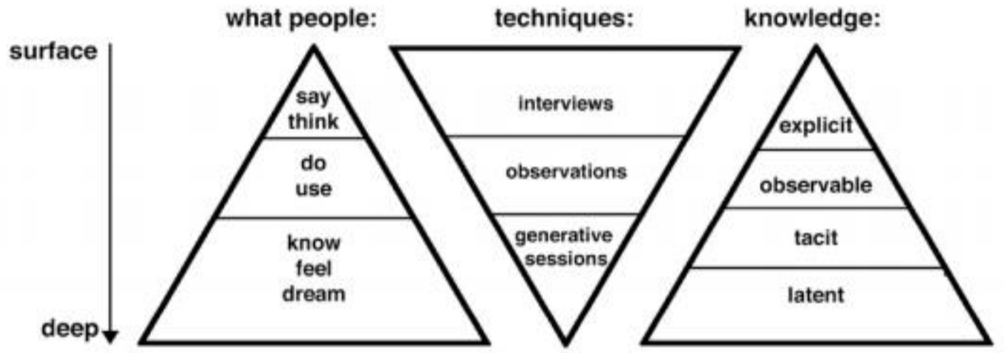
7.5 Final remarks – methods, knowledge acquisition and the concept of Tacit Knowledge

As a final word the researcher would like to address how the concept of *tacit knowledge* is often misused, or oversimplified, in design research methods and techniques. This thesis has sought to bring more nuance to the discussion of knowledge acquisition and transmission/communication and has recognised its complexity. As an example the researcher would like to highlight the limitation of a specific design research technique addressed at the very beginning of the methodology chapter (Chapter 2) and illustrated in Figure 122. This figure is an attempt by Visser et al. (2015) to represent Sanders (2001) previous studies on the different techniques that design researchers can use to attain and access differing levels of participants' knowledge through a design study.

As illustrated in Figure 122, it is claimed that to access those layers of knowledge which can be made 'explicit', designers should use techniques such as *interviews*. Thus, in order to reach *latent* or even *tacit* layers of knowledge, Sanders argues for the use of *generative sessions* as techniques enabling deeper insights (2001). *Generative sessions* are techniques that can be used by design researchers to guide participants in the construction and expression of "deeper levels of knowledge about their experiences" (Visser et al., 2005, p.122). Those experiences and what Sanders refers to as related *needs* and *dreams* are what users are generally unable to recognise and verbalise, unless guided by designers (Sanders, 2001).

Figure 122.

Techniques to access different levels of participants' knowledge.



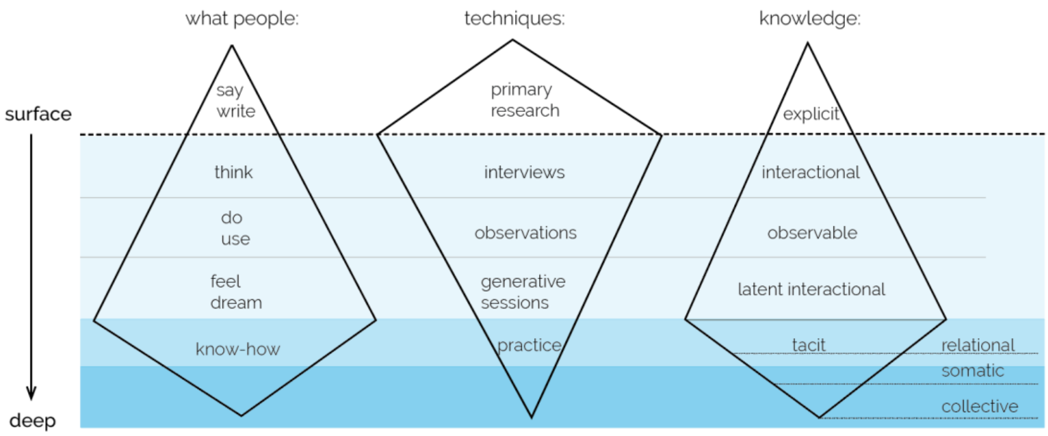
Note. From "*Contextmapping: experiences of practice"*, by Visser et al., (2005). *CoDesign: International Journal of CoCreation in Design and the Arts, 1:2, 119-149.*

The researcher, who herself initially used Visser's et al. (2005) illustration based on Sanders (2001) studies in order to show how *generative sessions* would have better facilitated her understanding and articulation of participants' *principles* on the topic of digital craftsmanship (see Chapter 2, Part II, Introduction), after gaining a deeper understanding of the theoretical debates concerning *Tacit* and *Explicit Knowledge,* and concepts related to the role of *expertise*, now believes it is relevant to underline the issue of the oversimplified and misused terms 'tacit' and 'latent' knowledge in Sanders' study and Visser et al.'s illustration.

In order to discuss this point further, the researcher readapted the illustration by Visser et al. (2005). Using the notions acquired from the studies conducted by Collins (2010) and Collins and Evans (2007) the researcher adopted labels that she believes are more precise, arguing that some current interpretations in design research suggest a misleading reading of the
terms articulated as 'latent' and 'tacit'.

Figure 123.

Illustrating techniques to access different levels of participant's knowledge



Note. Adapted from "*Contextmapping: experiences of practice"*, by Visser et al. (2005). *CoDesign: International Journal of CoCreation in Design and the Arts, 1:2, 119-149.*

In relation to this, there are several points that, in the researcher's opinion, are worth making.
The first one refers to the use of what Sanders calls 'explicit knowledge'. The researcher believes inaccurate the suggestion that the illustration provides concerning design researchers being able to capture participants' 'explicit knowledge' through the use of interviewing techniques (Visser et al., 2005). Drawing on Collins (2010) studies on *Tacit* and *Explicit Knowledge,* the researcher argues that *Explicit Knowledge* would not need researchers intervention if it were truly *Explicit.* Therefore, as illustrated in the readapted Figure 123, if design researchers were to use *interviewing* techniques to trigger what participants can express themselves, the researcher believes that design researchers would rather be provided insights thanks to participants' *interactional knowledge*. The acquisition of interviewing methods could benefit the process thus, if the researcher were to be new on the topic and the community interviewed, it would be difficult to address deeper concerns. *Explicit Knowledge* would be recognisable as primary research or anything already out there, explicitly communicated and informing the design researcher.

The second point to be addressed concerns the use of the term 'latent'. To be theoretically precise, reading Visser et al.'s illustration through the theoretical lenses of Collins & Evans (2007) notions on *latent interactional knowledge*, the researcher believes that the terminology 'latent' should be changed into 'latent interactional'*.* The researcher believes that through *generative sessions*, designers would be able to address layers of participants' *latent interactional knowledge*, which is that unexpressed knowledge that the design researcher would otherwise be able to capture through *interviewing* participants. The participants if *latent interactional experts* are not trained nor used to freely expressing their needs, beliefs, dreams and experiences. Sometimes, they are simply not challenged to practice their *interactional knowledge* because they are the only *contributory experts* in a field and/or they are not socialised within communities with similar beliefs or interests. Therefore, their *interactional* abilities become *latent* until spurred by social interactions that require them to reflect on specific themes that otherwise might never have been addressed (Collins & Evans, 2007). Thus, while Sanders argues that through *generative sessions* design researchers are able to access people's experiences, the researcher posits that for this claim to be true, researchers themselves need to first develop their *interactional expertise*. Hence, the researcher argues for a third point to be considered: to use specific design researching techniques (i.e., interviews, observations) design researchers do not need to necessarily hold *interactional expertise*; however, they do to undertake *generative session* techniques successfully. In other words, the researcher posits that to be able to acquire notions on what people 'feel' and 'dream', design researchers need to firstly develop their own *interactional knowledge* in the field of interest. *Interviewing* and *observing* techniques, together with primary research and other methods should be means for the design researcher to acquire insights and develop/improve their personal *interactional knowledge*. To be able to analyse and understand nuances and deeper layers of *latent interactional* knowledge (i.e., what is not yet said and that needs to be triggered), design researchers need to be first immersed in the context studied and, through continuous interactional exchanges with people in a community, they can develop an *interactional expertise* that will enable them to interact with participants at deeper discussion levels. Collins proved this point through the development of his *interactional expertise* among gravitational wave scientists (Collins, 2017). Similarly, the researcher proved this point through this research project.

It is acknowledged that holding *interactional expertise* from the start in a field would enable design researchers to script better interviews and to observe particulars that would be unobserved to the untrained eye. Yet, the researcher also believes that such techniques could be used independently from one's *interactional knowledge* and would still benefit the interviewer as they would provide insights and interactional occasions with the community studied. Thus, when it comes to *generative sessions* that should be designed to get to the core of an inquired topic, addressing the nuances and depth of participants' experiences and views on the world, the researcher believes that design researchers would have to first develop their *interactional expertise*. Hence, the researcher posits that interviews and observations should be seen as forming in terms of researchers' *interactional expertise* and, therefore, they should always be preparatory to the design of *generative sessions* that wish to access more depth in the conversations with participants of a study.

As seen through the analysis of *Tacit Knowledge* –and its different layers–, *Tacit Knowledge* is accessible solely through actual practice and by being immersed in a community of practice, constituted at least partially by *contributory experts* (Collins & Evans, 2007). Therefore, when Sanders (2001) addresses participants' knowledge as 'tacit' and then describes it as knowledge attainable through *generative session* techniques this is, theoretically, a paradox. On this point the researcher argues that only if design researchers develop their *interactional expertise* alongside the development of their *contributory expertise* in a field of practice (i.e., practical skills) will they become able create the potential to attain *tacit knowledg*e. Therefore, while in Figure 122 *tacit knowledge* is potentially attained through *generative sessions*, the researcher posits that unless the researcher retains both *contributory* and *interactional expertise* such an achievement is very unlikely. Typically, researchers will be able to articulate only bits of *tacit knowledge*, those at a lower degree of resistance to being made explicit (i.e., Relational, and partially Somatic Knowledge). Even if the researcher will not be able to ever fully articulate *Tacit Knowledge*, they will be able to acquire it through practice. As seen extensively in previous chapters, practical experience in a community gives access to the core of *Tacit Knowledge*: *Collective tacit knowledge.*

Therefore, on a conclusive note, the researcher posits that as seen through this research the ability to acquire *interactional expertise* should be valued as a technique to achieve deeper understanding of participants involved in a study, their reflections, and the context of a field of inquiry in general. Moreover, the researcher argues that the nuances in the understanding and the use of the terminology of *Tacit* and *Explicit Knowledge* are fundamental to acquire as design researchers. These would help to better (i) frame feasible techniques that designers could use to attain *latent interactional knowledge* whenever participants are included in a design study, and to (ii) avoid the oversimplification of concepts around knowledge transmission and acquisition. When these notions are oversimplified, human complexity is oversimplified and undervalued.

In some ways this study of Digital Craft has provided a useful focus and framework in which to unpick and explore knowledge acquisition and transmission more widely. Digital Crafts, within its very name, suggests the seeming tensions/dichotomies between knowledge that is inherently precise and explicable (the digital), and knowledge that is embedded in unspeakable/inexplicable skilled muscle memory (the crafts). The researcher hopes that this thesis, through deploying theory not previously brought bear on this field, both challenges and breaks down this dichotomy, and provides value to the wider design research as articulated in the previous paragraph.

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Appendix A

E-mail to the participants for the Kelly's Repertory Grid study

Dear [name of the practitioner],

I am a PhD student at Northumbria University in Newcastle upon Tyne (UK) and I am currently on my last year of studies, researching on the topic of Digital Craftsmanship. I have been doing research in the field for some time now, supervised by Justin Marshall and Jayne Wallace and I have developed a detailed knowledge base over digital forms of making that I would like to discuss with experts in the field like yourself.

I am writing because I would like to invite you to participate in a case study I am conducting. Indeed, I expect that your expertise on the integration of craft, technologies and design would provide key insights to advance and complete my research project.

I am planning to run the last case study for my research project using a research method called *Kelly's Repertory Grid.* Through this method, I wish to gain insights over your experience on diverse subjects of interest such as your relationship with materials, with traditional hand making and with digital technologies. **I am trying to understand whether digital craft practitioners share some core *principles* as it happens in more traditional craftsmanship practices.**

Originally, I was supposed to travel to meet a selection of participants in person but now, due to the COVID-19 pandemic, the study must be undertaken remotely. Hence, **if you accept and participate in this study, I would ask you to meet once via Skype (it might take up to 2 hours of your time) where I will run a Repertory Grid with you.** The meeting will be an open informal conversation and I will provide some material a couple of days before the interview as we will be discussing on/with/about them. **I attach an information sheet** that explains what the project entails in detail.

My project started in September 2020 and has to be completed by the end of October 2020.

Please, let me know whether you are interested in the study and available to participate. If so, I will be very happy to plan a meeting whenever is most convenient to you.

I look forward to hearing from you!

Best,

Erica Vannucci

Appendix B

Consent form for the KRG study

Consent Form
ON DIGITAL CRAFTSMANSHIP

Northumbria University
NEWCASTLE

Date:

Participant Name:

Please tick the box

I confirm that I have read the Information Sheet from Erica Vannucci for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

I agree to take part in the above study.

I consent to the retention of recorded data under the condition that any subsequent use will be anonymised and restricted to research projects that have gained ethical approval from Northumbria University

I understand that my participation in the study is completely voluntary and that I have the right to discontinue my participation at any stage without any consequences.

I agree to the use of anonymised quotes and comments arising from this study in academic publications and presentations.

I understand that I, the participant, will ask for consent from Erica Vannucci if I want to use the outcome for my own purposes.

Signature

Appendix C

Information Sheet for the KRG study

Northumbria University NEWCASTLE

Information Sheet

ON DIGITAL CRAFTSMANSHIP

I am a doctoral student at Northumbria University in Newcastle upon Tyne (UK) and I am currently in my final year. You are invited to participate in the research project ***On Digital Craftsmanship***. This project is the continuum of years of studies around the topic of craftsmanship and will help me to further advance in my PhD.

WHY YOU?

In this project I am mainly involving a spectrum of craft practitioners engaging with digital making but all coming from different backgrounds (i.e technologists working with craft-processes, craftspeople who have adopted digital production tools, craftspeople who have adopted digital interaction tools, digital natives who have only ever used digital tools). Because of your experience as a maker, your input would be very valuable for my research.

WHAT AM I AIMING FOR?

The aim of this project is to further investigate the notion of **digital craftsmanship** and how it relates to traditional forms of craftsmanship and technical hand-making practices. I wish to identify and define (i.e. explicitate) at least some distinct and shared emerging perspectives and characteristics that are considered important by craft practitioners employing digital fabrication technologies in their making processes. To do so, I wish to engage expert practitioners in the field like you, to talk about their theoretical and contextual understanding of digital craftsmanship.

ABOUT THE PROJECT

The project is divided into two main Parts.

Part I, is mainly individual. I will provide you the link of a website I personally created for this study*. The page contains sources describing 15 different artifacts chosen by me. The selection of the artifacts is not meant to be exhaustive thus, should provide a diverse range of artifacts that will enable us to have a shared ground and knowledge of the artifacts mentioned. What I ask you to do as a participant in Part I is to browse through these sources and to get to know the artifacts as much as you can. I will give you some time (approx. 7days) between Part I and the following Part II to make sure you will have enough time to familiarise with the artifacts.

Part II is the core of the Project and will involve a creative interview with me, in remote (online). The meeting will last approximately 1.30''-2 h. The 15 artifacts up mentioned will have a central role in Part II as they will be the central elements needed in order to use a creative framework called Kelly's Repertory Grid. I will explain to you how the Grid works when we will start our online meeting.
To run the Grid, I will guide you through a simple process that will become iterative: once you get the grip of how the grid works, the same process will be repeated 3 times, with small variations. Through this method, I wish to gain insights over your experience as a maker on diverse subjects of interest such as your relationship with materials, with traditional handmaking and with digital technologies. The artifacts from Part I will be the triggers and openers for these conversations.

DATA COLLECTION

If you accept to participate, I kindly ask to audio-record our conversation (see Consent Form attached).

If you have any questions, or concerns about the Project, you can speak directly to me **Erica Vannucci- +39 3890020746 / erica.vannucci@northumbria.ac.uk** . Alternatively, if you have any concerns on the research I am conducting you can contact my PhD supervisor **Justin Marshall- justin.marshall@northumbria.ac.uk**

*the page will be shut down as soon as this case study is completed

Appendix D

DIS'18 Conference workshop paper

Handmaking Food Ideals: Crafting the Design of Future Food-Related Technologies

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Abstract
Much technology is designed to help people enact processes faster and more precisely. Yet, these advantages can come at the cost of other, perhaps less tangible, values. In this workshop we aim to articulate values associated with *handmade* through a co-creative exploration in the food domain. Our objective is to explore the potential of integrating such values into future food-related technologies. In a full day workshop we will: critically reflect on the notion of *handmade*; engage actively with food—production, plating and consumption—as design material; and conduct collective discussions around the values that these processes and materials can embody when attended to through lenses other than efficiency. By *handmaking*: touching, smelling, tasting, listening, speaking and enacting choreographies with the materials at hand, we hope to deepen the discussion of the meaning associated with the *handmade* and bring a richness to ways that designers imagine future food-related technologies.

Author Keywords
Food; Crafts; Handmade; Futures.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Technology is increasingly sophisticated, carefully designed, and ubiquitous. Yet, the integration of technological artifacts into everyday activities can compromise important values: the richness of local heritage, personal and cultural traditions, historical legacies and more. Such values are commonly aligned with notions of *craft* and *handmade* [1, 13]. There has long been salient debate about the schisms and similarities between crafted, *handmade*, and highly technologized production processes [5, 8, 13, 6, 10]. For example, in 1998 McCullough cautions that the role of new technologies in production processes is growing to the detriment of "talent, of inarticulable knowledge, of contextual understanding and dedicated practice" [8]—qualities he attributes to craftspeople. A decade later Pallasmaa cautions that technological practices are overwriting "our magnificent, multi-sensory, simultaneous, and synchronic capacities of imagination" [10]. He explains that this is because technology-mediated artifacts afford interactions that are often virtual and intangible: the process happens through engagement of the eyes with the screen, until a machine manufactures the outcome. While this is not necessarily the case with food-related technologies, we often see the manipulation of forms become passive as the cook's hands shape the outcome through engagement with a controller, rather than with the food itself. In this scenario, the raw materials, and the chemical reactions engendered by their combination, become increasingly abstract, and compound the distance the machine already affords.

The schism between technological mediation and direct material engagement is not an easy boundary to fix. *Handmade* is a complex concept that embodies far more than the direct manipulation of materials. It is often considered an essential factor in defining the quality and value of a product yet seems far removed from any notion of advanced technology development. Recognising this challenge, our workshop investigates if a reflective process involving food preparation might assist the DIS community to bring food-related technologies and handmade values together.

Cooking has long been considered an archetype of handmade practice. Eating, of course, is essential to life, and cooking is an activity that humans have engaged in for millennia. In the food domain the use of digital technologies is gaining momentum, both in commercial kitchens and the home environment. Processes that were once carried out entirely by humans using hand-held tools are increasingly being performed with support from advanced technological artifacts. As a result, the influence of *handmaking* practices, and thus the presence of handmade values in food preparation, are diminishing.

To counter this trend, we take the view that even with heavy technological intervention, cooking can—and should—be approached as a craft: a reflective conversation with material [15], an activity in which "form is conceived in a continuous state of (de)composition" [7]. When cooking, combinations of food ingredients are defined and re-defined; temporal and spatial relations are composed and de-composed; time is used as a material ingredient; space is used to display, mix and combine flavors. Like with any craft, the way ingredients and processes are mixed and matched by the craftsperson reflects the judgment, dexterity and care which the maker exercises as she works, to determine the quality of the final outcome [11]. Cooking thus engenders the special human condition of being engaged with the materiality of the object [13] and the workmanship of risk [11].

Through a series of tightly structured tasks, over four acts, our workshop will open up the debate about *handmade* values in technology-mediated processes, in the domain of food. Participants will be invited—through direct engagement with food materials, tools and techniques—to uncover and articulate nuanced understandings of the interplay between food and tool

Background and Methodologies

Our workshop builds on prior experiments with Participatory Research through Gastronomy Design (PRGD) [12].

PRGD brings together Participatory Design, Research through Design and Food Design to afford the design of eating experiences that are more meaningful to end diners. In our workshop, it will help us creating a participatory context for participants to discuss the values associated with handmade food while directly engaging with food materials.

PRGD recognises that the experience of eating does not rely on food alone. It is influenced by many factors: multi-sensory stimuli [16], cultural factors [9] and social interaction [18] and the nature of our methodological approach seeks to recognise and utilize these.

use; and to consider how the handmade, in its nuanced understanding, might be foregrounded through future technology development.

Handmade food carries cultural appeal for those who cherish artisanal production processes, locally sourced ingredients and materials [4]. We believe that such processes—and the associated values—can be made more accessible through considered development of technologies. For this to happen, the associated values must be articulated in terms that make sense to technology designers and developers.

The new digital revolution is producing crafted artifacts that harness and celebrate the potential of technology [14]. Through the workshop we aim to reflect on how the digital revolution might become a powerful force for extending artisanal values of *handmade* crafted objects into the realm of food, by considering what kinds of thinking is needed to support such a shift. Our objective is threefold: (1) to grapple with how people experience *handmaking* food, (2) to articulate the values associated with *handmade* food in terms that resonate for the HCI community, and (3) to consider how those values might be embedded into wider technology-mediated production processes [c.f. 17].

Structure

The workshop will be a day long. It will involve 10 to 15 participants and will unfold over four phases. Phase 1 and 2 serve to familiarise participants with the possibilities and constraints of food as a material for designing and thinking. They also bring focus to the possibility of food as a playful domain of exploration. Phase 3 and 4 enable participants to draw on their findings from phases 1 and 2 to design and prepare dishes that embody notions of *handmade*.

Phase 1: Through a series of hands-on activities, participants, in groups, will prepare food using different artefacts as tools, ranging from a 3D food printer to woodcarving tools. Through an active engagement with the materiality of both the food and the utensils, participants have the chance to freely explore the potentialities the materials afford. Their challenge will be to convey their reflections on the values of *handmade* into experimental prototypes (or provocative prototypes [3]). Those prototypes are not meant to look like a finished piece; the focus is not on functionality or aesthetics, but on raising discussion over the idea of handmade when they are experienced alongside lunch.

Phase 2: The provotypes, presented using selected tableware, will be touched, tasted, discussed and considered, through a guided reflective conversation, over lunch. Participants will taste each others' creations to experience the explored values from the perspectives of preparing, presenting and consuming. In order to broaden the range of feedback on the provotypes, and we hope, provide an engaging addition to the wider conference, the tasting will be open to all attendees to engage and reflect on the central theme of the workshop. Verbal and/or written comment will be collected by the workshop organisers.

Phase 3: After lunch, participants will be re-grouped and invited to choose food, tools, and vessels for plating, in an open-market style set-up. The aim is for participants to choose the materials they will use to design (prepare, construct and plate) a dish that embodies –as far as possible– their ideals of *handmade*. Using a recipe template, participants will precisely document the steps taken for their *handmade* dishes and address which ideals have been represented in their final outcomes.

Phase 4: Each group will present their final dish to the other participants. The recipe templates will help generating discussions over the outcomes. The participants will explore if the assumptions concerning technological mediation, both in terms of mission and process, have been challenged or changed throughout the day. The attempt of this forth phase will be articulating how our extended understanding of handmade values could be integrated into new approaches to technology development.

Goals and outcomes

We contend that future food-related technologies will benefit from a strong association with *handmade* values. Through the workshop we will identify and articulate values associated with *handmade* food and artefacts and explore how those values could be integrated into yet-to-be imagined food-related technologies. We ask: What if—rather than standardizing the food-making process—kitchen technology enhanced cooks' agency as food artisans, along with their technical capabilities? What if food-related technologies transformed not only food preparation, but the entire dining experience? And, how might engaging with handmade values inform the development and use of advanced production/making technologies more generally?

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Appendix E

RTD’19 Conference full paper

Enticatypes: exploring how artifacts can entice conversation on craft values in digital making

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Abstract: In this paper we will focus on two bodies of work which used digital design and manufacturing technologies in their inception and production; one produced by an experienced digital maker (Marshall) and the other by a novice maker (Vannucci). We are proposing these sets of works as Pragmatic enticatypes (artefacts that sit between prototypes and provotypes to entice conversation).

We will describe and discuss the outcomes of a workshop where the participants, many of whom were craftspeople and designers, tried through our enticatypes to get under the skin of the dichotomies that can still persist between machine/digital produced and handmade objects. We will exemplify the role our artifacts played in the workshop and the participants' reflections and discussions raised across, and between, the analogue and the digital in relation to: novelty in contrast to originality, authenticity as a mark of respect for tradition, control as a measure of competence and competence as a measure of skill.

Moreover, as first attempt of enticatypes, we will underline their shortcomings in this workshop in order to discuss how very different craft results, both using a Research through Design approach, could potentially lead an audience to different types of conversations, interactions and outcome. And how a highly hands-on group of participants, such as craftspeople, recognises and interprets different qualities in the same artefacts.

Keywords: Craft, Hand-made, Digital Craft, Craft values, Pragmatism, Enticatypes, Practice-based research

Vannucci, Marshall, Wallace | *Small Bowl*, CNC milled rust stained oak [Marshall]; *Traced bowl*, hand carved oak [Vannucci].

Introduction

The continuous evolution of craftsmanship, the shifting role of hands and technologies in the active engagement with materials, and the different values in the production processes from handmaking to digital, has been widely addressed through a body of literature (e.g. Ihde, 1979; McCullough, 1998; Latour, 2008; Sennett, 2008; Pallasmaa, 2009). Moreover, since the late 1990's, digital craftsmanship has been growing as an area of applied research and professional practice (e.g. Bunnell, 1998, 2004; Marshall, 1999; Risner 2012). There is also research undertaken in this area that interrogates notions of hybrid craft using critical propositions and metaphors (Devendorf & Rosner, 2017) and that uses 'lo-fi' prototypes and provotypes to investigate the domain (e.g. Devendorf & Ryokai, 2014, 2015; Kim et al, 2017). In addition, many examples of the artefacts crafted through the crossovers of digital and traditional practices, have been promoted through events and exhibitions: 'Labcraft – Digital Adventures in Contemporary Craft' commisioned by the UK Craft Council (Fraser, 2010), the 'Power of Making' exhibition at the V&A Museum (Charny, 2011) and 'New Craft' (curated by Micelli, 2016), and promoted through innovation programmes such as Make:Shift:Do (Craft Council, 2014-now).

Despite the progress made through traditional and digital practices merging in hybrid artefacts (Zoran & Buechley, 2013; Zoran, 2013, 2015), the outcomes are still controversial for different audiences, including some craft practitioners. If for some they represent innovation and the future of craftsmanship processes, for many it remains difficult to recognise or appreciate the same rigour and skill an entirely 'handmade' artefact encapsulates. Consequently, the values that hybrid crafts embody, are seen differently if compared with handmade crafts, depending on the audience. So what does it mean to make 'by hand'? How does the value of hand-making contrapose or align with digital making; its techniques and praxis? And, perhaps most importantly, is this a useful question to pursue?

This paper will focus on a workshop held to interrogate these questions and sought to provide a foundation for new ways in which handmade values can be understood in a 21st century context. Furthermore, it sits within a broader mission to inform future digital making praxis and potentially the evolution of new breeds of meaningful making technologies. The workshop was based partially on a series of artefacts produced by Vannucci and Marshall. These artefacts sought to represent the tensions, dichotomies and possible similarities between digital and established ways of 'hand' crafting. The driving questions Vannucci and Marshall were asking themselves while producing the artefacts were:

How can we explore craft values in digital making through an artefact oriented method?

How could we begin to explore the tension between the digital and the analogue (handmade) in material artefacts?

The goals of both the artefacts made and of the workshop were twofold: firstly, the authors wanted to understand if attributes from traditional craftsmanship could map onto digital, hybrid objects. Secondly, they wanted to understand which types of artefacts (i.e. provisional, resolved, open, refined, experimental, incomplete, etc.) would better facilitate an open discussion around the theme of craft and handmade values in digital making. The past record of exhibited digital and hybrid craftworks, significant and valuable in their own right, tend not to actively use the objects to leverage reflections and understandings from these activities into a broader craft value orientated debate. Therefore, this research activity is distinct in that it attempts to think through things (Henare et al, 2007) by emphasising visual/physical characteristics of an artefact as potentially valuable aspects in a workshop context, and by using these characteristics explicitly to explore broader values within craft (i.e. it puts artefacts to work in a particular way).

The artefacts aim to entice conversation, not provoke argument, we will therefore make a proposition of them aspiring to be *enticatypes* : crafted objects that encourage a type of conversation that is different to those that prototypes and provotypes (Boer & Donovan, 2012) foster. The spectrum of the artefacts, their comparison and the contrasts in their conceptualization and production, was used as an opener to debate and further explore ideas of craft and the handmade in future digital contexts, with a range of participants.

In this paper we will present the artefacts we made, the workshop (its structure and the outcomes) and we will discuss the insights obtained and how our artefacts facilitated, or not, the process. Moreover, by presenting the artefacts as potential *enticatypes* and charting how the participants interpreted them, we hope to open a new space to discuss how very different crafted outcomes could potentially lead an audience to different types of conversations, reflections and conclusions.

And in line with this, reflect on the value of this approach as a new way of engaging participants in practice-based research.

What might an *enticatype* be?

At one end of the theoretical design development spectrum: *Prototypes* can be considered predominantly to sit within an instrumental tradition of thinking, focused on usability and ergonomics; "prototyping can be viewed as 'growing' early conceptual designs (..) into mature products (or services, environments, experiences, etc." (Sanders & Stappers, 2014, p. 6). *Provotypes* at the other end of the spectrum, can be situated in a critical tradition where they "expose and embody tensions that surrounds a field of interest to support collaborative analysis and collaborative design explorations across stakeholders" (Boer & Donovan 2012, p.288). In this paper we propose the concept of *enticatypes,* artefacts that are aligned to a Pragmatic philosophical tradition and sit 'between' prototypes and provotypes, where:

- The artefacts in the workshop were ends in themselves, they will not be reiterated to produce optimal designs destined for mass or batch production.

- They embody an *ongoing* research process without aiming to answer or give a plausible solution to a predefined problem (a brief), they are orientated to active 'ends-in-view' (Hickman, 1990).

- The knowledge that the researchers sought to embed in the artefacts is recognised as *situational*. Therefore the nature of the provisional artefacts created was specific to the workshop participants (i.e. we made craft artefacts to engage mainly with craft practitioners), with the aspiration this would broaden the depth of the enquiry.

The *enticatype* vessels

Prior to the workshop Vannucci and Marshall both produced new bodies of work . They were originally designed to fall into a bigger 'Future of Food Production' workshop (Vannucci et al, 2018) and therefore are related to the serving of food. This provides an element of coherence across the range work deployed in the workshop.

Vannucci and Marshall had significantly different levels of experience in using both digital and analog making technologies and both made vessels using a CNC (computer numerically controlled) milling machine in combination with handmade tools and techniques.

Vessels by Marshall: *Hand Thought* series

Marshall, as a practice based researcher, has been working in the area of digital craft for nearly twenty years. He recognises tools and techniques and their epistemic characteristics (Luscombe, 2017), not as neutral means to an end, but as active and constructive elements entangled in the creative making process (i.e. technologies are

Figure 1. Marshall's 'Hand Thought' series of CNC milled oak tableware (2018). From left to right: Small bowl 210x45mm; Japanese platter 230x120x40mm; Oval dish 370x260x60mm.

recognised as translational rather than reproductive). This position can be aligned with one of the tenants of craft practice; that work is borne out of a creative engagement with materials and processes.

Marshall made the set of oak tableware (Fig.1) with the conscious intention to create work that had ambiguous surface characteristics; combining and contrasting analogue and digital aesthetics, while using an entirely digital means of production. This was achieved by contrasting a seemingly hand carved top surface with an explicitly digitally generated and cut underside (Figs 7, 8).

Using some form of analogue input (i.e. hand drawing) was a key aspect to the project and technology was used that allows physical drawing to be captured directly in a vector format and used to generate toolpaths with no loss of fidelity/detail (Figs. 2a, b, c). The use of this novel approach created hybrid surfaces which are not easily categorized as definitively digital or analogue. In contrast, the underside surface of the pieces exploit and celebrate the software that generates toolpaths to create complex surface patterns and textures (Figs. 2d, e). Marshall's approach explicitly subverts the software's mission to create optimum toolpaths to efficiently reproduce CAD designs. For example, 'cheating' the software through mismatching settings with the actual tool shape and sizes used, a visual language can be created that is clearly digital in origin and is rooted, not in predetermined design work, but is born out of the mediation of the technologies (both hardware and software) used.

The proposition Marshall sought to embody in these 'finished' works was that, in order to engage an audience of craft and design practitioner-researchers in debates of potential concern/interest, there needed to be a commitment to the creation of physical work that displayed a good level of visual sophistication and resolution. This assumption will be returned to in the discussion and conclusion.

Figure 2a. Marshall using Anoto pen for analogue drawing.

Figure 2b. Toolpaths generated from imported vector data.

Figure 2c. CNC milling of drawn lines.

Figure 2d. Toolpaths generated from software parameters.

Figure 2e. Detail of milled surface.

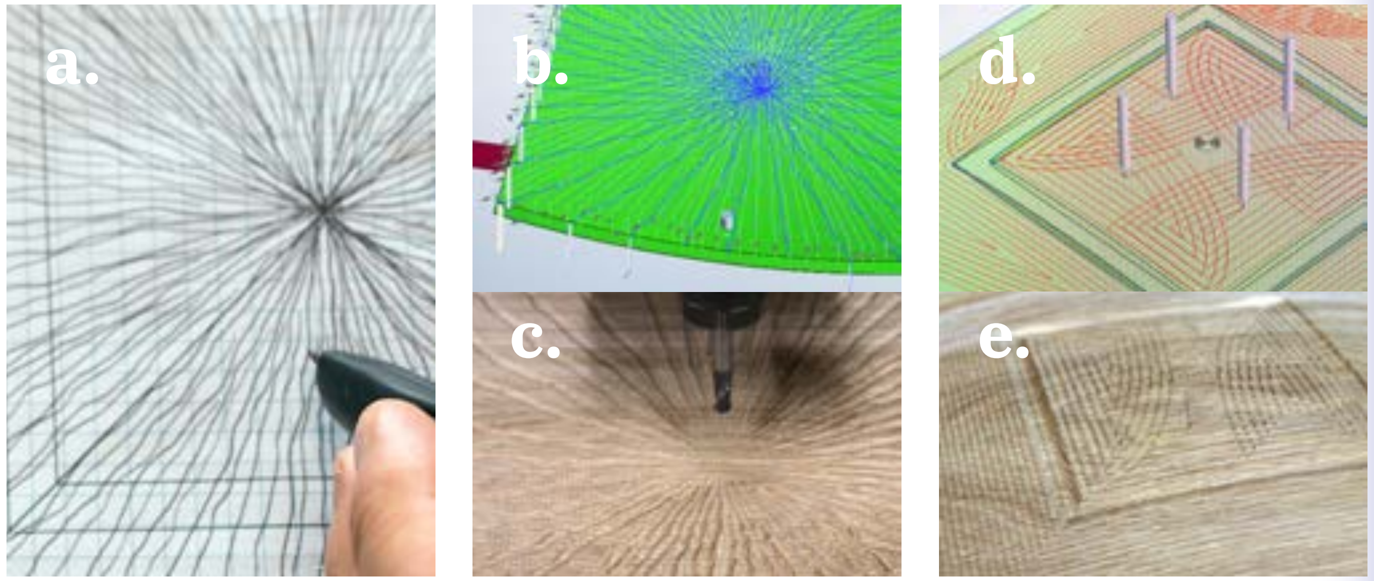

Figure 3. Details from E's 'Hand Fought' series of CNC milled and hand-carved wood vessels(2018). From top down: a) Orbital plate (front and reverse) 16.5mm; b) Mountained dish 16x17.5mm

Vessels by Vannucci: *Hand Fought* series

Vannucci had no previous experience of 3D modeling, digital making using a CNC machine, or hand carving. In contrast to Marshall, her proposition was that being a novice in both analogue and digital making, positioned her at a neutral starting point. The process of understanding the basics of both traditional and digital practices in parallel, through an active engagement with the making processes, enabled Vannucci to experience the possibilities and constraints that some machinery or handmade techniques afford, with the aspiration that the new knowledge acquired translated into the artefacts produced.

The three pieces of tableware that Vannucci produced explore the processes of both hand carving and using 3D modeling and the CNC machine for the first time. They represent the tension a novice experienced between marks and toolpaths that both the machine and the human hand are able to produce, in their imperfections. In these artefacts, making was conceived for Vannucci as the driving force behind the research question, which corresponds to the notion of 'knowing through making' (Mäkelä, 2006). What Cross describes as 'doing and making' (Cross, 1982) for Vannucci was prior to understanding the full potential of the digital hardware and software. Therefore, the vessels were sometimes purposefully left unpolished and unfinished with visible imperfections and/or mistakes.

In contrast to Marshall's aspirations, the main goal with these 'open' artefacts was to provide a loose frame for the workshop discussions without producing beautiful 'finished' artefacts that were easily understood in their form and function. Instead, they reflect Vannucci's interpretation of the dichotomies of the production processes explored: they address failures and shortcomings a maker encounters in digital making and hand making for the first time and they exalt the struggles and tensions experienced (e.g. Mountained plate, Fig. 3b and 10, presents two holes, results of miscalculations during the milling process). This raw unadulterated representation of the processes explored, was considered as a potential element that could encourage types of discussion where a finished polished artefact might not.

Workshop structure

The workshop was two hours long and was held in an academic context (University design school). It was principally developed by Vannucci and Marshall supported its delivery. The selection of participants (they will be referred to with the acronym P followed by a number: P1, P2...P8) was significantly based on the knowledge and experience some practitioners in the University have of established making processes associated with their fields of specialisation. Three participants had a background in metalworking (P6), furniture making (P7) and jewellery (P4) and the other participants were PhD students currently working in the field of practice based design research. This range of participants potentially had an investment in the values of making/crafting and/or designing as part of a professional, research and/or pedagogic practice.

The workshop was divided into three main phases. In the first two phases, the participants were divided into three groups of two or three. Initially they were given a deck of cards with attributes relating to craftsmanship and the organisers asked the groups to familiarize themselves with these attributes and the fuller description on the reverse of the card. The attributes were: authenticity, competence, creativity, innovation, interpretation, originality, talent, territory, tradition, training. They were taken from a book that attempts to define traditional attributes of crafting excellence (Cavalli, 2017). We chose to use these cards because we wanted to understand if traditional craftsmanship related values could be associated with digital making, and whether or not identifying differences would enable us to pin down opposing values attributed to digital crafts. However, we recognise that craft definitions are fraught with unresolved debate and therefore the attributes listed above are not intended to be exhaustive or conclusive.

In the second phase, each group was given a second deck of cards that represented six digital artefacts (Fig. 4a) selected from the book Digital Handmade: Craftsmanship and the New Industrial Revolution (Johnston, 2015). Each card presented on one side the picture of the artefact and on the reverse, how it was produced and its characteristics (Fig. 4b). Each group were asked to select from these six examples one that, in their opinion, embodied the highest number of craft attributes and one that embodied the least set of attributes (Fig. 4c). They were then asked to describe their choices and reasons.

Recognising that the nuanced assessment of the characteristics of a crafted artifact is most effective when it is directly experienced and handled, in the third and most important phase, we divided the participants into two groups and we assigned each three of our vessels, mixed randomly. In addition we provided some digital crafted objects, made using different technologies (i.e. a metalised 3D printed dish), and a small number of traditional

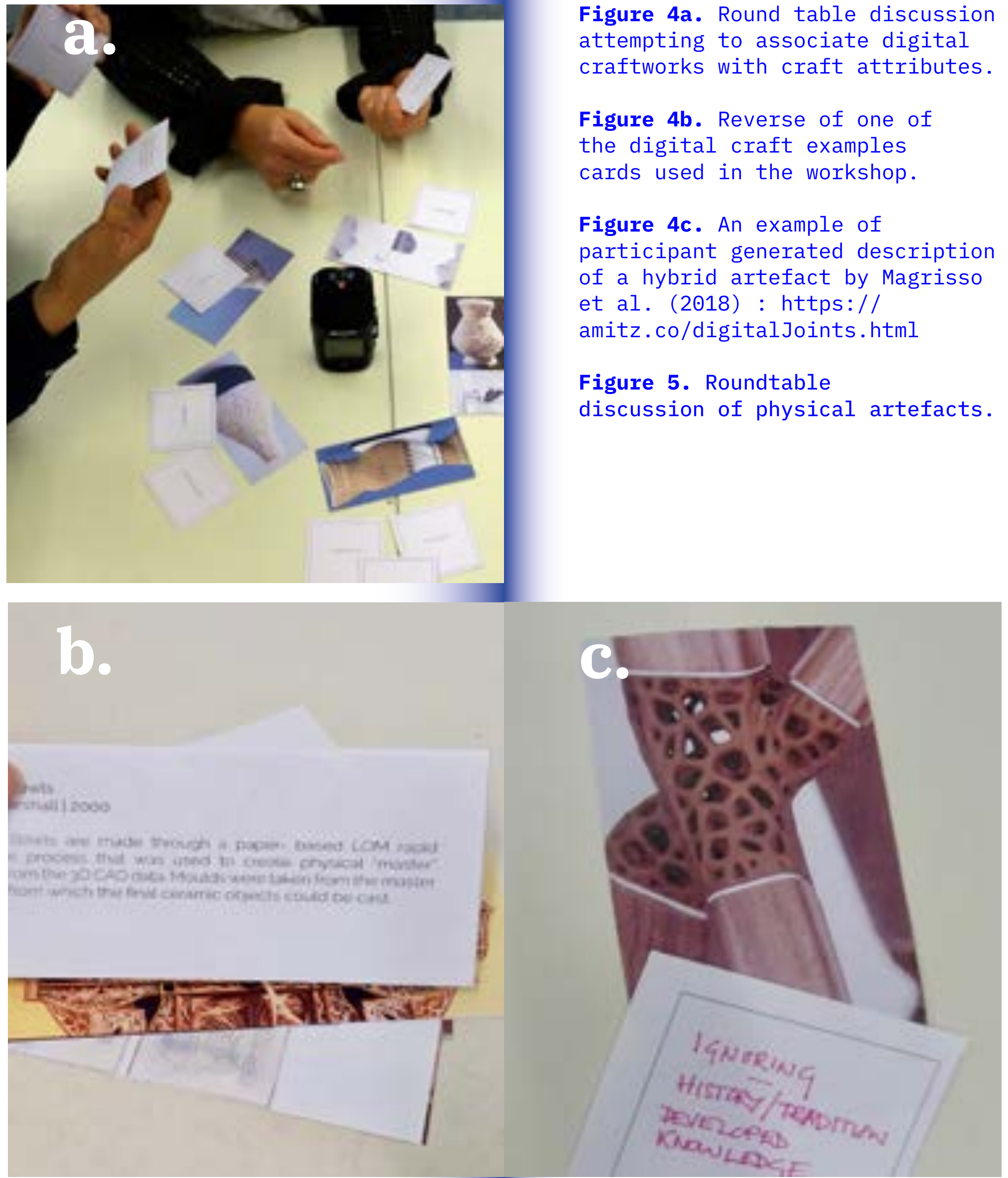

Figure 4a. Round table discussion attempting to associate digital craftworks with craft attributes.

Figure 4b. Reverse of one of the digital craft examples cards used in the workshop.

Figure 4c. An example of participant generated description of a hybrid artefact by Magrisso et al. (2018) : https://amitz.co/digitalJoints.html

Figure 5. Roundtable discussion of physical artefacts.

crafted vessels (i.e. hand thrown stoneware bowls). These were included to provide artefacts that can be associated with a wider spectrum of digital making and with established making practices.

The participants were asked to complete forms that had on one side the picture of the artefacts and on the reverse some space to give a title to the piece, describe it, suggest how it might have been made and list words or values that the vessels suggested to them. They could use previously mentioned attributes or new ones. The rationale for providing the participants with a wider selection of artefacts (not limited to the artefacts Vannucci and Marshall made) was that it would allow the participants to compare a wider spectrum of objects and their attributes and so help in defining and talking about their values and attributes at a more general level. After debate within the two groups (Fig. 5), their conclusions were talked over in a full roundtable discussion.

It can be noted that although there was a significant amount of writing based exercises within the workshop, their role was not to generate research data in itself, but to stimulate discussion. All conversations in both group and roundtable sessions were recorded. Transcriptions of these were used as the principal data source.

Reflections on workshop activities

In phases one and two the selection of artefacts on the cards generated a lot of debate around how the artefacts were made and the techniques that were used to make them. However, the participants found it difficult to associate the value cards with the artefacts, in all three phases (both the ones in the pictures and Vannucci and Marshall's tangible vessels). Therefore, they often drifted away from the attributes cards and most of the first two phases of the workshop became a free, open debate on the artefacts presented and on the perception the participants had of these artefacts. Participants P6, P7 and P8, clearly had extensive first hand knowledge and experience of established making processes. In addition, they clearly had some knowledge of digital processes, but whether this was first hand was less easy to ascertain. Within this group there was a shared attitude of *preserving* the value of the methods they knew well from their own practices. There was a reticence in considering the possible opportunities that other digital methods, that they perhaps have less ownership over, may provide. Both in terms of alternatives/extensions/augmentations of the practices that existed before the development of this toolset. This broad position manifested itself through a range of intertwined discussions, the most relevant of which we have separated out below.

Novelty in contrast to originality

A thought that was commonly shared by participants was that digital craftsmanship rarely seems to push the boundaries of what was considered *original* or *innovative*, and that it was merely *novel*. If certain production processes (i.e. 3d printing) were not considered as a central element in the physical requirements of a final artefact, the participants discounted the artefact from the start. Using a specific technique to add new aesthetic characteristics to the final outcome did not seem enough to consider something original. Comments such as: *"It is only a new aesthetic"* P1 or *"It is not even a nice looking thing"* P2 often come up in the discussions (referring to Solar Sintered bowl by Kayser (2011) and Digital Joinery for Hybrid Carpentry by Magrisso et al. (2018) Fig. 4c).

Authenticity as a mark of respect for tradition

One of the major concerns was that most of the artefacts presented would not have even needed digital technology in the production phase and could have been produced by analogue technologies: *"none of these things need to use technology"* (P4). Therefore, the ability of some artisans to bring together traditional and digital techniques, was not always considered by the participants as something unique and valuable. The shared opinion seemed to lie in the question: *"unless it is essential to the process of making itself, why would you use digital technologies?"* (P1). Where technology is not needed because there is already a traditional technique to achieve a specific pattern or form, the participants showed resistance towards the artefacts. P4 stated that digital manufacturing seemed to him as something *"ignoring tradition, rather than extending tradition"*. His main argument was that traditional makers know conventions and there is a reason why things are the way they are and generally these are perfectly logical reasons. The impression that digital makers drop into craft or manufacture without bothering to learn all the conventions first, was pointed out: *"They probably think those are boring things"* (P4). The majority of participants agreed that this perceived attitude of those that use digital techniques, somehow makes it harder for them to assess digital artefacts as crafted artefacts. When those artefacts are shown to those who actively use and know perfectly the conventions that lie behind certain techniques, they will immediately dismiss or diminish their attempt to present something new.
P4 continues: *"If you show these attempts of hybrid processes to most of the manufacturing technicians, they will deride about this because they would probably be able to make something better.. as they know their machines inside out. An educated craftsperson will be different from a craftsperson that did an apprenticeship, which will be different to an amateur hobbyist. Many of these objects say: look at me [referring to the authors of the artefacts on the cards]. Not really at the work and its own merits".*

Control as a measure of competence and competence as a measure of skill

The idea that *control* over the process of making manifests a preconceived outcome appeared to play a significant part in validating an artefact for the participants, consequently *intention* seemed an important measure to establish the value of a piece. *"Here there is a certain amount of roughness that suggests that they have never done it before"*, said P6 (discussing the sand bowl made by Kaysers' Solar Synter (2011)). From the description on the card it was unclear to the participants whether or not the roughness was intentional. And consequently, whether or not the artisan drew on previous experience and still decided to leave it that way, or if he had just *never done it before*, which for P6 was the probable option: *"We don't know if this was a criterion the maker had when doing it, but to me it seems the author needs more training to get competence (...) at this point he is doing badly what a computer can do".*

These opinions suggest that participants would have appreciated imperfection more if they had known that it was intentional. Which again suggests a degree of instrumentalism when considering the role of digital technologies, where technology is seen as an instrument that is designed to give predetermined outputs:
"An indication of control is important, and this connects to the need for training as a measure of craftsmanship, even more than the representation of skill. Skill is important but without intention it is difficult to measure or judge. Skill plus intention means making something and making it look flawless, no matter how many imperfections were hidden there, you have to look at the craft and not even notice them, they cannot stand out in such an obvious way" (P7).

It became clear that the participants were seduced by some artefacts more than others and P4 poked the group with a provocative question: *"Are we just being seduced by something that is just made properly?"*. He seemed to be reflecting on the reasoning behind his own artefact choices: *"I am picking this [card of an artefact] because it is shiny, nothing more"* (referring to *Centric Representation* and *Parametric Representation (x+y)* by Peter Musson: http://silverspeaks.co.uk/makers/peter-musson/).

Discussion: workshop limitations and key themes

We recognise some relevant limitations in how the workshop developed and in how the debate evolved among our participants. We briefly describe these here and then move on to unpack the themes found.
It is perhaps unsurprising that when engaging with a group of makers the concentration of discussion was on the way artefacts had been made. It is again unsurprising that technologies and processes were in the forefront of the participants' minds. However, what was unexpected, was the predominance of an instrumentalist perspective when considering the way in which technologies impact on us and what we make. This was exemplified through considerable focus on issues of utility, effectiveness and efficiency, and with a significance given to intentionality.

An instrumentalist view of technology

Instrumentalism (Heidegger, 1977) has a disinclination to recognise the impacts and values attendant to technology use beyond its ability to carry out tasks (goals/intentions); being a passive *means* to a predetermined *end*. In doing so, it limits the scope of discussions that seek to uncover significances beyond the practical.
Within the workshop there was a shared underlying belief between participants that digital processes need to be better or more effective at a predominantly procedural level. As P6 states: *"there is no point in doing something digitally that already exists unless it can be done more cheaply and effectively than a previous method"*. Such views seem to reduce the possibility of noticing, considering or appreciatiating a broader set of aesthetic outcomes that are not measured against pre-existing criteria. Although there was some recognition that Marshall's Oval dish (see Fig. 1) could be associated with craft attributes as 'skill, innovation, originality and aesthetically interesting' (descriptors stemming from Cavalli and the cards used in phase one), broadly there was little concession that a maker might want to use digital tools for the pleasure of their craft or for the particular aesthetics that a process may give.

Figure 6. Vannucci's Orbital Plate

Figure 7.(right) Underside of Marshall's Oval dish

Mapping craft values

Mapping a wide range of craftsmanship values, onto digital artefacts, had limited success within the workshop. From the selection of values presented (i.e. authenticity, competence, creativity, innovation, interpretation, originality, talent, territory, tradition, training), competence as a measure of skill, training as a prerequisite to competence, innovation in contrast to novelty, and authenticity as a mark of respect for tradition, were the attributes the practitioners mostly discussed, both from a positive and negative perspective. As the participants mostly shared a common language of making, because they came from similar disciplines, backgrounds and working institutions, they perhaps shared a common set of values and they had to differentiate themselves and their practices from the artefacts presented. In other words, considering digital approaches as something that could be considered as inventive or explorative would have automatically challenged the main cult values (Mead, 1923) of the practitioners. Stacey explains Meads' idea of cult values as: "People have a tendency to individualise and idealise a collective and treat it as if it had overriding motives or values, amounting to processes in which the collection constitutes a 'cult'' (Stacey, 2011, p. 376). Debating values associated with functionalism, usefulness, utility and practicality seemed easier to talk through than values such as inventiveness, innovation, exploration or recognising any aspects that were boundary-challenging or seeking to extend their existing practice. We recognise from our experience of the workshop that when you seek to explore and interrogate values that can be tracked across the broad spectrum of making, by whom they are questioned, is obviously an essential part of the equation.

The nature of examples presented and authored enticatypes

The nature of the artefacts presented in phase one and two were mainly explorative research orientated works seeking to embody originality, novelty and testing boundaries, rather than works made with the aim to incrementally develop processes, or create greater efficiency in the production. These choices did not create the hoped outcome in the discussions (i.e. debate across the spectrum of craft values). And as raised earlier, when the physical vessels were discussed in the third phase of the workshop, it became increasingly clear throughout the whole workshop discussion there was an inclination towards instrumentalism.

In the first phase of the workshop some participants seemed to acknowledge, with a touch of self-criticism, two interesting points: that they might be seduced by artefacts that are 'made properly' (which was one of the aspirations for the approach that Marshall took when creating his body of work). Thus, when they considered the physical vessels, the ability of the experienced makers to quickly assess whether things are 'made properly' and the level of experience (training and skill) that is required to make them, became the major criteria of judgement. For this reason Vannucci's pieces were quickly dismissed. This limited the discussion from the start and showed how the intention of leaving the objects as open and unfinished as possible, did not create a constructive space for wider exploration of the themes within this specific group of participants. The vessels did not reflect enough productive skills to be taken into consideration; they seemed too far away from displaying traditional and established qualities of workmanship in order to entice conversation (i.e. be enticatypes) or be considered

Figure 8. The top and underside of Marshall's Small dish.

finished crafted objects (which they were not intended to be). Conversely, the Marshall's vessels were not universally successful in driving forward conversations across the breadth and depth of craftsmanship values either. Their appearance suggested digital craftsmanship processes of manufacturing, thus the nuances in the ways in which the digital and analogue techniques interplayed within the making process, was not explicit enough within the visual characteristics of the final objects to entice discussion either. On one side experienced maker's vessels represent an answer to the particular research question on digital and handmade dichotomies and values and are an example of the ambiguities that can exist between digital craftsmanship and hand making qualities; on the other side the novices' vessels represent an argumentation of the research question itself, they represent sometimes the failure, sometimes the imperfections and the trials of a process that a craftsman might encounter through his/her developing practice.

On reflection, we must consider whether or not the instrumental inclination was the result of the workshop design and its focus on artefacts as isolated uncontextualized objects from the narrative and research ambition. The intention of this approach was to reduce biases and create an 'open' field for discussion. However, this was not borne out when working with this group of practitioners. When talking to craftspeople (and perhaps broader audiences) through crafted objects, maybe an artefact needs to communicate both the stories behind it and the research context in which it plays a role, to fully address its potential meaning and value. As Sanders and Strappers articulate:

"We really cannot separate making from telling and enacting. We have seen in practice that people make artefacts and then readily share their stories about what they made or they naturally demonstrate how they would use the artefact (if it is intended to be a representation of something concrete). Taken in isolation, the artefact may say very little or remain highly ambiguous." (2012)

Conclusion

The critique we have provided in this paper on the nature of our workshop is not intended to be a critique of the of the participants' responses and the values that they chose to promote. It is more focused on the aim of understanding how we might better create artefacts and activities to explore the tension between the digital and the analogue (handmade) through crafted objects more broadly.

We proposed the use of *enticatypes*, crafted artefacts that could entice conversation with a very specific audience to investigate craftsmanship values. This first workshop has revealed some interesting insights into the attributes that practitioners bring to bear when interrogating artefacts, but was limited in the range and depth of discussion we achieved. Our first iteration of *enticaptypes* did not entice as broad ranges of debates as we may have wished. In this workshop context, we realised that in order to talk about craftsmanship within crafts communities, the challenge is to create artefacts and activities that facilitate discussions that move beyond the instrumental. There are theoretical frames that can provide a different lens on debates concerning technological mediation and these provide alternative perspectives on values systems. We would argue that a Pragmatic understanding of technology provides such frame. It recognises that goals, intentions, are active and mutable through any process (including making an artefact), and that technologies are not value neutral instruments but as Dewey claimed, they frame our engagement with the world, hence are laden with values (Hickman, 1990).

From the lessons learned we tentatively propose some aspects that could be taken into consideration in future iterations of *enticatypes* and workshop structures. These include:

- Finding forms of aesthetic and material expression that are enticing by being 'open' without being considered as unfinished, or resolved without being considered 'closed' (i.e. finding a balance between a finished artefact that ends up being appreciated without further inquiry and an unpolished artefact that is mistaken for a scrap bin piece!).

-Providing an accompanying narrative of motivation and process.

-Using explicit activities to link material aspects of the artefacts to concepts that move beyond instrumental aspects of production (the why and so what, not just the how).

-Finding a set of participants who span the spectrum of skill and making in different ways.

-Introducing making activities as a mode of interrogation to work in parallel with and aid discussion.

-Getting people to bring things that they have made into the discussion in order to generate a better ground to talk through artefacts and values, and increase participatory inclusion.

We would argue that this work is of relevance for the RtD community, in which *making as a way of thinking* is a valued approach to knowledge acquisition. We think this paper provides an example on how artefacts embodying ongoing research (i.e. they are not ends in themselves, but are part of a wider process), can seek to entice conversations around specific topics with specific audiences.

For future developments of the *enticatypes* we seek to redo the workshop with different participants following the improvements suggested above in order to explore how a different audience might respond to the same artefacts. Bearing in mind that developing a better workshop structure might help enhance the characteristics of the *enticatypes* and their nature, form and scope, we aim to understand how much of a suitable narrative is needed to better explain contextual materials without biasing or limiting the conversation.

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Figure 9. (From Left to right) Details of Marshalls's Japanese Platter and Vannucci's Mountained dish both top and underside

Figure 10. Vannucci's Mountained Dish, top view