ROUTLEDGE ADVANCES IN ART AND VISUAL STUDIES

CRAFT AND DESIGN PRACTICE FROM AN EMBODIED PERSPECTIVE

Edited by
NITHIKUL NIMKULRAT
AND CAMILLA GROTH

ROUTLEDGE

"This splendid collection advances our understanding of embodied cognition and experiential knowledge in craftwork and sets the pace for future theory. Its multidisciplinary cast of authors deliver unique insights into human-material interactions, skilled situated practice, and the dynamics of thinking through making – both in traditional crafts and the emerging digital and virtual realms".

Trevor H. J. Marchand, *SOAS, University of London*

"This book shines a light on the nature and value of embodied experiences within the spheres of making and materiality. The various chapters bring ideas around becoming, feeling, wellbeing, interconnection, and relationality to the fore, which are all critical aspects of craft and design practices that seek to counter dominate modes of production and affect positive change. I would recommend this book to those who wish to establish, understand, and champion such practice".

Faith Kane, *Toi Rauwhārangi College of Creative Arts, Massey University*

Craft and Design Practice from an Embodied Perspective

This book brings together contributors from multiple disciplines, such as crafts, design, art education, cognitive philosophy, and sociology, to discuss craft and design practice from an embodied perspective.

Through theoretical overviews of embodied cognition and research-based cases that involve the researchers' making experiences, different phenomena of human-material interaction are presented, analysed, and discussed. The practical cases exemplify ways in which embodied notions show up in action. Contributors examine topics such as the embodied basis of craft activities and material manipulation, experiential knowledge and skill learning, reflection in and on action, and material dialogues. Several chapters specifically discuss the hybrid forms of analogue and digital crafting that increasingly takes place in the field of crafts and design, and the changed notions of material engagement that this entails.

The book will appeal to scholars of crafts, design, art education, anthropology, and sociology.

Nithikul Nimkulrat is Associate Professor at OCAD University, Canada.

Camilla Groth is Associate Professor at University of South-Eastern Norway, Norway.

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Routledge
Taylor & Francis Group
NEW YORK AND LONDON

Designed cover image: The artist Alexandra Engelfriet performs her art of embodied engagement with wet natural clay. Still image from the film Tranchée by Estelle Chrétien. https://www.alexandraengelfriet.com/.

First published 2025
by Routledge
605 Third Avenue, New York, NY 10158

and by Routledge
4 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

Routledge is an imprint of the Taylor & Francis Group, an informa business

Library of Congress Cataloging-in-Publication Data
Names: Nimkulrat, Nithikul, 1974– editor. | Groth, Camilla, editor.
Title: Craft and design practice from an embodied perspective / [edited by] Nithikul Nimkulrat and Camilla Groth.
Description: New York, NY : Routledge, 2025. | Includes bibliographical references and index.
Identifiers: LCCN 2024015289 (print) | LCCN 2024015290 (ebook) | ISBN 9781032356815 (hardback) | ISBN 9781032356839 (paperback) | ISBN 9781003328018 (ebook)
Subjects: LCSH: Handicraft—Social aspects. | Design—Social aspects. | Material culture.
Classification: LCC GN429 .C73 2025 (print) | LCC GN429 (ebook) | DDC 745.5—dc23/eng/20240514
LC record available at https://lccn.loc.gov/2024015289
LC ebook record available at https://lccn.loc.gov/2024015290

ISBN: 9781032356815 (hbk)
ISBN: 9781032356839 (pbk)
ISBN: 9781003328018 (ebk)

DOI: 10.4324/9781003328018

Typeset in Sabon
by codeMantra

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Contributors

Ingar Brinck is Professor at Lund University, Sweden.

Venere Ferraro is Associate Professor at Politecnico di Milano, Italy.

Camilla Groth is Associate Professor at the University of South-Eastern Norway, Norway.

Marte S. Gulliksen is Professor at the University of South-Eastern Norway, Norway.

Flemming Tvede Hansen is Associate Professor at Royal Danish Academy, Denmark.

Tim Ingold is Emeritus Professor at the University of Aberdeen, Scotland, and Fellow of the British Academy and the Royal Society of Edinburgh.

Michael Kimmel is Senior Researcher at Sigmund Freud University (SFU) and the University of Vienna, Austria.

Lambros Malafouris is Professor at the University of Oxford, UK.

Justin Marshall is Professor at Northumbria University, UK.

Kristina Niedderer is Professor at Manchester Metropolitan University, UK.

Nithikul Nimkulrat is Associate Professor at OCAD University, Canada.

Michael Nitsche is Professor at the Georgia Institute of Technology, USA.

Catherine O'Brien is PhD candidate in Archaeology at the University of Oxford, UK.

Erin O'Connor is Associate Professor at Marymount Manhattan College, USA.

Stefano Parisi is Postdoctoral Researcher at the Delft University of Technology, The Netherlands.

Anniken Randers-Pehrson is Associate Professor at the University of South-Eastern Norway, Norway.

Valentina Rognoli is Associate Professor at Politecnico di Milano, Italy.

Jihan Sherman is a PhD candidate in Digital Media at the Georgia Institute of Technology, USA.

Lovise Søyland is Associate Professor at the University of South-Eastern Norway, Norway.

Katherine Townsend is Professor at Nottingham Trent University, UK.

Jelle van Dijk is Associate Professor at the University of Twente, The Netherlands.

Preface

Material engagement and related reflective processes, exemplified by the act of making something in a material, have increasingly been a subject for research outside craft and design research, not only in anthropology, archaeology, material culture, art history, sociology, philosophy, and phenomenology but also in ecological and enactive strands of cognitive sciences. Such research interest shows that craft and design practices are exemplary situations for human-material interaction and thus manifest the idea of embodied cognition in ways that can be seen, studied, and discussed.

The practitioner's situated perspective is not always communicated in research *into* design and craft practice conducted through other disciplinary lenses and calls for a collective effort to discuss *thinking through making* as it is experienced in situ. By creating an interdisciplinary setting for this anthology, we welcome voices from multiple perspectives to generate a holistic understanding of what *thinking through making* might entail. We invited the authors for this book based on their documented activities and contributions to the design and craft field and on their general interest in aspects of embodiment involved in the process of making. We particularly aim at developing the field through displaying the wider spectrum of belief systems that are at stake in this field. Since many of the authors refer to Tim Ingold, although he is known as being critical of the concept of embodied cognition, we invited him to write the afterword for this book. By doing so, we acknowledge that even though we speak about similar phenomena, the theories and concepts that we use to discuss these issues are not yet fully matured but are developing as we speak and stir up further discussions. This is the best place to be in an academic sense – in a state of agitated and interested commotion in pursuit of understanding more, better, or more deeply.

We recognize that most contributions come from a Northwestern and largely Anglophone geographic area, including several Nordic and south European authors, while the African, Asian, or Australian geographic areas are not represented equally well in this volume. However, our group of authors is by no means homogeneous but consists of different career stages and expertise, from design and craft practitioners, philosophers, sociologists, and art educators to cognitive scientists and archaeologists.

As the material environment is in a process of shifting partly into the virtual realm, the context of designing and crafting is enduring changes that affect our interaction with physical materials. Through documented case examples, we present insiders' views of embodied experience in engaging with analogue and digital/virtual materials in both tangible and intangible making processes. The examples include various craft and design practices, from ceramics, woodwork, textiles, metal work, and glass blowing, to hybrid crafts, game design, and interaction design, as well as teaching and learning crafts online and children's art education. By doing so, we gain insights into multiple types of material engagement and practitioners' direct *thinking through making* that contributes to the theoretical discussion of ways of knowing in such situated practices.

This book has come about due to the mutual interest in experiential knowledge that we, the editors, have shared over a decade. It continues our longitudinal work in discussing design and craft from a first-person perspective and in providing platforms for other design and craft practitioners' voices to be heard in academia through organized conferences and special issues. We hope that this book will be an interesting reading for anyone involved in material engagement and making, including scholars, students, teachers, professional practitioners, and theoreticians within the field of creative practice and embodied cognition. Essentially, we hope that the division of making and thinking will be an idea of the past and that craft practitioners' reflective practice is recognized as a contribution to knowledge.

Introduction

Making as reflecting through interaction with the material environment

Camilla Groth and Nithikul Nimkulrat

Why making is reflecting

Much debate in design research has evolved around the role of thinking, planning, problem-solving, creative ideation, and imagination. But where does the making of artefacts come in? What role does the act of making have in the process of thinking and reflection? Is making or crafting just the implementation of a particular idea in material form that takes place after the thinking phase is completed? Or is the act of making and crafting actually an integral part of the process of thinking that enables the ideation of an artefact?

Recent advances in cognitive sciences support the idea that cognition is not just happening in the head, but it is an embodied activity facilitated by a person's active engagement with their material and social environment (Baber, 2021; Malafouris, 2013; Varela et al., 1991). This "paradigm shift" in cognitive sciences might at first appear distant from the daily businesses of designers and craftspeople. However, theoretically, it means that planning and making or designing and crafting, which have traditionally been understood as separated (cf. Baber, 2021, pp. 39–43; Dormer, 1993, p. 9; 1997, pp. 18–19; Gedenryd, 1998, pp. 7–8), may now be seen as integrated and mutually intertwined activities. Design thinking is thus extended to involve a reflective material practice, and crafting is elevated from the status of mere manufacturing to that of facilitating reflection in action, thus closing the intellectual gap between designing and crafting.

The shift in cognitive sciences towards a more holistic and embodied view of the human mind has influenced many fields of study outside the cognitive sciences, including design and craft. For design and craft researchers, the recognition that cognition involves action and interaction with the social and material environment makes the notion of embodied cognition (EC) interesting and relevant, as it grounds the idea that making with a material is a form of thinking.

Craft, as one of humanity's oldest practices, forms the basis of human interactions with materials and the design and making of artificial environments that in turn make us who we are (Ihde & Malafouris, 2019). The theoretical framework of EC touches on notions in which pragmatic design and craft theorists have long been interested, including acknowledging the situated and bodily aspects of knowing, material engagement, affordances, expertise, and skill learning. While we could say that nothing is new here for the craft practitioner, that EC theories come too late, or that they are too limited, it is a relief for the field of craft research since what we knew all along has now been confirmed in other disciplines too. It also helps us theorize our own practice through alternative concepts. An even better understanding of these issues is critical in the digital era when the materiality of our environment is changing rapidly.

DOI: 10.4324/9781003328018-1

Only a few of the authors in this book are cognitive scientists, thus the purpose of the book is not to enhance knowledge in the cognitive sciences. Rather, by involving authors from multiple disciplines, we hope to cross-fertilize the discussions on craft and design from an embodied perspective. Through research-based cases that involve the researchers' making experiences, different phenomena of human-material interaction are presented, analysed, and discussed. The practical cases exemplify ways in which embodied notions show up in action and are reflected upon by the authors. Through these cases, the book examines topics such as the embodied basis of craft activities and material manipulation, experiential knowledge and skill learning, reflection in and on action, and material dialogues. The book further discusses the role of affordances in making as well as mental imaging and rotation and how these may be scaffolded, teaching and learning situations, design collaborations, or resistances felt in material engagement. Several authors specifically discuss the hybrid forms of analogue and digital crafting that increasingly takes place in the field of craft.

The theoretical frame of EC is still developing and there are several directions with similar, but sometimes conflicting, standpoints (Newen et al., 2018). In this anthology, we do not promote any of these varying directions in particular; rather, we have given the authors autonomy to interpret the notion of *embodiment* in their own reflections. The topic of craft and design practice seen from an embodied perspective can be understood in several ways, thus some of the authors have written from their situated perspectives rather than addressing the theories of EC in depth. Others have utilized aspects of EC theory to reflect on their own practice in a wider sense, in relation to phenomena that they experience and consider important, such as wellbeing.

From design cognition to embodied cognition

Design and craft research and related theory have been heavily influenced by different cognitive orientations over time. Being a "planning" profession, design scholars have since the 1970s linked design practices to cognitive sciences, promoting a design cognition theory based on the fact that designers tend to work with problem-solving, i.e., they think and solve complicated and ill-defined cognitive tasks (Cross, 1982, 2001, 2011; Simon, 1988). The problem-solving paradigm was influenced by information processing models of cognition established in the 1970s–1980s that considers human problem-solving foundational (Newell & Simon, 1956, 1972; Simon, 1996). It views designing as a search process that applies knowledge to addressing a specific problem. These early theoretical underpinnings of design research often refer to the design cognition theory developed in conjunction with the design methods movement in the 1970s–1990s, a largely representationalist and computational understanding of the planning tasks, where ideas are first solved in the head or by calculations and then implemented in material (Kimbell, 2011; Rittel & Weber, 1984; Rowe, 1987). Design cognition theories have since merged to form a more applicable approach in what has been called "design thinking" (Kimbell, 2011).

However, already early on, parallel lines of thought offered a different view. Knowledge gained through experience and material interaction is called *procedural knowledge*, a kind of knowing *how* rather than knowing *that*, as explained by Gilbert Ryle (1971). Ryle was an early proponent of situated and embodied knowing as he shed light on the relevance of the procedural aspects of "intelligence" at a time when the word "embodiment" was on few lips. Another proponent of the embodied or "personal" knowledge was Michael Polanyi (1958, 1966), who differentiated the "tacit" dimension of practitioners' knowledge from the more explicit and theoretical. Both Ryle and Polanyi felt the need to argue for their views in a knowledge landscape that was not entirely ready for an embodied view of cognition or the value of introspection and personal knowledge. However, both theorists have been amply referenced in research on crafts and making processes.

By the end of the 1990s, supported by Donald Schön's (1983) concept of reflection-in-action, and with the emerging practice-led research tradition, experiential and embodied views have surfaced in the research practices. Through this development, more phenomenological and embodied approaches have come to influence design and craft theories too, but these two strands were for a while in parallel existence, with the latter promoting a more material-based starting point for design (cf. Dorst & Dijkhuis, 1995). While Don Norman (1988) was inspired by James J. Gibson's (1986) ecological theory of affordances, Norman was not ready to abandon the traditional cognitive theories, as Bill Gaver (1991) did in the field of interaction design. Paul Dourish (2001) was one of the first to write a book on the embodied view in human-computer interaction. However, craft researchers, especially, have found the ecological and phenomenological cognitive theories relevant to their material interactions and reflections.

Researchers in the more phenomenological tradition have largely followed a pragmatist orientation that already 100 years ago acknowledge the role of the body in knowledge creation, such as John Dewey's (1938/2005) *Art as Experience* and other writings on art making, followed by Donald Schön's (1983) *The Reflective Practitioner*, Peter Dormer and colleague's *Art of the Maker* (1994) and *the Culture of Craft* (1997), Richard Sennett's (2009) *The Craftsman*, and many others. Due to the academicization of the arts and related PhD opportunities in the creative arts fields, this thread has lately been expanded by practitioner-researchers who reflect on material interaction from a first-person perspective and articulate their experiences as thinking through materials and processes (Mäkelä, 2007; Niedderer, 2007, 2013; Niedderer & Reilly, 2010; Niedderer & Townsend, 2014; Nimkulrat, 2009; Vear, 2022; Westerlund et al., 2022), thinking through hands (Groth, 2017), or a material dialogue (Fredriksen & Groth, 2022; Mäkelä & Aktaş, 2022; see also Brinck & Reddy, 2020). Personal and experiential forms of knowing are highlighted in such autoethnographic reflections, giving access to the practitioner's embodied perspective of the making and thinking process.

What is embodied cognition and how does this theory relate to research on design and craft practices?

EC is a group of related theories that generally holds the perspective that cognition is dependent on an organism's interaction with its environment via action and perception (Newen et al., 2018; Varela et al., 1991; Wilson, 2002). Based on phenomenological views first arising at the turn of the last century, there are now several lines of inquiry (cf. Newen et al., 2018). These separate "schools" of EC theories are founded in different domains, mainly in cognitive sciences and psychology, philosophy of mind, as well as ecological directions of psychology and neurosciences. Not only are different views connected to different scientific domains and traditions, but they also vary along an axis from so-called strong to soft interpretations, basically determined on how much they deviate from the traditional "intra" mental and representationalist or computational cognitive sciences (Newen et al., 2018, pp. 3–4). EC theories are often grouped into the 4Es (embodied, embedded, enacted, and extended cognition), to show the more general issues that these theories promote as a group. While there are disputes within these sub-groups too, the general common standpoint is that the proponents of 4E cognition reject traditional cognitivism, i.e., the idea that thinking only takes place inside the head by manipulation of representations (Menary, 2010; Newen et al., 2018). To quote Chris Baber (2021, pp. 1–2):

> However, there is a broad consensus that humans, as cognitive agents, are *embedded* in environments in which they *enact* their *embodied* skillful coping in response to the scaffolding of artefacts that allow for the *distribution* or *extension* of cognitive activity.
>
> (Italics in the original)

The 4Es explained in relation to design and craft activities

Embodied

Thinking, or cognition, does not happen only in the brain; instead, the whole body and its sensory faculties play a constitutive role in cognition since they enable perceiving and interacting with the environment (Chemero, 2013; Noë, 2004, 2009; Wilson, 2002). Consequently, sensory experiences and the information handled through acting with materials and other beings are key to processing these experiences, hands and touch being especially relevant (Ratcliffe, 2018). For example, our ability to make sense of what we see is an embodied skill that we have acquired through interacting with our environment; even if we have visual sensory input, our vision does not make sense to us unless we have gained experiential knowledge in relation to what we see (Noë, 2004). Learning skills and becoming an expert involve a process of automating the interaction between actions, materials, and tools – to the point where actions become, so to say, “second nature” or “embodied”. Tools used disappear from consciousness and become “ready-to-hand” meaning that the practitioner’s thinking and making happens *through* materials and tools, just like when a blind man feels the irregularities of the street through his cane (Baber, 2021, p. 110).

Embedded

People exploit features of the physical and social environment to increase their cognitive capabilities (Malinin, 2015), thus cognition is always embedded in a social and material context, such as in a craft studio where there are other practitioners, tools, and materials. This becomes especially relevant to apprenticeship in which a craft learner is enculturated into a craft identity through what Jean Lave and Etienne Wenger (1991) called the “legitimate peripheral participation”, a form of situated learning. Communities of practice, according to Lave and Wenger (1991), are collectives of practitioners who participate in an activity system by a set of relations between persons, activity, and the world (p. 98). Within such communities, we can speak of a shared embodied understanding that is the product of socialization and culturation over a long period of time. *Situated cognition* is not mentioned separately in the 4E group but is in a way an early concept for the idea of the 4Es, especially in the learning sciences (Brown et al., 1989; Robbins & Aydede, 2009). Situated cognition basically means that cognitive activity does not simply take place in the head but in the context of a real-world environment (Wilson, 2002). Varela et al. (1991) were seen as the first real introducers of the concept of EC; however, situated cognition and situated learning were introduced at a similar time, building on a phenomenological worldview. *Distributed cognition* means that thinking does not happen in a vacuum but is distributed across individuals and builds on a socially shared activity. It also means that we build our thinking on previous ideas we have gathered through our social interactions with other people and that these people's ideas help us think further. Similarly, an apprentice under the influence of a master craftsperson in the workshop is able to build on the master's knowledge and thus extend their own knowledge (see also Haraway, 2016).

Enactive

Cognition emerges from, is constituted by, and depends on sensorimotor activity (Johnson, 1987; Noë, 2004, 2009). The idea that an organism is in a constant interaction with its environment is originally an idea based in enactivist biological psychology, where the perception-action loop is an example of how this interaction is grounded in perceptual and sensory functions. Basically, an organism orients itself in the ecology by sensing its environment and by making sense of it through acting in and interacting with it and learning from this interaction (Varela et al., 1991). Babies' ways of learning through touching, tasting, and trying out different actions is an example of this. Engagement with different types of materials thus affects the nature of what is perceived, learned, and understood (Malafouris, 2013). Design and craft practices are bodily informed in multiple ways, not only in the act of making and manipulating materials (Malafouris, 2020) but also in the reception of designs and using of objects (Baber, 2021) as well as the general creative process (Withagen & van der Kamp, 2018). Even imagining is an active process that relies largely on previous sensory experiences, even if we are also able to imagine beyond these (Rucińska & Gallagher, 2021). As EC, and hence also embodied knowledge such as craft skills, are seen as implicit (i.e., tacit), they are not always readily available to us for our conscious reflection. However, a person can make their skills seen through the *enactment* of them, thus we can show how a craft practice is performed while we may not be able to explain all aspects of what is going on in our practice. Embodied knowledge can thus better be communicated through action and may, to some extent, be experienced through enacting other practitioners' practices (Almevik et al., 2013) feeling what it is like doing them with one's own body.

Extended

Cognition extends beyond the boundaries of the individual, for example, through the use of tools and technologies, such as a hammer, or a potter's wheel. Making is a form of thinking through actions, tools, things, and materials – or *thinging* – as Malafouris would write (2020). The tools we use naturally also affect what we can make with them and how our thinking is distributed through them (Baber, 2015). While digital tools may take time to embody, they also afford considerable opportunities for extending cognition beyond the body (Clark & Chalmers, 1998; Hutchins, 2010). However, even taking notes with a pen on paper is an example of such extension of cognition outside the brain. In design and craft processes, sketching, drawing, and prototyping work as explorative "thinking through action" or "thinking with hands" (Baber, 2018). Not only do they enable us to better understand the physical strains and the "realities" of our designs, but they also work as mental "crutches" when imagining 3D rotations, i.e., what something would look like from a certain angle. By "externalizing" our ideas in material, we also communicate them to others and can discuss them concretely without having to imagine what ideas are going on in each other's minds.

While the 4E list does not include the *distributed* or *situated* nature of cognition as their own points, these are thought to be part and parcel of the EC theory in general, playing a part in the other "Es". Some authors like to write the 4Es ++ with plus marks, to indicate that there are even more aspects to this conceptual group, some even pointing to "emotions" and "affect" as missing from the original group (Newen et al., 2018).

It is also important to mention that, while the notion of EC highlights the human perspective in the practice of making, it is not "human-centric" or in opposition to post-human views on making. On the contrary, especially the *enactive* line of EC theory (Noë, 2004, 2009; Varela et al., 1991) highlights *any* organism's (human or animal/flora) interaction with the environment as a form of sensemaking. Material engagement theory (MET), for example, promotes the idea of material agency and the equal relationship between the maker and material (Malafouris, 2008). The way the "voice" of materials affects the making process also links the maker with their environment concretely in some cases (Fredriksen & Groth, 2022). Such "negotiation" with the material and dialogical reflection in action is central to many authors of the chapters in this anthology.

Material dialogues in craft and design practice

The contributors of this book discuss their embodied experiences and "material dialogues" based on a variety of concepts from EC theory, as well as from their personal experiences. Interestingly, it has become evident that, to discuss the topic, they largely adhere to similar concepts such as material dialogues, material engagement, affordances, as well as the changed materiality in hybrid crafting that involves physical and digital materials in the making. While these are not the only topics, we open these up a bit already here to aid in reading the chapters later.

Material dialogues

Many craft and design practitioners refer to their making as a process of negotiating with the material as if they are having a dialogue with it (cf. Malafouris & Koukouti, 2022). Inspiration may be sought in the material, in the properties or uses, or in technical aspects such as challenging the material resistance or applying it to a new context. Even if a design idea or image of a wanted result is developed before manipulation starts, oftentimes this idea will be modified in the process of prototyping or constructing the artefact as the situation unfolds. As Tim Ingold (2013) pointed out, the idea that a separate design and thinking part is followed by an unreflective making part is unrealistic; he criticized this as "hylomorphic" (pp. 20–21). Instead, he promoted a more interactive way of thinking about the making process in which he used the idea of "correspondence" to exemplify the maker's dialogical relationship with materials and situations (p. 107). Also, Donald Schön (1983) described the practitioners' reflective thinking in and on action, and in a later speech (1992), he further explained material dialogues as a "reflective conversation with the materials of a situation". Such a reflective stance is based on the ability to be sensitive, open, and reactive towards the situated aspects of the making process that resonate with ideas of situated and embodied knowing.

Affordances

Gibson's (1986) affordance theory is at the core of the embodied mind thesis and has been a central concept in the understanding of material "dialogues" experienced by researchers in design and craft. In short, Gibson (1986) introduced the idea that the environment offers certain possibilities for action that different individuals may activate depending on their physical abilities and constraints. Affordances become important not only in the material dialogue between craft practitioners and their material situation but also when designers create future interaction possibilities for users of artefacts or services (Norman, 1988). Affordance theory has evolved after Gibson and is actively expanded to also encompass the active creation of affordances (Kimmel & Groth, 2023) and affordance landscapes (Rietveld et al., 2018).

Material engagement

In many ways, Lambros Malafouris' (2013, 2018, 2020) MET takes this idea of material dialogues further to create a theory around the dialogical relationship that practitioners have with matter, their tools, and their task ecology. However, this theoretical framework represents a different school of EC theories – the enactive view. This view is seen by some as incompatible with Gibson's ecological view (Alessandroni & Malafouris, 2022), while others try to build bridges between these, arguing that they have more in common than what separates them, and that both perspectives are necessary (Baggs & Chemero, 2021).

Malafouris's MET relates to all making, and his influence stretches over several domains such as anthropology, cognitive archaeology, philosophy, and cognitive sciences, but is perhaps especially visible in the craft practitioner's interaction with materials. For this reason, many of the examples in his writings are from the field of craft, in particular clay throwing on a potter's wheel. The main idea is that the situation of making a material artefact involves not only one actor (the maker) but also the material agency and properties, the tools, and the environment. These are all co-agents that are equally participating in the emergence of the artefact. Further, the theory promotes the idea that sensory evaluations and reflection in action are what grounds cognition in the actions of the practitioner (Malafouris, 2013, p. 225).

Hybrid crafting

When the material realm is moved into the digital and the virtual, affordances and ways we make with materials are changed. Virtual material experiences have become increasingly important due to the digitalization of design processes and fabrication technologies. As user interfaces are getting more seamless, embodiment of tools and actions are also experienced in virtual space – in different, but not always entirely dissimilar ways. The phenomena are familiar in human-computer interaction research and the gaming industry, but much less discussed in the craft context. Digital tools and processes may seem detached from the act of material making when they do not permit direct engagement with tangible materials. The process of working with digital technologies may even be seen as "'hidden' making understanding and controlling the process from concept to end product seem more complicated", as pointed out by Ann Marie Shillito (2013, p. 9). On the other hand, Malcolm McCullough (1998) recognized that access to digital fabrication and tools in fact expands crafting possibilities, due to their capacity to "reunite visual thinking with manual dexterity and practiced knowledge" (p. 50) and that the practitioner's subjective decisions are still essential in the production of digitally fabricated artefacts. Several contributors to this book, who are craft practitioner-researchers working in the hybrid realm of craft making, illuminate the importance of prior experiential knowledge of handling manual tools and physical materials in the shift from analogue to digital/virtual processes in their practices. Where possible, they are able to adopt and adapt their experiential and embodied knowledge to the new context of practice.

When it comes to education, digital tools have many benefits for its users and may even extend the capacity of the users; for example, digital drawing tools enable fast and uncomplicated deletions of drawn marks and instant changes of colours without having to discard the first version of the paper drawing. However, for very young children's experiences of material interactions and tactile manipulations of materials, physical arts and crafts materials have more sensorial experiences to offer than a screen or a mouse. While students will certainly need digital competences in their future lives, material properties and constraints are different in the virtual space and need to be experienced bodily to be interpreted realistically in the virtual realm (Søyland, 2021). This is also important for design students in higher education, who might encounter new materials for the first time in their computer-aided design (CAD) programmes material toolbox.

A note on the use of terms

As made apparent in this introduction, thinking through making is not a new idea but has influenced research in crafts and design for a few decades, shaping the understanding of craft and design practice. When it comes to *craft research*, we need to clarify that craft theory from an insider's perspective is relatively young and was for some time not considered "research proper" due to its situated, experiential, and subjective nature (cf. Niedderer, 2007; Niedderer & Reilly, 2010; Niedderer & Townsend, 2014). This led to the use of the word "design" to refer to both the planning and making of artefacts and "design" or "design research" to indicate traditional craft practices in academia during the early 2000s. It is not our intention to make a stark contrast between these very interrelated domains of crafts and design. On the contrary, we would rather aim to show their similarities and that they have almost everything in common, especially when the designer is also making prototypes or possesses the material knowhow that we discuss extensively in this book. The reason for pointing out the use of these words in this introduction is because most authors of research literature in crafts or design tend to use the word "design" in their texts despite the craft-oriented content. We generally prefer to use the "creative practices" when relevant (to also include the arts) as we acknowledge that the domains overlap to a large degree.

The structure of the book

The book is structured into three parts, each of which has its role in synthesizing the embodied perspective in craft and design processes. Part I: Craft as Embodied Making and Learning provides a ground for theorizing craft practice as a process of thinking in action, by explaining the theoretical background for it, with examples from material interaction and learning. Part II: Materiality of Materials and Non-materials in Craft scrutinizes the new and changing materiality of craft practice that we face due to digitalization and the possible challenges and benefits of hybrid material practices. Part III: Artefacts as Material Extensions of Craft Experience illuminates the roles of artefacts as carriers of memories and imprints of human-material interactions and material extensions of craft experience.

In the beginning of each of the three parts of the book, there is a short introduction to emphasize each part's concept and how it will be exemplified and elaborated on by the chapters included in the part. We hope that the discussions and reflections presented in this book will be transferable to many other practice-based domains and can support researchers, teachers, and practitioners widely in their acting and thinking with, and through, materials and artefacts.

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Part I

Craft as embodied making and learning

Part I

Introduction

In this part, craft is examined as embodied making, thinking, and learning. The chapters in this part offer a ground for theorizing craft and design practice from an embodied perspective through various concepts in embodied cognition (EC). The part starts with Chapter 1 “Dynamic Affordances in Human-Material ‘Dialogues’” by craft practitioner-researcher Camilla Groth and cognitive scientist Michael Kimmel who examine the role of affordances in the craft and design discourse. Through a case example of clay throwing, the chapter demonstrates how one of the authors, an experienced ceramicist, maintains the integrity of the throwing process by keeping affordances intact through respecting the material’s constraints, while searching for and creating new affordances. Affordances offer an analytical lens on how the craft practitioner regulates creative processes. In Chapter 2 “Craft thinking: A Relational Approach to Making and Design”, philosopher Ingar Brinck sets the stage for bodily intelligence and introduces how it has been discussed in cognitive sciences in relation to crafts and physical actions. By placing collaboration with the material in the centre, she relates thinking and intelligence to actions performed by hand. The chapter approaches nonverbal craft thinking within the framework of embodied and embedded cognition. It illuminates how craft thinking takes place in the making process when the maker uses their hands and body to critically engage with materials and handle problems occurring in the process, such as uncertainty, insufficient information, and insufficient quality within the craft making process.

In Chapter 3 “Becoming with Glass: Medium and Materiality in Embodied Knowledge”, sociologist Erin O’Connor reflects on and discusses the material interactions that go on in a glass workshop and how becoming intimate with the glass can affect a person’s becoming *with* the practice and the material. She articulates her embodied experience of learning glassblowing for an extended period as part of her ethnographic research. The process of skill acquisition and development of proficiency bring about a way of becoming with glass that involves blurring the boundaries between self and material. While several contributors to this book find material engagement theory (MET) relevant to the discussion of their own making practices, cognitive archaeologists Catherine O’Brien and Lambros Malafouris expand the theory further in Chapter 4 “Feeling How: MET and Embodied Cognition in the Learning of Pottery Skills”. MET is discussed in relation to the development of feeling *of* and *for* materials through a case of novice potters learning skill through digital learning platforms. With the pervasive materialities of the digital, the authors extend MET to consider human engagements with digital materials, whether they are intangible (e.g., algorithms and codes) or tangible (e.g., touch screens and keyboards). They suggest that such engagement should take place in tandem with analogue materials, such as clay and other manual tools.

DOI: 10.4324/9781003328018-3

The practice of craft and making can also have an effect on emotions and how we feel in our bodies. Craft practice can affect the maker in multiple ways, for example, on a psychological level by offering flow experiences in the act of making. It can also offer social interaction through joint making that promotes contextual belonging and sharing. While flow is a state of mind that is usually reached in solitude, through intensive concentration on a particular task that is challenging enough in relation to the practitioner's skills, social interaction can be equally satisfying. Designer-researchers Kristina Niederrer and Katherine Townsend write about this in Chapter 5: "Embodied Craft Practices: Mindful Flow, Creativity, and Collaboration as Drivers for Wellbeing".

1 Dynamic affordances in human-material “dialogues”

Camilla Groth and Michael Kimmel

Introduction

Manipulating a material is perhaps the most central aspect of making an artefact. From an evolutionary perspective, the ability to perceptually “read” the significance of materials and manipulate them has grounded our possibilities to transform and optimally attune with our living environments. Although this is a fundamental condition for any organism, only humans have mastered this skill in unprecedented ways due to owning such nimble hands and high-level planning skills. This ability to improve our artificial environment connects well with Gibson’s (1986) ecological psychology that highlights organisms’ tendency to respond to and to change the affordances of their environment – to better adjust them to their ecological niche. While this theoretical frame is developed in psychology, it has found its way to design and craft and often been mentioned by design and craft theorists, even though the scientific theoretical background is not always articulated.

Gibson’s concept of affordances has interested design and craft practitioners for several reasons. First, it provides a concept and a significant theoretical understanding for sensing and interacting with materials, tools, and artefacts. The concept highlights the practitioner’s dynamic “in-process” regulation of their actions in relation to the material task ecology (Baber, 2021). Second, the notion highlights the key role of sensory experiences and experiential know-how in grasping which specific information in materials or tools that guides technical, aesthetic, functional, or other decisions in the making process.

Designers and craft practitioners are familiar with affordances from the writings of design thinker and computer scientist Don Norman (1998) and interaction designer and researcher, Bill Gaver (1991) who discussed affordances related to product and interface design as well as product acceptance. Within craft research, affordances are more closely connected to material manipulation and phenomenological accounts of craft practitioners having a “dialogical relationship” with their materials, tools, and environment (Brinck & Reddy, 2020; Mäkelä & Aktaş, 2022). At the same time, the interdisciplinary field of cognitive approaches to skilful practice are constantly developing the theory of affordances. In this chapter, we will draw on a transdisciplinary understanding of cognitive psychology and craft practice and combine theory and practice from these disciplines to discuss how affordances shed light on clay throwing before providing a nomenclature for general features of craft practices.

We will first introduce the theoretical background of affordances and connect the notion to how design and craft researchers have described material manipulation. We will then show how affordances can be applied to an analysis of clay throwing and different aspects of affordances that come to light. Finally, we will discuss the possible benefits for the craft researcher and practitioner.

DOI: 10.4324/9781003328018-4

Affordances and their epistemological foundations

Affordances are, following Gibson (1986), opportunities for action that the environment of a living being offers. The concept attempts to explain how organisms, human or animal, pick up information and how this mediates their actions in their environment. Gibson (1986) has described his concept as follows: "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill" (p. 127, italics in original). Materials and tools provide a good example, offering – and possibly even soliciting – various alternative ways of active bodily engagement with them. According to Gibson's fundamental idea, instead of intra-mental operations such as categorization or reasoning, cognition is primarily for (inter)action in the world and happens in a continuous loop between an actor and their ecology, commonly referred to as a perception-action coupling. Thus, an affordance is not *in* the things, but rather in the relation *between* an actor and the thing. For example, a medium-sized stone affords sitting for a human but climbing for an ant; it affords very different actions, depending on the actor's physical composition and abilities.

Gibson's ecological theory of information pick-up is an early influence on embodied cognition theory. It rejects the idea that the mind computes inputs to give them significance and that the mental process imparts meaning to the inputs, which then get passed down to the action system – the body. Gibson's ground-breaking hypothesis is that the world frequently offers extremely rich, reliable, perceptual arrays, such as visual flow properties that guide action, so that the mind need not add inferences about what some perceived information means. Moreover, perception is not held to be a passive registration of information; rather, it is based on active movement, manipulation, and exploration of the world, as eye and head movements illustrate well for visual perception. Gibson's wife, Eleanor Gibson (1988), further developed the theory in relation to learning. She suggested that learning to perceive is not learning to run the correct algorithm on "raw" input but instead involves an optimal *attunement* of the whole organism to the ecology in which the senses are part of a much larger embodied system.

Gibsonian psychologists have since debated definitional specifics, e.g., whether affordances are actual solicitations for action (Withagen et al., 2012) or whether ongoing interactions with people, spaces, or things are necessary for them to arise (Chemero, 2009). Experiments have addressed how specific relationships between ecological information and the actor (body, site, strength, etc.) specify affordances for particular tasks and posit "laws" of actions for given tasks, such as climbing stairs or passing doors (e.g., Warren, 1984). However, psychological approaches often discuss well-defined and set tasks such as opening doors by different handles, which are quite different from what typically happens in the contexts of arts, crafts, or performance improvisation where every moment presents countless affordances and where atypical and non-conventional "actionables" may dominate. For this reason, the next section will look into the contexts of craft and design as they may shed more light on how a person's objectives, skills, and imagination make some affordances stand out as well as how actors contribute to the creation of new affordances in the process of making.

The reception of affordances in design, crafts, and creativity

Through the applied writings of Norman (1988), especially the book *The Psychology of Everyday Things*, affordances have attained wide circulation among design researchers. With a focus on user experiences of artefacts, Norman's early work claimed that the affordances a designed object offers its users are essential for a product's success. Consequently, the designer needs to be conscious of ways in which users may interact with a designed product's properties (Norman, 1988). However, in his later writings (Norman, 1999, p. 39, 2008, 2013), he admitted to having misunderstood Gibson's theory. The ecological model of mind was, at the time, a radical theory that stood in stark contrast to the computational tradition that Norman worked within, and the two scholars clashed over this difference in epistemology (Norman, 2013, p. 12). Revised from *The Psychology of Everyday Things*, *The Design of Everyday Things* (Norman, 2013) developed the idea of "signifiers", which refers to "signs" of an affordance, not the affordance itself, and these signifiers are what designers should focus on. What Norman missed was that affordances are not in the product but between the product and the user, as products offer different affordances to different people (Baber, 2021, p. 67).

Writing on interaction design, Gaver (1991) identified several types of affordances when navigating and interacting with virtual, physical, or auditive artefacts. Gaver agreed with Gibson's ecological view that presents affordances as offering a *direct link* between perception and action. He distinguished between used and unused affordances, pointing to the fact that the organism might not act on an affordance but have other intentions and, therefore, aims and preferences play a part. Gaver further differentiated perceptible from hidden affordances and what he called *false affordances* when an object presents confusing affordances that make the user act in an unwanted manner. Gaver (1991) also introduced the notion of *sequential affordances* to capture the fact that, in extended activities, there is an integral relationship between different affordances along the timeline. For example, sometimes one affordance must be acted on for the next one to appear, e.g., when opening a lid and discovering a button to push. Finally, Gaver discussed how visual affordances (the main focus of Gibson) differ from affordances discovered through haptic, auditory, or other modalities.

The concept of affordances has affinities to research on material experience. Barati and Karana's (2019) *material potentials framework* shifted the focus from the designer's ideation and conceptualization of a novel material's potential use areas to the designer's skilful ways of unlocking novel affordances inherent in a material. With this, they took a step towards highlighting the affective role of materials in a design process.

Similarly, in the context of crafts, attention has lately been turned to the practitioner's experience of materials in the making process rather than their interaction with designed objects, thus highlighting the responsiveness of materials. Studies of how materials respond and how practitioners listen to their "voice" in the act of manipulation, such as Brink and Reddy (2020) and Mäkelä and Aktaş (2022), highlight the relevance of affordance-based real-time guidance while engaging in a "material dialogue". This view is not uncommon in design and crafts. Schön (1991) also referred to having a conversation with a material situation – a claim that affordances provide a perceptual lens on.

Ingold (2000, 2013) has further influenced the discussion of affordances in an ethnographic and crafts context. Engaging with Gibson's epistemological foundations, he spoke of material flows that mediate action and rejected hylomorphic creation, i.e., the idea that makers simply implement work after a set plan or design. Instead, Ingold (2000) stressed that craftspeople engage in a "creative undergoing" with the materials. Through this, Ingold (2013) showed how the "forces" of the material guide the process, emphasizing that the environment has an active and equal role in the "correspondence" with the maker (pp. 21–22 & p. 107).

Affordances have also been studied in research on creativity. Vlad Glăveanu (2014, 2020) discussed affordances as part of a cultural psychology of creativity. He is noteworthy for asking what "creative affordances" might be. His framework of "distributed creativity" describes the interplay of actors, actions, artefacts, audiences, and affordances (Glăveanu, 2014). According to him, creativity happens at the fringes of unconventional, unnoticed, unexploited, and norm-violating affordances, or affordances that need to be brought into existence, i.e., "new collections of affordances generated by the combination or transformation of basic (existing) potentials" (Glăveanu, 2014, p. 219).

Finally, the "skilled intentionality" framework (SIF) developed by Rietveld and collaborators cross-fertilizes Gibson's theory with Wittgenstein's ideas about *practices* and applies these to the field of architectural design and creativity (Rietveld & Kiverstein, 2014; Rietveld & Brouwers, 2017; van Dijk & Rietveld, 2017; Yakhlef & Rietveld, 2019). Useful distinctions of affordances have been introduced in Rietveld and Kiverstein (2014), including "landscape of affordances" for opportunities in a domain and "field of affordances" for a person's situated opportunities.

Evaluating affordances in the broader perspective

Enactivist scholars (after Varela et al., 1991) have contributed (largely constructive) critiques of ecological psychology, pointing out that it focuses too little on action and presents an impoverished view of both intentionality and subjectivity. This is relevant to a craft context when what the maker had planned on doing before starting a craft process or their personal preferences are as pertinent as the affordances offered in the situation. Enactivists stress an organism's activity and basic orientedness towards its environment. Thus, *how* someone actively shapes the "dialogue" is more than just responsiveness to the existing ecology; it means that a person's objectives, skills, and imagination make a difference to what affordances are acted on. In this view, it may even be claimed that Gibson's affordance theory is more of a *possibility theory* than a fully developed *action theory* without a sufficient discussion of intentionality.

Additionally, affordances are cited in emerging alliances between different theoretical orientations. Gibson's opposition to cognitivist (i.e., computationalist and representationalist) views has influenced embodied, action-oriented, or interactionist cognitive scientists. One strong emphasis overlapping with affordance theory is that thinking can (partly) happen as action in the world through exploration, active manipulation, or perspective change (Steffensen, 2013). Another is that creativity emerges in the ongoing coupling dynamics between practitioners and ecologies (Davis et al., 2015), an idea that has lately become influential in craft research through Material Engagement Theory (MET), developed by Malafouris (2013).

Case example: Affordances in clay throwing on a potter's wheel

The range of possible actions at each moment in a craft process is delimited by the properties of the materials, the tools, and the set-up of the workspace (i.e., the ecology) in relation to the skills and aims of the practitioner (i.e., the actor), thus reflecting the relationality that Gibson talks about.

How, then, do affordances mediate skilled action? Affordances provided by the situation can be turned into actions once they have been filtered by the practitioner's

Figure 1.1 Interview study of affordances in clay throwing via Zoom. Screenshots from the Zoom video recording by the authors.

intentions, task-specific constraints, and the general affordance landscape for that craft practice. Affordances depend on the sequential structure of material work processes. For example, throwing clay on a potter's wheel must follow a particular path, or a certain order of progression to succeed, from centring the clay and making a hole to throwing the sides. Such path-dependency is generally common in craft practices and requires skill and longitudinal experience to master, making crafts less flexible than many other creative practices.

We will now present a case of clay throwing (see also Kimmel & Groth, 2023). The study was conducted online via Zoom and utilized a phenomenological process analysis interview method originally developed by Petitmengin (2006).

In this study, Michael Kimmel, a cognitive scientist and creativity researcher, interviewed Camilla Groth, who is a craft practitioner-researcher, while she was throwing clay in her studio. Due to long distances (Vienna-Helsinki) and travel restrictions during the COVID-19 pandemic, the interview was conducted and recorded via Zoom (Figure 1.1). Groth also recorded the throwing event from a first-person view using a go-pro camera attached around her neck. In the interview, Kimmel posed questions and Groth talked out aloud about the different situations she encountered while throwing the clay and how she interpreted what was going on in the process. The process was later analysed by both authors.

Although it was decided that the clay throwing should aim at making a vase, we kept the process open as to what shape it might have. We allowed emergent affordances of the material give direction to the shape finding process, whilst conforming to the basic order of sub-tasks in the craft process.

Preparing the material

The event started with Groth making an informed choice regarding the most suitable type of clay for making a vase on a throwing wheel. However, she also considered her aesthetic preferences, therefore she chose porcelain despite its demanding properties, such as low plasticity, which makes it difficult to handle. After taking the clay from the bag and noticing that the clay was too wet and too soft to throw, she kneaded it on a plasterboard to dry it out and stiffen it a bit before starting.

Figure 1.2 The clay being first centred and then thrown into a narrow basic cylinder. Screenshots from the Zoom video recording by the authors.

Preparing the process

She then sat by the wheel and started centring the clay on the wheel head. Doing this carefully is necessary for proceeding with the process. The base of the vase was prepared by making the shape of the clay ball high and narrow before hollowing it. Then, the sides were slowly turned up into a straight narrow cylinder that makes the starting point for any kind of vase profile (Figure 1.2).

So far all efforts had gone to setting up the generic structure for a vase shape, while maintaining a broad field of affordance opportunities for the continuation. There were not many creative choices to make in relation to the shape at this stage of the process yet. The main task was to set up an enabling condition for future possibilities and keep basic material affordances in a workable state. This was done by choosing a suitable material, correcting the degree of humidity, keeping the clay centred, and shaping the base narrowly – thus making sure that no future possible affordances were diminished by accident.

Once the clay cylinder was high and thin enough, the next step of shaping – or rather "shape finding" – of the vase could ensue, and, with it, placing an additional focus on the type of affordance that would indicate the creative path itself.

Finding a shape

At this moment, Groth looked at the rim of the cylinder which was still a bit thick and clumsy and, in her view, did not conform to how a technically well-made vase should look. She also knew that adjusting the thickness and regularity of the rim might get more difficult at a later stage. Therefore, she decided to make a correction at this point by cutting off excess clay with a little stick (Figure 1.3). This action caused the rim to bulge out slightly under the top. A minor distortion like this could normally be corrected before continuing the process. However, the tiny bulging shape appealed to Groth as a nice starting point to give direction to the "shape finding". She followed the shape of the neck to continue shaping the rest of the vase by bulging out the middle of the vase and narrowing the foot – in this way echoing the shape of the rim.

New opportunities along the way

While working on the shape, Groth noticed excess clay in the base that should be utilized to make the vase taller, and so the base would not get too thick. While thinning out the

Figure 1.3 Cutting the rim causes a bulge in the shape but provides an inspiration for the rest of the vase's shape. Screenshots from the Zoom video recording by the authors.

Figure 1.4 Attempts to manipulate the base cause the "tired" clay to sag, which is accepted as a serendipity. Screenshots from the Zoom video recording by the authors.

base by pressing the clay from the sides, not only did the rest of the upper parts move up, but the general shape was also slightly distorted due to the now very wet and soft (tired) clay (Figure 1.4). This was expected and could easily be corrected, but again, the effect was embraced as a positive affordance instead. Groth decided to accept the unintentionally achieved shape as *serendipity* (Ross & Valée-Tourangeau, 2021). This meant directly picking up on an emergent affordance and further accentuating it or following its "lead". It was more than just finding and accepting a useful affordance; it triggered a much further reaching creative "vision" in the imagination as the affordance led to an inspirational insight and a new direction. The decision to follow the affordance imparted a "wider creative perspective" to use Glăveanu's (2020) notion. Groth thus had an emerging mental image of a bulging shape and how different features, existing and future ones, would be coherent with the shape. Affordances and the imagination began to interact at this point of the throwing process.

The material has its limits

By now, the porcelain clay was reaching its limits for manipulation. It had got very soft due to the added water that was needed to keep the fingers slipping smoothly over the clay but wore the material down in conjunction with gravity. This reduced the field of

Figure 1.5 Narrowing the base further causes the clay to sag even more. Screenshots from the Zoom video recording by the authors.

affordances, as the deteriorating condition of the material narrowed the possibilities for action and even threatened the entire process. Groth decided to finish the process quickly while still slightly narrowing the base for aesthetic reasons and removing water from inside the vase with a sponge to hinder further deterioration. However, even this minor manipulation immediately caused the shape to sag more and the rim to open up slightly in a not-so-appealing way (Figure 1.5). A final effort was made to fix this unwanted development by narrowing and correcting the rim and the "shoulders" of the vase. This was only partially successful, and the shape ended up sagging slightly more than what seemed aesthetically ideal to her.

Groth finished the vase by smoothing out the lines in the surface of the clay caused by her fingers, which she deemed an unwanted feature and thus decided to remove it. For this, she employed a kidney-shaped metal tool commonly used for this purpose – again an example of affordance-based regulation through feedback.

Discussion

We may now discuss how affordances can become a focalizing lens when analysing craft processes and skills. To use the terms proposed by Rietveld and Kiverstein (2014) mentioned earlier, a focus on *affordance landscapes*, i.e., what a material such as clay affords *in general* is insufficient. Therefore, we focus our discussion on the *field of affordances* (Rietveld & Kiverstein, 2014) that emerges in a specific making process.

The first question to consider is the specific relationship between the practitioner's sensory know-how and situated actions. When we look at specific momentary decisions, craft practitioners generally draw on their rich longitudinal practical experience of material properties and processes as well as processing repertoires that they use more or less consciously. With their previous experience in mind, they actively "query" the material for its afforded potentials through probing by touch, sight, tool-use, perspective change, and other epistemic actions (Kirsh & Maglio, 1994). This affordance probing can be strategic, and the feedback revealed by materials when manipulated can suggest the next possible decisions, both at a technical and creative level.

Evidently, in relation to the practitioner's intention and the task logic that is building up, only a few of all possible affordances can actually be acted on. Practitioners only consider an affordance actionable if conforming to technical constraints that ensure the process's integrity and to functional and aesthetic constraints of the finished artefact. What a material affords in general (and clay allows doing *many* things) is filtered through the demands of the ongoing task and the practitioner's personal views and preferences. This means that there are technical limitations for aesthetic choices, as some ideas for shapes are simply not feasible. Similarly, even if a creative shape is technically feasible, it might still not be deemed to be of aesthetic value.

Due to the extended task of managing the process as a whole, craft affordances span different timescales and functions. Thus, practitioners monitor various levels and functional layers simultaneously in the progression towards a finished artefact. These levels include, for example, making sure that actions for the next stages of the process are prepared at the same time as working on the task at hand. Some affordances signal whether the practitioner is on track with the task-dependent order of the activity, and whether the material condition and constellation are ready for the next stage to begin. Other affordances orient the maker with respect to technical details, such as possibilities for error correction and specific haptics of handling the clay and monitoring that a decision, such as a particular thickness or shape of the walls, comes along as intended.

Acting on one particular affordance both reveals and has consequences for the next possibilities, as described by Gaver's (1991) term *sequential affordances*. Affordances to which a craft practitioner responds in an earlier phase sets the scene for what can happen later. This is quite unlike contexts such as dance improvisation, where each affordance stands for itself and each creative action of the dancer is ephemeral. In craft practices, affordances are limited by the fact that the sequence of actions needs to make sense *as a whole*, as effects build on each other. The artefact embodies a trail of evidence of those action sequences, which experts who possess "code-competence" may recognize through analysing the finished piece (Almevik, 2012). This all means that the affordances, while path-dependent, must also be integrally and holistically handled at the task scale.

What have we learned so far?

In examining clay throwing through the lens of affordances, we can identify several broad categories in which affordances (directly or indirectly) mediate behaviour. This begins with a category of *basic enabling* actions, whereby the practitioner sets up the possibility space for later affordances to emerge, including "preparing the ground" through workshop maintenance, clay preparation, making sure all tools are ready, and reserving enough time (see also Baber et al., 2019, p. 288). Experts generally minimize the risk of unwanted situations while laying the ground for wanted affordances to appear, drawing on the experience of similar situations and materials, which provide some "foresight" (cf. van Dijk & Rietveld, 2021). Such activities are not yet constitutive of *specific* affordances; they simply create a background for a whole range of possible ones, with wide leeway for later decisions.

Looking at affordance-based task regulation also clarifies how practitioners organize *task maintenance* as well as how they manage the *artefact-specific order of actions*. On the one hand, this concerns the use of multi-sensory feedback to decide when the next phase is ready to begin. On the other hand, it involves micro-practices of handling the clay for each particular sub-goal, such as centring the clay or throwing the first cylinder shape. In this, short-lived affordances are provided by the sensory feedback and used to fix small issues, "saving" a situation or working around a problem. More broadly, practitioners must also know how micro-practices depend on one another and, thus, recognize dependencies between affordances across the task. For example, Groth manipulated the clay through several stages of action, so that it offered desired affordances later (e.g., the centring of the clay as a precondition to creating even walls). Finally, task maintenance through affordances involves balancing the process between risk and opportunity. The expert's skill lies in knowing not only what to keep constrained and what to keep flexible but also how to hold the process "alive" to enable the global affordance of seeing the work through to its end.

A wider issue is that of the role of affordances in *decision-making*. As we saw in the vase making when the mistake in the denting of the rim was picked up on, decision functions of the crafts process can be supported by just noticing an unexpected affordance that fits in. Affordances that unintentionally emerge can provide an option for interesting new shapes. The ability to spontaneously recognize affordances offers a way to explain creative ability as a perceptual skill (Withagen & van der Kamp, 2018), which many theories of creativity disregard. Yet, we should not overstate the perceptual emphasis by neglecting how practitioners actively produce or invite desired affordances. Firstly, an initial action afforded by material properties must often be further developed. Secondly, affordances may be brought forth by strategic actions, drawing on technical and processual know-how (see task maintenance, earlier in this section). There is a deep material know-how regarding which directed shaping efforts make desired affordances available or give a new twist to a known shape or process. Affordance *shaping* is especially manifested in skilled creative twists that are actively proposed in the material dialogue. This can involve immediate interventions but also indirect activities. For example, a task constraint can stimulate the practitioner's exploration, or the practitioner may actively move towards an interesting new area in their familiar practice matrix to stimulate their creativity. Strategies of *niche-shaping* (Heft, 2007; Ramstead et al., 2016) are utilized, e.g., when using a new tool or moving to a different workshop that shifts the field of affordances (Rietveld & Kiverstein, 2014).

Our analysis indicates that affordances not only influence technical best practices but also shape creative decisions. We discussed, for example, how *serendipitous* affordances contributed to ad-hoc aesthetic decision-making. However, serendipity is not just about finding and accepting an emergent affordance. Every "happy accident" must be actively recognized as useful as well as actively developed. When a serendipitous affordance triggers ideas about how to proceed, the practitioner must consider how the newly found feature can contribute to a larger coherent and aesthetic whole. Thus, affordance responsiveness typically works hand in hand with the practitioner's imagination or creative vision. Glăveanu's (2020) proposition that affordances and creative perspectives complement each other dialectically captures this well. A wider perspective responds to the broader layout of existing affordances but, once embraced, determines which of the newly emerging affordances seem most relevant to a creative project. This is one example of many in which affordances need to be discussed in the context of other mechanisms.

Conclusion

We can see that various applications of affordances provide the craft and design discourse with a tool for analysing and explicating the role of sensorimotor know-how and skills, including, for example, task preparations and maintenance through in-process action regulation, decision-making, aesthetic development, and even creativity. When a practitioner orients towards affordances that matter in the practice, ongoing "material dialogues" offer guidance. Affordances thus help ground the epistemology of craft processes in ways consonant with Malafouris' (2008, 2013) Material Engagement Theory or Ingold's (2013) notion of *correspondence*. As craft or design processes do not simply draw on *hylomorphic* implementations of earlier ideas, the focus shifts to a perceptually guided in-process regulation or a real-time "dialogue" with material mediated by affordances as makers feel their way forward. While affordances highlight a certain openness and dynamicity of skilled action, they equally bring to the fore normative aspects, e.g., how failing to act in the right way at the right time will lead to failure, or inversely how experts maintain the process's integrity by keeping affordances intact through respecting the material's constraints.

As our case example suggests, if we want to understand how affordances are selected and worked with we need to do two things: Firstly, we need to look at multiple nested timescales and functional roles of an affordance-regulated activity, from microscopic to macroscopic and from technical to aesthetic issues. Secondly, we need to consider how a highly skilled practitioner attunes with the material ecology through knowledge of task constraints, aesthetic/functional constraints, and general domain orientations such as style and repertoire. Only the expert practitioner's longitudinal experience of material properties and contingencies can unlock desired affordances and avoid unwanted ones. This rich experiential backdrop needs to be considered for giving affordance-based analysis sufficient nuance and context.

At the theory level, affordances explain how creative and aesthetic processes can be regulated while orchestrating the interplay of a highly skilled body, a well-kept workspace, and material properties. They encourage us to embrace a genuinely relational perspective on the relationship between actors and ecologies, emphasizing their connectedness in evolving loops. This relational way of thinking is a cornerstone of theories of ecological cognition, which also resonates with practitioner viewpoints and with post-human theories as well as approaches that see material interactions as a dynamic dialogue between makers and materials (Fredriksen & Groth, 2022). From this perspective, affordances correspond to what practitioners subjectively care about, thus connecting the experiential realm with the theoretical one. As seen in this contribution, transdisciplinary conversations between sciences and creative practices (see also Groth et al., 2020, 2022) allow studies of expert practices to enrich both theory and practice (e.g., van Dijk & Rietveld, 2017; Baber et al., 2019). Craft and design are a central arena for leading this conversation and can help practitioners and researchers from both craft and design as well as the cognitive sciences to understand the nature of crafts and making processes more generally.

Acknowledgements

The research for this chapter was funded by the Norwegian Research Council grant 324758 and Austrian Science Fund grant P-33289.

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2 Craft thinking

A relational approach to making and design

Ingar Brinck

Craft thinking

The term *craft thinking* refers to a certain manner of proceeding within craft practice that is shared among and used by craft makers to increase the quality and efficiency of their work, and continuously is tested and refined within the craft communities. Craft thinking is intelligent, not intellectual, used to instruct and teach, to criticize a failing performance and infer the errors behind it, and to work out new ideas. Emerging within the relational dynamics of maker and material, it is a process that plays out against the background of expertise and specialized knowledge and permits dealing with novel circumstances in novel ways. Whereas design thinking is oriented towards satisfying the needs of the users, craft thinking takes its starting point in the potential of the material.

The concept of craft thinking, or holistic craft design as it has been called in craft science and related education (Rönkkö & Lepistö, 2016), underlines that craft practice includes planning and implementation in the form of mutually dependent perspectives that merge in a single variable process. It grants that the maker can control their own actions and the craft-making process and, furthermore, enjoys the freedom to experiment as a route to refinement (Slivka, 1961).

Putting collaboration with the material on centre stage, craft thinking relates thinking and intelligence to actions performed by hand. The notion of thinking with the material recurs in the literature on craft practice, with slightly different meanings. Curator and historian Glenn Adamson (2007) defined craft thinking as “a way of thinking through practices of all kinds” (p. 7). Sociologist Richard Sennett (2008) referred to the dialogue between craft maker and material that creates a coordination between mind and hand (p. 167).

Placed in the context of dialogue, craft thinking calls forth two distinct interpretations. The first one is in terms of verbal reasoning and criticism, used to scrutinize difficult and uncertain aspects of the craft maker’s work while pausing the ongoing interaction, with criticism and assessment feeding back into the activity when it resumes. Thinking and doing play complementary roles. Famously developed by Schön (1983), this view has a prominent position in design and crafts, both in practice and research.

The second interpretation concerns nonverbal thinking. Grounded in sensorimotor processing, nonverbal forms of craft thinking draw on motor simulation, perceptual experience, feelings of emotion, and selective attention to monitor and control the craft-making process. Sometimes the material is addressed in the second person, as “you”, within material agency. Craft makers regularly express the experience of having an embodied, emotional, and wordless dialogue with the material, while they are interacting with it (Brinck & Reddy, 2020).

DOI: 10.4324/9781003328018-5

The chapter concerns craft thinking in the second sense, as it occurs within the craft-making process when the maker is engaged in manipulating the material using the hands and body. The aim is to explain how nonverbal craft thinking enables operating critically and coping with problems such as uncertainty, insufficient information, and insufficient quality within the craft-making process. I identify three cases of nonverbal craft thinking and examine them one by one, focusing on how each fulfils its function and what skills and cognitive processes they rely on. Referring to research in psychology, philosophy, and cognitive science and to practice-led research, I will model the explanatory framework on dynamic systems theory (Brinck, 2007), focusing on the relational dynamics between maker and material.

Before embarking on the investigation of the cases, I will present two perspectives on craft thinking, one that emphasizes its dialogic nature, and another that considers the constraints imposed on craft thinking by its developmental trajectory that restricts its use.

The relational dynamics between maker and material

An experienced potter will throw a bowl within minutes, while weaving a rug by hand on the loom can take several months. Whatever the material, technique, and length, the craft-making process exhibits a similar progressive development driven by the relational dynamics between maker and material. To illustrate the intricacy and fundamental reciprocity of the craft-making process, the next paragraph describes the characteristic elements of wheel throwing.

Before the clay is placed on the wheel, it needs homogenizing. The potter wedges or kneads the clay mound by repeatedly placing their hands with the palms down on top of it and moving them downwards while applying pressure to smooth it out. Throwing begins by centring the lump of clay on the wheel, moving it into a symmetrical position on the wheel head by a series of raising and lowering movements. The mound is raised into a tall, narrow cone (i.e., coned up) by placing the hands opposite one another, pressing from the bottom moving up towards the top, hard enough to make the centre of the mound move with its surface and avoid a hollow on top. Then lowering begins. Exploiting the rotating force of the wheel, the cone is tilted in the wheel direction, pushed down, and made to disperse. The procedure is repeated, each time with a smoother, more compact, and on centre mound.

The last raising of the mound initiates forming. To make a bowl shape, the potter puts their cupped hands around the clay and forms a ball. Beginning the interior of the bowl, fingers or thumbs are slowly pushed down into the centre of the ball. The wall is pulled apart, leaving a base that is compressed to a bottom with lateral sweeping of the fingers to prevent later cracking. Finally, one hand is placed on the interior and the other on the exterior, synchronously pulling up (i.e., raising) and thinning the wall, with the fingertips of both hands reaching the top together.

The spinning wheel puts potter and material in contact, transforming one kind of energy to another (Ingold, 2013, p. 102). Potter and university teacher Kenneth Beittel (1989) underlined the importance of bringing body, wheel, and clay into harmony from the beginning, since error in the relational dynamics cannot be undone. As minor behaviour changes may cause overall transitions, mistakes can be costly. The first raising is the most difficult, because the mound "has memories of wedging, clapping, and off-centredness within it" (Beittel, 1989, p. 51). You need to make the inert mound move without forcing it, or the clay's memories of the past will not be replaced by the new manipulation. M. C. Richards (1989), potter, poet, and teacher, explained that if you move the clay before it is physically ready, it will regain its previous shape (p. 35).

Overcoming these obstacles involves striking a balance between body and clay, using the speed and force of the wheel to transport the mound, and then bring oneself to move with it. Organized by timing and rhythm, the movements of maker and material are mutually constraining. Synchronizing to the movements of the clay permits the emergence of patterned behaviour that stabilizes the dynamics. Built around the notions of reciprocity and material agency, craft making – and craft thinking – is fundamentally collaborative.

Considered instead within the perspective of motor learning, craft making and so craft thinking are determined by sensory and motor processes outside the reach of conscious awareness. New skills develop by the acquisition of new movement patterns relative to task and context (Mirdamadi & Block, 2020). However, lacking the resources that later will guide motor learning and permit understanding the teacher's instructions, the novice is unable to perform the movements involved in learning the new skill.

As it happens, skill development begins by random explorative behaviour performed relative to the physical goal (Mirdamadi & Block, 2020). On first encounter, the clay on the spinning wheel will trigger chance behaviour in the novice. Persistent training to gain control of the movements soon will lead to the growth of muscle strength (Sternad, 2018). Stronger muscles permit training other movements that increase speed and flexibility of the fingers.

Eventually the novice will be ready to start practising the very actions that define the craft, such as raising and lowering movements of throwing. Now the sensorimotor contingencies that link sensory input to motor output within craft making start to build. In time, they will form a meaningful pattern that supports the self-organization of behaviour and perceptual experience and enables perceptually guided action, that is, cognitive, or intelligent behaviour.

The sensorimotor contingencies that support the on-line emergence of craft thinking within the craft-making process, simultaneously limit its scope. By grounding craft thinking in the situational context where it once begun to develop, they limit generalization to other domains. Hence, the learning perspective reveals that an individual's capacity for craft thinking is constrained by the situation in which it first emerged. The *contextual determinants* of craft thinking do not necessarily show up in the phenomenology of making but may remain hidden to the craft maker. This raises a host of questions, concerning experiential embodied knowledge such as: What are the consequences of sensory and perceptual experience that constrains behaviour, but does not show up in phenomenology, for experiential embodied knowledge, for instance, for its epistemic status?

To provide another example, in craft practices that favour manual action, craft thinking originates in the joint processing of touch, which depends on feedback from the environment, and proprioception and kinesthesis, which rely on feedback in the body. This means that the awareness of force, effort, fluency, and precision of movement, the experience of motion (i.e., movement kinematics), and haptic and tactile sensing are basic to craft thinking. However, visual experience often appears primary within the phenomenology of making. What does this mean for how we understand the role of sensory and perceptual experience in the craft-making process and within craft thinking? To stress, the two perspectives are not as such in conflict, although they may work at cross-purposes. It seems important to recognize that the practice of craft thinking is influenced by sensorimotor processing in ways we do not always understand, and this concerns the choices and decisions made within the craft-making process too.

The remainder of the chapter examines the notion of nonverbal craft thinking in detail, examining three cases related to epistemic action, thinking-in-action, and withness-thinking.

Epistemic action

Within the craft-making process, most actions occur relative to the material. The hands are not only used to feel, grasp, and create but also play a cognitive role in managing the pragmatics of making. Making shows a mix of pragmatic and epistemic, meaningful physical actions (Kirsh & Maglio, 1994, pp. 13–15). *Pragmatic* (tangible, applied) actions are performed to achieve a task or reach a goal such a forming a bowl from clay. *Epistemic* (interrogative, probing, explicatory) actions are performed to improve the conditions for pragmatic action by revealing information and facilitating cognition, such as re-organizing the workspace, re-positioning the clay on the board of the wheel, or visually checking the state of the clay and comparing with how it feels to the hands (Kirsh, 1995; Shercliff, 2019). The arrangement of tools and materials in physical space indicates a temporal order and mode of procedure. Reducing memory load or simplifying search and categorization will increase efficiency and disclose information.

Epistemic actions can change the course of events and the outcome of making in one single move. Consequently, they play an indispensable role for the quality and efficiency of performance. Often performed absentmindedly, they stay one step ahead of conscious deliberation and verbal reflection that are notoriously slow. In verbal form, epistemic action would entail significant cognitive and processing costs.

Research about craft practice tends to focus on the pragmatic actions that shape the material, while epistemic actions pass under the radar, and have gone unnoticed (Penny & Fisher, 2021). The tendency to epistemic action is strong enough to permit putting them on hold, without negatively influencing performance. When manual tools and handheld powered machine tools are used, one might expect the ensuing lack of contact with the material to hamper epistemic action, which draws on sensory contact with the material. However, the lack of tactile and haptic information to monitor and control the motorized work process can be compensated for during the breaks, when the tools are resting, and does not necessarily change anything of importance to the making process. What matters is that the hands can draw the right conclusions from the information, predict the adequate actions, and determine how to go on, all of which depends on learning and demands paying attention to the present.

The following situation, based on my first-hand experience of woodwork and observations of carpenters at work, illustrates the function of epistemic action, and how epistemic actions occur spontaneously in a tide of passing tests and nonverbal analyses. The carpenter is shaping and cutting wood with his chisel – shaving rough surfaces, chopping out corners, making the joints – while regularly taking brief breaks, letting the work rest. The focus is on the events that transpire during the breaks, when the carpenter's hands intervene to check the progress of the process and the quality of the work, as it seems, without the carpenter's paying attention.

The resting hand holds the tool, whilst the other hand takes complementary action, exploring the worksite efficiently and flexibly. Clearing the surface from the chips of wood left behind by the chisel, the hand is moving back and forth, engaging the fingertips to feel the marks that the chisel left on the surface. Then the index finger traces the curves of the lines caused by etching. Once finished tracing the lines, the right arm is stretched out towards a mortise, the hand reaching into the hole with the finger to check its depth and the angle of the corners, then feeling the texture of the walls. When the carpenter resumes his work again, the results of this explorative behaviour will feed directly into the enduring chain of pragmatic action.

Thinking-in-action

Epistemic action constitutes a spatiotemporally dispersed form of craft thinking. Action sequences underlie another type of craft thinking that to its form parallels trains of thought but fundamentally is a practical ability. Philosopher Gilbert Ryle's (1949, pp. 40–48, pp. 137–138) notion of intelligent skill, or *thinking-in-acting*, is functionally independent of language use and logical reasoning, yet captures the (strictly) intelligent facets of craft thinking. Craft making involves using intelligence in real, variable, and unpredictable situations, determined by maker, material, tools, technique, and task together. Coping with such situational uncertainty requires flexibility and thoughtful improvisation – produced on the spur-of-the-moment by applying lessons already learnt to unfamiliar conditions (Ryle, 1976, p. 77). Ryle convincingly argues that paying heed, that is, acting carefully and vigilantly, is necessary for coping.

In practice, paying heed means thinking what you are doing while you are doing it, and minding how you do it (Ryle, 1949, p. 45; 1976, p. 71). It presupposes *situational awareness* that is established by, first, selective (perceptual) attention to the current situation that permits assessing its difficulty, and second, self-assessment that makes your degree of skill explicit. Research about expertise in sports psychology and related areas corroborate the importance of situational awareness. Summarizing their own and others work on expertise during the last two decades, Toner et al. (2023) concluded that body awareness, active attention to one's own movements and correlated contextual changes, and skill-focused attention to performance are vital for maintaining competence when performing in difficult or uncertain situations characterized by insufficient information.

Balancing perceived difficulty and personal skill, situational awareness constitutes the starting point for paying heed by the online generation, evaluation, and selection of criteria for action. These criteria help you predict the outcome of action and determine whether an action matches your skills. The use of criteria constitutes the backbone of thinking-in-acting and can guide the craft-making process moment-by-moment. It provides a strategy for breaking down complexity to simple steps and making thinking tangible. If you go wrong, knowing which criteria failed you will help selecting others.

Thinking-in-acting serves as a guarantee against slip-ups and carelessness, manifest in the ability of seeing something through (Ryle, 1949). The methodical use of criteria that align maker and material with the situation entails proceeding in small overlapping steps and affords the maker continuous access to the unfolding stream of events. Nothing is left to chance although the activity in its entirety is improvisational. The procedure is rigorous (Niedderer & Townsend, 2014). It shows that sequential cohesion does not allow for exceptions and, given situational awareness, keeps to the highest standards.

To illustrate his theory, Ryle (1949) described how an experienced mountaineer manages to walk over ice-covered rocks in strong wind in the dark (p. 42). The mountaineer does not move his limbs by habit but walks with skill and (perceptual) judgement. He is attentive to each step he takes, and economizes in effort, while experimenting. Thinking what he is doing whilst doing it, the mountaineer is systematically yet spontaneously choosing his movements and actions while adapting to the capricious situation.

Concomitantly walking, and teaching himself how to walk, the mountaineer shows integrity and competence. Because every operation performed is a lesson to perform better, his skills are continuously improving.

Ryle's (1949) thinking-in-acting and Schön's (1983) reflection-in-action display a spurious surface similarity. Ryle's notion does not depend on (nor exclude) verbal thinking or logical reasoning. Thinking-in-acting involves methodically engaging with the physical situation while probing it for information that will help achieving the ongoing task. Intelligent skill is integrated with the situational context. In Schön's case, the physical context is not part of the actual thinking. It functions as a backdrop to verbal reflection about the present and what to do next, involving criticism and re-description. Schön (1983) demonstrated that practitioners can have a reflective conversation with the design situation, while Ryle argued that practitioners can be skilfully engaged with the material in an intelligent yet nonverbal manner. They investigated different but compatible behaviour.

An ethnographic study of how the master potter instructs his student based in visual data, discloses the profoundly embodied nature of craft making (Gowlland, 2015). The student's growing understanding of his task materializes in visible action while he is interacting with the clay (for a glass context, see also O'Connor, 2005). In contrast to correctly executed movement, skilful behaviour engages the entire body in the developing process. Within the action sequence, each movement has its proper place, and knowledgeable movements are both skilful and graceful – skill and grace re-enforce each other within the process. The master potter demonstrates that craft thinking too is multimodal and multidimensional, distributed over hands and tools, across the senses and the body, and manifest in the proactive and anticipatory movements of gaze, feet, torso, hands, and hips, joined in one continuous, dynamic probing motion. Fluid, automatic transitions that connect experience, motion, and emotion, organize the behaviour holistically, signalling competence, expertise, and hindsight. *Fluidity* across movements results in less effort being spent while efficiency increases. This explains why the novice regularly interrupts the work out of exhaustion, while the master carries on without effort.

Finally, emotion has strong significance for thinking-in-acting. Groth (2015) argued that the body generates multimodal embodied experiential knowledge about the material that is used to assess its quality and the purposes for which it might be employed. Thus, holding the clay in the hands will result in the complex haptic experience of temperature, density, plasticity, humidity, and resistance. Groth ventured that the way something feels to the perceiver seems to affect the way the perceiver feels, suggesting an interrelation between tactile experience (i.e., having skin contact with the material) and feelings of emotion.

The *cognitive role of emotion* relates to the emotional expression of materials (Niedderer & Townsend, 2014) and the close tie between motion and emotion in the perception-action loop (Brinck, 2018; Sheets-Johnstone, 1999). Motion constitutes the "how" of bodily movement, manifest in qualitatively felt, kinetic flow blended with affect that resides in the margins of awareness (Sheets-Johnstone, 2012). The potter can use kinetic flow to shape performance, alternatingly matching, complementing, counterbalancing, countering, compensating, and reinforcing the changes in the clay.

Research about motor skill and expertise in psychology verify the critical role of perceptual attention for the monitoring and control of performance (Brinck & Liljenfors, 2013). Metacognitive experience is prominent in craft making. Groth et al. (2015) described how the potter monitors the progress of throwing through the fingertips in continual contact with the clay, noticing that the process is guided by emotion (p. 76).

They found that feelings of emotion related to confidence and stress contribute to risk assessment, decision-making, and problem-solving. Metacognitive feelings reflect the maker's understanding of the creative process, as illustrated by textile artist Emma Shercliff (2019), who writes: "I know when it feels right. Repeated practice and correction over time has habitualized this knowledge into my hands" (p. 74). In short, in monitoring-based control, feedback concerns the outcome, such as feelings-of-knowing; in control-based monitoring, feedback concerns the process itself, such as fluency and the effort required to perform a certain task (Brinck & Liljenfors, 2013).

Withness-thinking

Based on high speed and accuracy of movement (Fuster, 2004), the tight timing of the master of craft readily will cause maker and material to couple. Coupling is sudden and transformative, beyond the craft maker's control. When two cognitive systems reorganize into a configurational whole, it results in the compression of similar behaviour. Maker and material temporarily will function as a single agent with increased capacities for action that provisionally decrease the risk of error in the relational dynamics. Coupling will cause synergies, or unforeseen combined effects, such as the emergence of novel shared behaviour and affordances to act.

Practitioners sometimes refer to integration instead of coupling, suggesting it would bring great benefits to craft making. Architect Juhani Pallasmaa (2009) maintained that designers and craft makers internalize materiality in a manner that transforms the makers themselves into material and permits feeling and experiencing with materials. Sennett (2013) maintained that integrating with the material allows for predicting its imminent movements and shape, and the ensuing interaction. Textile artist and researcher Nithikul Nimkulrat expressed similar views in a study that examines whether manipulating the material will influence its expressive qualities (Nimkulrat, 2010; 2012).

Nimkulrat (2010) argued that letting the material take the lead in the creative process will permit understanding the making process from within the practice. Specifically, she claimed that manipulating the material can establish a rhythmic interplay between bodily and thinking practices. She described how she would decide what rhythm the hands should keep in relation to the knotting structure – how hard to pull the strings and how fast to perform the cycle of manipulations. Then focusing on maintaining the "accurate force and speed of manipulating the material" (p. 77), the motion of the making hand allowed her to anticipate how the making process would unfold. Sharing the rhythm with the material would permit transferring the material's expressive properties to the emerging artefact, which means the material actively influenced the generation of form, content, and context of the work (p. 65).

Coupling has a participatory effect on the maker that boosts motor skill (Tholander & Johansson, 2010) and generates feelings of trust in the material and connectedness. Experiencing such changes in a material, as directed at me, and having a personal value, springing from the precise actions and movements I just performed, makes the details of the interaction strongly meaningful and facilitates re-shaping and fine-tuning performance.

Similarly, the motion and efficiency of movement reflect a master potter's engagement with the moving clay. When "changes in the position, posture, and movements of the body are co-constituted with the changes in the form of the clay" (Malafouris & Koukouti, 2017, p. 199), the potter is experiencing *with* clay (Brinck & Reddy, 2020, p. 42).

Consequently, coupling affords *withness-thinking* when the maker purposively acts with the material instead of towards it, and they are moving in the same direction. The qualitative experience of simultaneously feeling and seeing the clay's movements will move the potter towards new possibilities for action. Joint processing of touch and kinesthesis entails that the sensation of touch is determined by movement on the scale of the body, which means it can connect the potter to other agents experientially, be it clay or human, as embodied selves. By pressing the hands against the clay on the wheel and moving with it, the potter experiences sharing its rhythm.

In physical contact with the clay, the experience of moving together prompts the potter to engage emotionally. Emotional engagement constitutes the phenomenological side of coupling (Brinck & Reddy, 2020). Driven by curiosity and interest, it turns an encounter into an exchange that plays out in the negotiation of feelings with the clay. Emotional engagement has strong motivational force. Accordingly, what makers' experience in engaging with the material is determined not merely by what they do and know how to do as in thinking-in-acting, but *what they are ready* to do (Noë, 2004, pp. 1–2).

The potter takes possession of the creative process by emulating the clay's movements and orientation, and continuously re-distributes body weight, orientation, and attention in correspondence with the clay. Experiencing with the material leads forward beyond individual limitations and abilities (Brinck & Reddy, 2020). Distinct from turn-taking and dominant-subordinate relations, emotional engagement puts the opportunities and needs for the material first and places the potter in the listener's position. The sensitive potter is thinking with the clay, gaining direct access to the agency of the material, which permits knowing its state of transition, and predicting how it will change.

Examining the maker-material dynamics in felt making, Aktaş (2019) noticed the emergence of a similar relational dynamics as in witness-thinking. A certain kind of movement and manner of touching the material leads to the transformation of behaviour and the emergence of complementary patterns of practice. Attaching equal importance to sensing and acting on the felt results in the continuous improvement of skill and increased complexity. Aktaş concluded that attentive listening is critical for the development of a resilient relational dynamics between maker and material and for establishing a successful practice. This conclusion should apply to all the crafts.

Concluding remarks

The analyses of epistemic action, thinking-in-acting, and witness-thinking showed that each has its own modus operandi that permit them to perform both the critical and restorative tasks of craft thinking, and moreover, they draw on separate cognitive resources. Generally, the examination reveals that the material is not conceived a means for craft thinking but rather is a partner that can assist the craft maker in their work. This view is especially evident in withness-thinking where the material is explicitly addressed as co-agent.

The collaborative attitude towards the material can be traced back to the moment when the craft student first learns to synchronize their movements with the material and share the rhythm. Moving together with the material and literally sharing the orientation apparently constitutes a precondition for producing craft of high quality. The opposite would mean working against the tendency of the material. This will not merely increase the difficulty and effort of craft making, but destroy the inherent potential of the material, and so may be perceived as unethical. Consequently, the very possibility of craft thinking as a viable manner of proceeding presupposes that the maker strives to align with the material, showing respect and care for it.

Certain craft makers show a strong motivation to realize the potential of the material and satisfy its needs, for instance, preferring a tool that is more arduous to work with but minimizes the impact on the material. Phrasing this behaviour in terms of professional pride might be useful to clarify the difference between craft thinking and design thinking, as designers conceive of it today.

Acknowledgements

I would like to express my sincere gratitude to the editors for their patience, encouragement, and helpful suggestions. Thanks to my colleagues in the WASP-HS projects on interaction with social robots and autonomous systems for many valuable discussions. This work was supported by the Wallenberg AI, Autonomous Systems and Software Program – Humanities and Society (WASP-HS) funded by the Marianne and Marcus Wallenberg Foundation and the Marcus and Amalia Wallenberg Foundation.

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3 Becoming with glass

Medium and materiality in embodied knowledge

Erin O'Connor

Introduction

Drawing from ethnographic research conducted during 2003–2007 in a glassblowing studio in New York City, this chapter explores embodied knowledge from phenomenology to agential realism. This includes investigating not only perception in practices such as drawing but also how practice with and ideas about hot glass as both medium and material matter for theories of embodied knowledge. Turning from analyses of the development of proficiency and skill towards an inquiry into the heat of glassblowing – that which most readily transverses the various "bodies" of the hot shop – this inquiry turns the question of embodied knowledge from inter- to intra-corporeality. For philosopher Maurice Merleau-Ponty (1964), glassblowers "are like organs of one single intercorporeality" (p. 168) in which each person completes the other. For anthropologist Thomas Csordas (1994), such corporeal interstices of interaction, wherein persons experience themselves as extended in relation to and in interaction with each other, constitute intercorporeal meaning. Intra-corporeality, in distinction, builds upon feminist philosopher Karen Barad's (2007) concept of *intra-action*, which understands that agency is a phenomenon arising from a dynamism amongst so-called things – humans, objects, elements, and so forth – rather than an inherent individual, human capacity (p. 141). Attending to corporeality rather than action, the phenomenon of becoming a glassblower is arguably not only about interaction or intra-action but also about a human and nonhuman intra-corporeality replete with various materialities. One only has to think about the shared heat of the glassblower and glass. Rather than locating such materialities within the human sphere of action to illustrate how glassblowers become *among* materials, I instead reveal how the glassblower and glass co-become. This offers an alternative to understanding hot glass as a medium, arguably a concept and practice only possible within an onto-epistemology of mediation.

Drawing close

Three weeks into my Intermediate Glassblowing class at New York Glass in the fall of 2004, Paul, our instructor, took us back to the basics:

> Ok, you guys tonight we're going to learn how to make a punty and blow out a nice round sphere. I've seen what some of you have been doing – a lot of the mistakes we are making later in our pieces could be avoided if we have the proper set up. You can make nine out of the ten basic shapes, excluding a long-neck bottle, from a basic sphere.

DOI: 10.4324/9781003328018-6

Paul walked us to the chalkboard to sketch the process – a typical first step for any class at New York Glass – "Everybody has their sketchbooks, right?" Some students scuttled to their bags thrown along the wall and retrieved their notebooks, me included. Others, like Joyce, a retired teacher committed to becoming at least a competent glassblower already had hers open to a blank page with pencil earnestly poised; her notebooks are expressive replications of observed demonstrations and pages of daydreamed objects of production. "Damn", Paul exclaimed, patted down his pockets, and sighed: "No chalk" (Field notes, October 5, 2004).

Pivoting towards the workbench positioned in front of the glory hole, Paul squatted at the bucket of water filled with submerged wooden hand tools, dipped his index finger into the water, and drew a sphere-shape off a pipe's end through the dust-coated cement floor. Paul is a faithful reader of Ed Schmid's hand drawn "how-to" glassblowing books and had encouraged us to buy *Advanced Glassworking Techniques* (1997) because it contained all the information from Schmid's *Ed's Big Handbook* (1993) plus more. Each book takes the novice – an amateur in the studio rather than industrial factory – through the steps of making given objects, various hot shop tasks, and glass culture. Like Schmid, Paul encouraged us to draw regularly as did many of his generation for whom Schmid's how-to books were revelations. He advised that drawing would train our capacity to observe in class, hone our understanding of shapes outside of class, including those in glass magazines, production videos, and gallery or museum exhibitions, and attune our perception to "good form". Herman, the shop technician explained as much:

> Making glass is not about making a drawing and then making it. Once you understand that the point is to [learn to] manipulate the glass, and not to blow a bowl, there is a shift in the manner of thinking about the glass, the tools, and the designs. It actually changes how you see the glass, how you feel it through the tools.

For Paul, Herman, and Schmid, drawing, be it by chalk, water-wetted fingertip, or pencil, drew the glass into the transformative dynamics of glassblowing, transforming our perception and how-to knowledge along the way.

A year after I began glassblowing, I wrote of how the iterative process of drawing and doing bore a new style of sketching:

> Before, I knew that [the angles and curves] needed to be there, but not why. [I] didn't understand the relation of the particulars to the whole object. [Tonight] when I was sketching the piece that my instructor was blowing, I drew the curves and the line of the tools against the curves. Before, I would draw the general shape, like a caricature of what the "acorn shape" was supposed to be. [Tonight] was different – just to look at one aspect, like focusing on the curve of the neck versus trying to capture the whole piece with real general lines.
>
> (Field notes, March 3, 2005)

In one book, Schmid (1993) told the readers that "your sketchbook will be your most valuable tool in your workplace" and commanded in crescendo-ing script: "DRAW DRAW DRAW!" "You'll find", he continued, "[that] by sketching already existing objects (studies) your ability to visualize qualities of the medium will become more acute" (p. 4). You draw to see, rather than draw what you see (Sennett, 2008, pp. 40–41).

I have spoken with Schmid about drawing (Personal communication, February 21, 2015). When he was in college, a friendly librarian familiar with his penchant for drawing showed him a trade catalogue from Steuben Glass Works with "thousands of these small little line drawings" by renown designer Frederick Carder (1863–1963) tucked into the back. At the same time, an art professor recommended that Schmid trace over the drawings of "Old Masters" to discover "how they made all their little marks". Schmid explained that this dialogue between Steuben's trade catalogues, Carder's sketches, tracing the Old Masters, and drawing in the hot shop "moved [him] from a representational and tight style of drawing to a loosened one of little marks [that] define[d] the action and the shape". Coupled with observation and practice, drawing helped Schmid to "break down the process into smaller components and … develop a language of glassblowing", which, he added, "is an international language", namely that of traditional glassblowing. Drawing speaks, and through drawing, the drawer learns the art's language.

Drawings and drawing can be understood to belong to what anthropologist Cristina Grasseni (2004) called an "ecology of perception, cognition and action" (p. 47) at once cultural, social, and material (see also Goodwin, 2000, p. 170; Ingold, 2000). In Grasseni's (2004) study of skilled vision in cattle breeding, she apprenticed as well as observed novices learning to see desirable breeding traits in cattle, distinguishing the good from the ordinary. As in the glassblowing social world, visual media scaffolded the learning process. Allen, one of the hot shop's young and increasingly proficient glassblowers, regularly watched video home system (VHS) videos while in college. In a later advanced glassblowing class, a retiree dutifully recorded Allen's demonstration on a digital camera, burnt the digital files to DVDs, and then distributed them to those interested. For Grasseni, these are "focusing media", namely that which, more than delivering content, frame, situate, or organize perception and practice (p. 44). Learning to see – the "enskilment" of vision – is artefact-mediated and conversely, the "organization of perception" by such "cognitive artefacts … brings forth a certain orientation to the world" – "a structure of intentionality" – that "creates a moral and aesthetic order" (p. 47). Scaffolded with such artefacts and repetition, novices who enrolled in how-to glassblowing classes at New York Glass typically learnt traditional vessel-making techniques. Through focusing on the media in interaction with drawing and doing, the novice learnt to see and blow, for example, a nice round sphere.

In *How Things Shape the Mind* (2013), Lambros Malafouris argued that the interaction of maker, material, and object is that *from which* intentionality emerges; intentionality does not belong to a circumscribed subject, but rather is an emergent property of creative material engagement. Ontologically speaking, this indicates the "process where people and things are inseparably intertwined and co-constituted" (Ihde & Malafouris, 2019, p. 198); this breaks down the distinction between making and knowing and suggests that "thinking [is] a process of material engagement" (Malafouris & Koukouti, 2017, p. 293). Thinking is conceived as a *hylonoetic* field – a "mindscape extending into the extraorganismic environment and material culture. Human cognition … entails processes and materials outside of the skull" (p. 296). We did not reproduce an interior image lodged in our minds – a representational model of drawing; when we sketched the nice round sphere, we learnt to see and eventually blow the sphere through drawing and material engagement with the paper, pencil, chalk, hot glass, and so forth. Drawing among glassblowers is, in this sense, *haptic* rather than *optic*; the pencil converts the "register of bodily movement and awareness to that of material flux" (Ingold, 2013, p. 128). Drawing does not manifest knowledge about something but is itself thinking (pp. 128–129). Through both drawing and studying drawings, we drew hot glass into our experience, transforming ourselves in the process. We can now turn to the shifting notions of hot glass as a medium and material in order to reflect further upon the materiality of those epistemic artefacts with and through which the glassblower becomes.

Mediating materiality

Glass "talks back – a lot", said Hattie, a glass professor who instructed a summer glass class in which I was enrolled (Personal communication, July 14, 2006). Once a painter, Hattie experienced herself in "dialogue" with hot glass in contrast to the "monologue" of painting, in which she felt that she had to "tell the paint what to do". In *Making: Anthropology, Archaeology, Art and Architecture*, anthropologist Tim Ingold (2013) inquired into common usages and meanings of *material* and *materiality* in anthropological discourse; while the former often serves to define brute physicality, the latter often indicates that transformed from raw material by human design and meaning into artefacts (p. 27). Hattie's relationship with the glass is neither. In her words, she was not interested in being told what the material could do, but rather in asking: "What can this material do?" Unwontedly, Hattie articulated what the great contemporary metallurgist Cyril Stanley Smith (1903–1992) found to drive the craftsman's skill and discovery:

> The desire of the craftsperson to see what a metal can *do*, rather than the desire of the scientist to know what a metal *is*, enabled the former to discern *a* life in matter and thus, eventually, to collaborate more productively with it.
>
> (Bennett, 2010, p. 60)

Hattie's dialogue with the hot glass proceeded from a perception of "vibrant matter", to use Bennett's term, such that the direction of her artistic practice was revealed in and through actual material engagement – that emergent intentionality:

> I [am not] interested in illustrating an idea. I want to embody an idea. There were strengths and weaknesses in the material that I could manipulate. As I gain knowledge about the material, it becomes more evident how I want to use the material. Like the sound pieces where I'm trying to record whether sound vibrations from a speaker or bellringing in molten glass – it is this idea that you can actually accumulate information in a transparent material. That comes from all those years of doing weird stuff and mucking about. Like conceptually, I'm not that smart. There is no way I would have gotten there without messing with the material. It comes from seeing different things.
>
> (Hattie, personal communication, July 9, 2006).

Messing around and mucking about yielded an answer to the practical question of what to make – an example of that emergent intentionality of material engagement. As a painter, she would ask herself what she should paint, but found it a "weird" question: "It could be a very arbitrary answer. There can be these categories – death, sex – it can be very heavy-handed". In dialogue with the hot glass, by contrast, she, in the words of many glassblowers, could "follow the glass" such that her work expressed material discoveries rather than a preconceived idea. Insofar as such a process, in the words of philosopher Gilles Deleuze and psychoanalyst Félix Guattari (1987), "connect[s] operations to a materiality, instead of imposing form upon a matter"; hot glass in the case of Hattie's practice was "less a matter submitted to laws than a materiality possessing a *nomos*" (p. 408). Hattie's work testifies to Ingold's (2011) claim that the properties of materiality are "not attributes but histories" (p. 32). Hattie created and thought through and with, not about, engagement with hot glass as materiality, creating emergent phenomena beyond, and exceeding any conventional understanding of the bodies of maker and material. At the same time, like many glassblowers in the studio, Hattie also referred to the glass as a medium:

> I was interested in the whole issue with transparency even before I knew how to make anything [in glass] given my fine art background. As a painter, painting on different supports that is classically linked to ideas of illusionistic space, representational space … Glass is like a support for abstract thought. All of a sudden, these images were floating space rather than being bound by canvas or wood. Just the way ideas float around in your head – there was a transparent medium that could support these images. As a painter, I always had this idea that there was this thing that I didn't want to do, which was illusionistic space and representation. I wanted images to float and not be illusionistic.
>
> (Hattie, personal communication, July 9, 2006)

Similarly, Schmid had heralded drawing as a technique through which to visualize the qualities of the medium. Schmid's understanding of medium seems akin to that of David Pye (1968) for whom properties are objective and scientifically measurable (p. 47; see also Ingold, 2013). As a medium, true to the word's meaning as intermediary or middle, glass functions as a substance at hand for an individual's expression.

Material and medium are often used interchangeably in the glass studio – a discursive practice dating to the origin of the American Studio Glass Movement (1960–1990). An example can be taken from the written work of Harvey Littleton (1922–2013), a ceramicist who is widely credited with launching studio glassblowing through its incorporation into college art programs and the art market (Byrd, 2012). On the one hand, Littleton (1971) heralded glass a "virtually undiscovered … medium for artistic expression" (p. 6). Littleton's link of medium and expression echoes the philosophy of John Dewey (1934/2005). For Dewey, a material becomes a medium when it is "used to express a meaning which is other than that which it is in virtue of its bare physical existence: the meaning not of what it physically is, but of what it expresses" (p. 201). On the other hand, influenced by Abstract Expressionist Ceramics, Littleton (1971) declared:

> Essential to the artist's work with glass is his understanding of the material and the basic, element subconscious action-reaction of man and material, not only in the forming of the hot glass – the melting and the forming – but in the complete integration of man and material in a totally controlled time-space concept.
>
> (p. 13)

Whereas the former belonged to a growing understanding in the mid-twentieth century of an artistic medium as a substance made available for expression by an individual, the latter echoed the valorization of "media specificity" in aesthetic theory, which called upon artists to liberate the material particularity of given medium from subject matter as had the Abstract Expressionist painters (see Greenberg, 1940/1992). In Littleton's case, he carried plastic automatism – a technique employed by the Abstract Expressionists of direct and unmediated expression of visceral-material experience – from ceramics to glass (See Koplos & Metcalf, 2010, p. 152; MacNaughton, 1994, pp. 51–61; Slivka 1961/2010, pp. 528–530). As Hattie had both learnt to engage glass as a medium and followed it like the artisan of new materialism, namely as vibrant matter expressive of its own agency (See Bennett, 2010; Deleuze & Guattari, 1987), so too do novices learn the double-belongingness of glass in the hot shop.

In our "Beginning Glassblowing" class in the spring of 2004, for example, Paul continued with our lesson on the "nice round sphere" with an exercise that encouraged us to see glass as a substance to be commanded by technique: "Ok? First, let's work on your gathers". We parted our student circle so that he could access the steel blowpipes and solid pipes known as "punties" resting horizontally in the "pipe warmer", where their tips bathed in the blue flames of natural gas. He grabbed a punty and, to our surprise, did not take it to the adjacent heated kiln called "glory hole" to heat and then to the furnace to gather glass. Instead, he dipped the punty's tip into the bucket of water next to the workbench and tabletop of hand tools. Ignoring the sputtering steam, he directed our attention to the reflection of the pipe in the water: "You see the reflection of the pipe in the water? It's going to be the same in the furnace. You have to look for the reflection so that you know when you're going in for the gather". My eyes, like those of the other eight students, were fixed on Paul, the punty's tip, and the "fake gather" via the bucket of water. "When you retrieve the glass", he continued,

> like, as soon as you break out of the glass, you have to slow your revolutions down. If you keep rotating quickly, you'll spin off all the glass that you just gathered. So, slow rotations on the way out. Everybody got it?

We nodded and each fake gathered from the water bucket and rotated the pipe mid-air in anticipation of our next turn (Field notes, March 11, 2004).

The heavy punty swiftly cut through the water unlike the sticky, viscous glass. As we took turns fake gathering, Paul and his assistant, Maureen, corrected the speed of our pipe rotation, dip-depth, and angle. Similarly, Hattie had also been instructed to fake gather as a beginning student. Some "old-time glass factory workers" had come by her university to give a lesson, lined the students up to gather and – to Hattie and her fellow students' surprise – had them gather from a bucket of rubber. The rubber did not stick to the pipe, the tip of which bounced up when the student removed the pipe after depressing its tip into the rubber to gather. When she described the experience, Hattie laughed wholeheartedly with a contagion that soon had me laughing along. Smiling, with shoulders shrugged and hands upturned, she seemed to think the exercise absurd.

In theories of embodied knowledge framed by skill acquisition and the development of proficiency (Bourdieu, 1990; Dreyfus, 2004; Herzfeld, 2004; Wacquant, 2004), such fake gather exercises are variously understood as preparatory – a step towards assimilating and incorporating the bodily dispositions of "real gathering". Herein, embodiment is theorized as an extension into, or inhabitation of, the world, such that I am said to experience the blowpipe not as a thing in hand, but as an extension of myself. I feel the limit of my body not in my hands, but at the pipe's end – the aqueous silk of water, buoyant rubber, or viscous hot glass. In virtue of this belonging to the world, the body experiences itself as extended through tools, feeling them as things into which we have "transplanted" ourselves and "incorporat[ing] them into the bulk of our own body" (Merleau-Ponty, 1962/2005, p. 143; see also O'Connor, 2005, 2007). The brothers, Stuart E. and Hubert L. Dreyfus (2004), a mathematician and philosopher respectively, developed a five-stage model of skill acquisition through an analysis of novices learning to drive. Therein, novices who can shift from following rules to coping with real situations become "advanced beginners" (p. 177). In this framework, a fake gather shifts the novice towards a situational understanding of gathering from a domain-independent rule (p. 177). Via an analysis of the reproduction of social power, status, and order, sociologist Pierre Bourdieu's (1990) theories of practical knowledge reveal how practical competence – *habitus* – is forged through the incorporation and adaptation of a given domain of social interactions, the *field* (p. 50). Through an iterative process of adapting previous skills to a new situation, the novice incorporates the glass, tools, and bodywork such that she can anticipate and practically comprehend a given world (O'Connor, 2005). Such a process is akin to the drills of the boxer in training described by sociologist Loïc Wacquant (2006), whose ethnography of boxing explains how boxers become invested in their practice, in which exercises are grafted onto basic patterns to slowly make progress (p. 70). It is important to note that accounts of skill learning herein proceed by way of analogy: the novice *does like* in order to *become like* the master. Of what therein is the stuff of practice – glass, water, rubber, tools?

In this sense, theories of embodied knowledge tend to proceed by way of an analysis of *operative intentionality* in univocal action – those standardized processes in which individuals do like in order to become like (Gallagher & Miyahara, 2010, p. 119). Such a framework limits understandings of knowledge to benchmarks of progress; doing like in univocal action can only ever be a matter of differing degrees of perfection (Kotva, 2015, p. 103). When the acquisition of skill is a matter of similitude and progress, that is, the enterprise of learning to blow glass is relegated to a forever-embedded hierarchy. This pertains not only to glassblowing but also to craft in general. When univocal action is the focus, the materiality of a given fake gather acquiesces to that process; it is mediated and therein creates a third term between maker and material, namely *medium*. When the novice fake gathers *as if* a general substance is introduced somewhere amidst the rubber, water, or hot glass and the gather: a medium. The absurdity of the bucket of rubber may have less to do with its indifferent buoyancy than the fact that Hattie was meant to ignore exactly those dynamics and engage the rubber *as if* it were glass. This practical lesson in mediating materiality sets a precedent for making, the glassblower's working knowledge and theories about that knowledge. When materiality is mediated, a theory of embodied knowledge, and cognition, extolls emergent intentionality and distributed mind but stops short of theorizing the intra-corporeality – the entwined corporeality – of practitioner and materiality. To draw a theory of intra-corporeality into that of embodied knowledge – a matter of materiality rather than medium – we can turn to the heat.

"In heat" among sticks and men

In the spring 2004 intermediate class, Paul gathered at the furnace, counting one, two, three, four, five, gathered again, and turn towards us, asking: "Ok, everybody?" Returning to the workbench, he grabbed a wooden block that resembles a ladle from a bucket of water behind the adjacent tool bench. Rolling the pipe back and forth over the metal "arms" of the workbench, Paul raised, cupped, and continuously rolled the "block" under the gather of hot glass, shaping the glass into the block's orb-like cavity. Lifting up the pipe's opposite end, he put both it and his thumb into his mouth and gave a terse puff of air. Removing the pipe, he watched a bubble expand at its end. As I watched Paul, I knew that the rate at which I saw his bubble expand meant that the temperature of the glass was "correct" – a cool skin with an evenly hot interior. I had seen instructors overblow too hot glass bubbles and blow cold when the glass was too cold and stiff to the point of going red in the face. I had done both myself.

Heats always punctuate the steps of the glassblowing process to maintain the glass' malleability. Paul reheated the orb at the glory hole and returned to the bench: "Hello, yes, I am giving a demonstration here". Most of the students, largely hobbyists who had opted for an after-work class, were not sketching, but chatting, hushing, and dispersing around the bench to observe. Blocking the orb once again, Paul continued, "[n]ow we're going to neck the piece". He picked up the tong-like jacks with his right hand, lowered them perpendicularly onto the bubble just off the pipe's end, beckoned Maureen, his assistant, to blow and squeezed. Slightly angling the jacks as he squeezed, he created a gentle valley between the moile and the bubble, constricting but not closing the air passage created by his first puff. To form a sphere, an opening must remain. Paul exchanged the jacks for the "newspaper" – four folded sheets of the water-soaked *New York Times* that fit to the palm like an oven mitt – and by playing Maureen's breath, the centrifugal force of rotation and the centripetal force of the palm-held newspaper, a perfect sphere expanded before our eyes (Figure 3.1).

It was our turn now. My partner, Sam, went first and promptly smushed her sphere into a floor-level scrap-tray when she overblew it into a pear shape. I was up next. Paul was standing by the scorching hot furnace (around 1,100° Celsius) and opened the furnace door as I approached. Resting the pipe on the ledge of the hip-height opening, glass ablaze, I lowered the pipe, looking for its reflection in the molten smoulder – an indication of how close the pipe's tip was to the glass. Continuing to lower, the hot glass gripped the pipe's end, and I rotated, counting as Paul had demonstrated. I could already tell that I was gathering too deep by the too-short remainder of pipe above the glass and the weight of the far-too-submerged end.

Figure 3.1 Newspapering a sphere. Drawing by the author.

Heat followed each step of the process, but "didn't count" in an earlier class when Paul asked students what the steps of blowing a vessel were: block <heat>, paper and blow <heat>, marver and blow <heat>, hang then neck <heat>, paper and blow <heat>, paddle <heat> (Field notes, October 3, 2003). At the same time, the intense reality of the heat in glassblowing was a dealbreaker for many. The next week, Paul counted us one by one before the start of class, noting an absence: "So, who's here? Or, who's not here? There are six of you". He counted us again as two more students hurried into the circle. Paul realized that the missing student was the young woman, who had been overwhelmed by the heat the week prior. "Hmmm", he worried, "I think we scared her off the first day". In my field notes, I described her speaking of the furnace as an "air-less tomb of heat" into which she felt like she was "falling" when gathering. Another woman was "scared to pass out [from the heat]" since she was "on antibiotics". Many students – be they my classmates or those I later served as a teaching assistant – "couldn't take the heat". They became dehydrated and suffered heat exhaustion even though they drank plenty of fluids and used the protective corrugated steel shield that stands between the glassblower and furnace or glory hole as a buffer. I consistently wrote of the heat, the sweat, the blazes, being scorched and burnt, thirst, deep slumbers following a day of wage-work in the hot shop, and, notwithstanding, the deep pleasure of becoming hot, penetrated to the core by heat.

Despite Paul sweating constantly, beads falling from the brow of his flushed freckled face, he could "blow glass all day and night" in his own words. Paul was one of the people who, glass artist Noah Sparks described in an interview, "were constitutionally very easy or confident around [the hot shop]" (Sparks, personal communication, November 7, 2007). For Sparks, this was critical to learning to blow glass in a productive way:

> If you actually said that you wanted to teach glassblowing in a way that would lead to productivity or whatever and you wanted to actually encourage people to do that, the first thing that you would do is either do a bunch of activities to get people comfortable with the situation of the noise and the heat or do the converse, try to scare the hell out of everybody so that most people would leave.
>
> (Sparks, personal communication, November 7, 2007)

Sparks' comment is couched in the context of developing proficiency that does not start with skills like so many accounts of craft knowledge, but with the heat. We have a choice here. We can either first invite the heat into the glassblowing social world of human action, as did Paul's tutorial explanation of the steps of blowing a bubble or sphere, or second acknowledge the hot intra-being-knowing of hot glass and glassblower. Choosing the former would be to acknowledge the importance of heating the glass or get the glass hot for the purpose of glassblowing. Choosing the latter would also be to accept that to blow hot, which is to say to think and act like a glassblower, *any-body* must be hot. Arguably, to be hot is not simply a descriptor of body or glass, but the felt *intra-corporeality* of heat. For Barad (2003), there are no independent objects with ontologically inherent boundaries and properties, but rather phenomena that are the entanglement of "intra-activity", namely emergent and co-constitutive with materiality (p. 822). To account for being-hot is not to "democratize" embodied knowledge by "invit[ing] nonhuman entities into our [human] sociality", but rather to reconceptualize body as *intra-corporeality*, namely the entanglement of human and nonhuman entities (Barad, 2007, p. 378).

Reconsidering the gather, the student must always *be hot* in order to grasp gathering. Imitating Paul's demonstrations is never a matter of reproduction. Jean Lave (1982), an anthropologist who has studied craft practice, has noted that imitation does not "internalize a direct replica of the behavior" in a "haphazard, … osmotic, … passively observational or imitative" way (p. 182). Instead, Lave has emphasized that novices should strategically approximate and slowly acquire a personal style in interaction with an ever-changing environment and systems that structure perception. Yet, when the logic of production (be it traditional or expressive) remains the primary context for an analysis of embodied knowledge, the "stuff" therein engaged easily remains an unthought medium. In the case of glassblowing, the intra-corporeality of being-in-heat, for example, is left unaddressed in favour of describing the working properties of hot glass as engaged by the glassblower. The consequence is that accounts of glassblowing focus on technique, tools, and collaboration (i.e., inter-corporeality) rather than intra-corporeality. This explication portrays the glassblower *in heat* among sticks and men, but not being-heat herself.

Getting at the heat of the intra-corporeal knowledge in glassblowing is not only a matter of understanding learning as participation, or apprenticeship to life, rather than simulation (Illich, 1971, p. 34), but also that of unpacking the ontology of participation. Pipe in hand, extended through it to the glass at its end, I touch and feel not just the hot glass at the somatic limit of my body (phenomenological embodiment), but I *am* the heat. Agential realism "denies the suggestion that our access to the world is mediated, whether by consciousness, experience, language, or any other alleged medium … call[ing] into question the presumption that a medium – an 'ether' – is even necessary" (Barad, 2007, p. 409). Blowing glass, I'm moved by a calorific body, practice, and imagination. Doing *with* rather than doing *as* means not only doing with the teacher and heat but also becoming with and of heat. Here, we might consider heat's inoculation as a primer without which the novice could not learn. Heat, if you will, is the radical immanence of the glassblower's art; you're either hot or you're not. By following the heat in a consideration of the intra-corporeality of glassblowing, we follow the heat as materiality, co-emergent with and of glassblower, fire, and furnaces. Unlike a consideration of heat as a working property of glass as a medium, this acknowledges the intra-penetration of heat across human and nonhuman bodies. Becoming with the glass means becoming with the heat. Not unlike the licks of flame that escape furnaces and glory holes, heat exceeds any arc of action, production, operative intentionality, or goal. Attending to intra-corporeality, a theory of embodied knowledge must dispense with operative assumptions of a working medium.

Conclusion

Though beyond the scope of this chapter, the intra-corporeality of heat among glassblowers, particularly its non-operative excess, presses us to consider other excessive and forgotten materialities. Most readily, the constituent components of glass – silica, soda, lime, and others, which make the mixture known as *batch* – come to mind. On any day of my fieldwork at New York Glass, I arrived with barely a thought of this. Studio technicians had already melted 50-pound bags of batch such that the hot glass was ready and waiting to be gathered into that day's production – that arc of operative intentionality or action. Yet, it is precisely this absence that is meaningful for understanding how medium and materiality work in theories of embodied knowledge. When an explication of embodied knowledge analyses materiality associated with skill acquisition without an account of its appearance outside of the arc of action, it arguably participates in an onto-epistemology of mediation. It is precisely the absence of the constituent components of glass in studio conversations, lessons, and curricula, for example, that allows for its appearance as a working medium on a given day. From this vantage, an account of embodied knowledge is freed from excess and unwanted materialities to focus on the acquisition of skill in relation to and with a medium. Yet, the development of skin irritations, coughs, or in the worst case, silicosis, is no less part of embodied knowledge of the glassblower. Turning towards forgotten, discarded, and usurped materialities, we can attend to becoming with glass in multiplicity, in excess of a given arc of action or intention, deepening and broadening accounts of embodied knowledge.

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4 Feeling how

MET and embodied cognition in the learning of pottery skills

Catherine O'Brien and Lambros Malafouris

Introduction

In this chapter, we focus on the teaching and learning of skilled actions, or embodied knowledge in craftwork, and the central role of material engagement in skill, as a (radically) embodied cognitive process. To do this, we discuss the complexities of communicating skilled knowledge, and how skill emerges through developing a feeling *of* and *for* materials (Malafouris, 2014). From this perspective, we argue that notions of *showing how* or *telling how*, which are prevalent in discussions of instructor-novice interactions, would be better termed *feeling how* to illustrate the importance of instructors facilitating novices' coming to know materials for themselves. Drawing on online semi-structured interviews with potters, this chapter discusses the ways in which novice practitioners developed a feel *of* and *for* clay when learning from home during the COVID-19 pandemic in Britain. While our participants used a variety of learning resources encompassing social media sites, printed media, and pre-packaged beginner kits, this chapter attends specifically to the use of online video tutorials on YouTube and Domestika, an online learning platform. We investigate the challenges and opportunities of learning through using such digital video resources utilizing the theoretical perspective of material engagement theory (MET) (Figure 4.1). This perspective adopts a radical view of embodiment that sees cognition as an emergent process arising from situated dynamic engagements between materials and activities.

MET and embodied cognition

This section discusses the specific approach to embodied cognition adopted by MET, which proposes that the brain can only be understood as one component of a larger intelligent bodily system incorporating material culture (Malafouris, 2016, p. 71). This approach is based on three core and interrelated working hypotheses which argue that:

> things are consubstantial, continuous, and coextensive parts of minds in action (the extended mind); agency is not a human property but the relational and emergent product of situated activity (material agency); and things as material signs bring forth rather than simply represent preformed concepts (the enactive sign).
>
> (Malafouris & Koukouti, 2022, p. 268)

Taken together, these hypotheses provide a unit of analysis that allows us to view the mind as situated within and constituted by the material world rather than merely

DOI: 10.4324/9781003328018-7

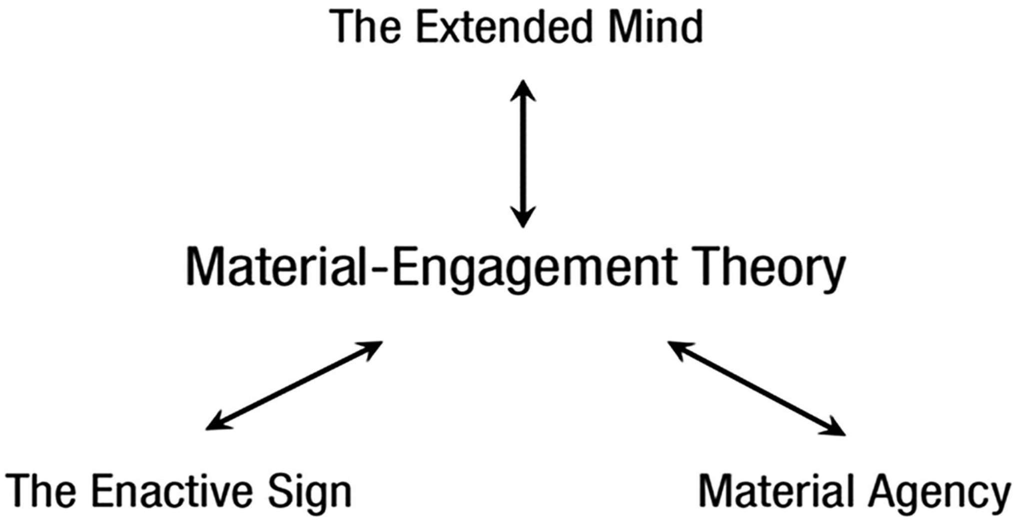

Figure 4.1 The major postulates of MET (Malafouris & Koukouti, 2022, p. 268). Diagram by Lambros Malafouris.

being about it (Malafouris, 2018, p. 756). This is a rejection of the "cognitivist" view of the mind that regards it as confined within the brain and principally dealing in the construction and manipulation of internal representations of an external world (for a review, see Newen et al., 2018; Gallagher, 2017; Malafouris, 2013). In the context of skill research, examples include arguments predicated on the idea of mental representations (e.g., Schack & Frank, 2021), divisions between cognitive and motor skills (e.g., Christensen, 2019), or "computationalist" or "instructionalist" perspectives that argue that internal explicit instructions direct the performance of the human agent (e.g., Jeannerod, 2006).

MET adopts an enactive-ecological view of embodied cognition that can be understood as "hard" or "radical" (Baber, 2021; Baber et al., 2019; Chemero, 2009; Clark, 1997; Gallagher, 2017; Rietveld & Kiverstein, 2014). This contrasts with "simple" or "weak" perspectives on embodiment, which can be considered restating some of the established failings of cognitivism that understand the mind to be localized or identifiable solely with the brain and that there exist hidden mental operations (Malafouris, 2016, pp. 74–76). From this perspective, bodily experience and gestures are not taken as important in themselves, but only when they are considered revealing of an inner representational realm (p. 76). Such a view has been termed "embodied cognitivism" by Malafouris (2013, 2016, 2018) and might, for example, be seen in the work of Lakoff and Johnson (1980) who have been critiqued by enactivists for their emphasis on mirror neurons (Gallagher, 2017, p. 33). Comparatively, from Malafouris' (2016) "radical" perspective, "cognition is grounded in situated action and constrained by the specific kind of body we possess" (p. 73). In contexts of situated action and material engagement, the boundaries of the embodied mind cannot be confined solely within the physiological body but are co-extensive and co-defined by its material sociotechnical mediations and prostheses (Ihde & Malafouris, 2018). Therefore, for MET, the body, and not just the brain, is considered a genuine part of cognitive processes, and the same logic needs to be applied to incorporate the relevant material environment (Malafouris, 2016, p. 77).

Relating to the move away from human-centred conceptions of agency in many anthropological studies (Ingold, 2017; Latour, 1992; Malafouris, 2013), MET adopts a process ontology (Whitehead, 1929/1978) of material culture, appealing to an anti-representationalist enactive view of embodied cognition (Baber, 2021; Chemero, 2009; Gallagher, 2017; Malafouris, 2021a; Malafouris & Gosden, 2015). The potter does not use their body to execute and externalize a preconceived mental plan from inside their skull to the world through clay – but instead bodily acts and prosthetic gestures generate and constitute them (Koukouti & Malafouris, 2021; Malafouris, 2020a, 2021b; Malafouris & Koukouti, 2022). If we take the example of the potter working with clay at the wheel, rather than thinking of the clay as simply offering content for the potter's tactile experience, the clay can be viewed as a "second skin to touch with" (Malafouris & Koukouti, 2022). By this, they mean that the clay acts as a prosthesis through which the potter experiences changes in pressure, vibration, texture, and temperature, as "dynamic properties of the kinaesthetic patterns of movement" (p. 17). There is reciprocity in touch – the hand of the potter touches and is touched by the clay (see Merleau-Ponty, 1968). Instead of considering clay as merely a passive material upon which form is imposed, we must think of it as an active tool for the potter's perception, and through this collaboration, the possibilities of form emerge. The potter develops a feeling of and for clay (Malafouris, 2014, p. 149) as they uncover the relevant affordances and develop perceptual attunements to the materials and skills employed in the form's emergence. Taking such a radical view of embodiment, we expand the boundaries of the body beyond the skin. Cognition can be considered as an emergent process arising from situated dynamic engagements between materials and activities.

Enacting skilled knowledge

It has been well-documented that the "tacit" (Polanyi, 1958) or "experiential" knowledge involved in skilled craftsmanship is difficult to articulate verbally. Partially, this difficulty arises in relation to the sensory, phenomenological, and experiential elements of craft practice (Howes, 2019; Ingold, 2013; Koukouti & Malafouris, 2021; Sennett, 2009). From a MET perspective, this is because skilful bodily *actions* are inseparable from the actual *enaction* and *re-enaction* of such skills as bodily memories involves material assemblages (Malafouris & Koukouti, 2018, p. 171). Concerning this statement, action can be understood as the movements made by an individual as they interact with materials and tools to accomplish a task. Enaction refers to the processes of acquiring and enacting a skill through radically embodied interactions with materials in the environment. This is a dynamic and reciprocal process whereby the environment is shaped by actions, and cognitive and social processes emerge through such engagements (see also the related notion of "enskillment" in Ingold, 2000). Finally, re-enaction refers to the performance of an acquired skill, which is maintained and developed through such repeated engagements. This emphasizes how previous human-material interactions continue to shape and influence current and future actions (for further discussion, see Malafouris & Koukouti, 2018).

Returning to the example of the potter at the wheel, we can consider how this enaction of a skilled memory emerges not only through brain and body but also in conjunction with the wider material ecology of action (Malafouris & Koukouti, 2018, p. 173). Apart from this material ecology there is no engagement, and without engagement, there is little that the body, which includes the brain, can remember about the actual process of making. Through engagement with clay in the act of throwing on the wheel, skills emerge as a form of remembrance. Bodily fine-tuning, memory, and sensitivity to different affordances, or selective affordance responsiveness (Bruineberg & Rietveld, 2014), arise through the potter's participation in skilled mediated action. The affordances and resistances of the clay actively engage the potter to produce this form. Affordances are used here in the ecological Gibsonian (1979) sense of interactive relational possibilities that arise in use contexts (Malafouris & Koukouti, 2017). Developing a feeling of and for clay through such interactions with material means that cognitive processes are extended beyond the boundaries of the body through socio-technical prostheses and gestures. Situated at the potter's wheel, it is the actual engagements with clay, in the act of throwing, that allow for remembering (Malafouris & Koutkouti, 2018, p. 173). Skill can thus be considered distributed forms of enactive material knowledge actualized both by neural and extra-neural resources (Malafouris, 2008). From this perspective, how the body recalls its skills is through the process of re-enacting them within the world through interactions with things (Malafouris & Koukouti, 2018, p. 159).

Showing, telling, and feeling how

If developing a feeling of and for the materials at hand is central to the development of skills, then we are interested in how instructors might facilitate these material explorations, and thus the development of skills. Often, we think of teaching as occurring by means of a master *showing* or *telling* how to do something, which novices then mimic and repeat over time, until they gradually gain competency (for further discussion see Sennett, 2009, pp. 179–193). Referring to several examples, in this section, we will discuss how such showing or telling interactions also constitute *feeling how*, which we define shortly.

We use *telling how* to refer to interactions in which language is mainly used in communication between a master and a novice regarding what they must look for or what skilled actions to make. However, the limited capacity of language to describe the embodied and multisensory material engagements involved in executing the skilled actions performed in craftwork becomes evident when expert practitioners must find the words to communicate to novices what to look or feel for. This is not to erase the importance of language in learning and working amongst skilled practitioners. For instance, the use of metaphors and similes has proved important in learning and building communities of practice, as discussed in reference to anaesthetists (Maslen, 2015) or geochemists (Goodwin, 1997). These studies illustrated the complexities of communicating multisensory knowledge, and how the use of metaphors to communicate and facilitate the learning of such sensory sensibilities relies on shared experiences. There is a requisite level of skill and correlated sensory or perceptual awareness of the materials and tools at hand to make language useful in these contexts. Thus, personal exploration of sensory engagements is necessary for developing skills beyond the instructional or social interactions with masters and novices.

Alternatively, *showing how* interactions can be considered instances when the master offers a visual demonstration, through gestures or actions, that communicates what the novice must do. Demonstration was discussed by O'Connor (2007; see also Chapter 3 in this book) based on her experience of learning to blow a rudimentary goblet at the New York Glass studio. The first step in this process is to gather the glass. Gathering is made up of a series of steps, which the novices would practice independently of each other, and abstracted from the actual process (p. 128). As these steps are often explained and demonstrated distinctly, the mark of a novice is their tendency to proceed in successive steps. As skill develops, the tool recedes from consciousness and becomes an extension of the body, as discussed in Polanyi (1958). The more proficient novice does not blindly stick to each step, which follows the way in which they have been taught through demonstration, but instead attends to the process of gathering as a whole and adjusts their techniques in response (cf. Malafouris & Koukouti's (2022) discussion of haptic attentive unity (HAU). Just as we have argued with the case of *telling how*, these examples of *showing how* illustrate the core role of materials and hands-on engagement in the development of skilled knowledge. Observation alone is not sufficient but must be accompanied by imitation, i.e., working with the materials for oneself. In this way, the novice develops skills through coming to know the materials at hand. It is only through practice that O'Connor was able to break down the overly prescribed set of steps that demonstrated the skill effectively but hindered the overall process in practice.

This idea that access to practice needs to include more than just access to an expert practitioner is not new and is well-documented in the literature on learning and apprenticeship (e.g., Goodwin, 1997; Ingold, 2000; Lave & Wenger, 1991). For example, Lave and Wenger (1991) have argued that "the important point concerning learning is one of access to practice as a resource for learning, rather than instruction" (p. 85). We might consider how this becomes a greater challenge when we think about remote or physically distanced learning – where there is differently mediated access to instructors and resources – as we will discuss later in this chapter. Moreover, we might consider who has access to know-how in remote learning. Novices require access to not only clay and tools, which can be expensive to procure and operate for an individual but also learning resources and the digital literacy needed to navigate them. However, this is beyond the scope of this chapter.

While we have used these examples to illustrate how instructors show or tell novices what to do, what they actually illustrate is how these interactions encourage the notion of *feeling how*. We use this concept of *feeling how*, drawing on MET's understanding of developing a feeling of and for clay (Malafouris, 2014), to highlight how instructors might present opportunities for novices to explore and come to understand materials for themselves (see Ingold's (2000) concept of guided rediscovery). Instead of focusing on the auditory and visual sensations that are used in communicating how to perform a task, we focus on how teaching can facilitate engagement with materials and tools, during a situated activity that occurs in the total environment of which they are part. By this, we do not just mean the tactile sense of touch but also proprioceptively the engagement of their entire bodies utilizing multiple sensory modalities in situated action contexts and allowing them to become attuned to the total ecology of persons, tools, materials, and environment. Additionally, it serves to question the Western prioritization of seeing and hearing as the predominant channels of knowledge-making practices which has become prevalent in anthropology (e.g., Howes, 2019; Ingold, 2011; Pink, 2015). Furthermore, the concept of feeling also implies an affective dimension which cannot be disentangled from skill in such skilled material engagements (Koukouti & Malafouris, 2021; Malafouris, 2020b). By shifting emphasis onto *feeling how* rather than the more frequently referenced ideas of *showing how* or *telling how*, we aim to question the prioritization of human-human interactions in learning and instead focus on material engagements, emphasizing how learning skills takes place in a wider cognitive ecology (Hutchins, 2010).

Feeling how may happen in instances where mentors facilitate engagement with materials, such as through the physical manipulation of a novice's body. Take, for example, Groth's (2017, p. 105) discussion of working with deafblind participants. One of her participants, Olavi, sought to throw on the wheel, which would have required Groth to communicate verbal instructions to the participant through their tactile language interpreter with their hands. As the participant's hands would now be busy with clay, instruction and interpretation could not occur simultaneously. Therefore, Groth decided to throw with the participant's hands, communicating her own embodied and tacit knowledge of throwing to the participant in action. Rather than visually mimicking Groth's actions, the participant was physically mimicking them. In this way, he gained access to the precise timings, pressure, and hand movements through non-linguistic communication, and eventually was able to throw his own bowl un-aided. In this case, the novice was induced into experiencing new tactile sensations and sensory timings, which aid in their skill development and their coming to know the material for themselves through hands-on tactile communication with a master. From an MET perspective, however, it is not just Groth's hands and body guiding her participant, but so too is the clay. When throwing on the wheel, it is not just the potter acting on the clay, but there is a reciprocity to touch; the potter's hands are touched by the clay too (Malafouris & Koukouti, 2022), directing their action and shaping the resultant form. Although this is a more extreme case, given the visual and auditory impairments of the participant that made showing and telling impossible in this context, we might think about this as an example of *feeling how*, which has also been more generally used in teaching tactile skills (see Downey, 2011; Marchand, 2010 for other examples of manipulating the body of a novice). *Feeling how* can also be communicated in less direct ways, such as through encouraging hands-on engagement and exploration with materials, which we will focus on for the rest of this chapter.

Learning to pot using video resources during the pandemic

Here we draw on a series of one-to-two-hour semi-structured interviews undertaken between March and July 2021 by the first author, O'Brien, using Microsoft Teams with 25 participants ranging from novice to professional potters in Britain. Participants were recruited through social media posts, free advertisements in the London Arts and Health Forum newsletter and the magazine *ClayCraft*, and direct messaging public Instagram accounts using O'Brien's account @anthro_pottery. The username was inspired by Bluteau's (2019) @anthrodandy and aimed to reflect O'Brien's role as a practitioner-researcher. The participants discussed here ranged in their prior experience of pottery – some having taken evening classes in the past, and others having taught themselves exclusively at home, but mostly considered themselves beginners rather than expert practitioners. While some participants had fully kitted out home studios, and others made do working on desks in single-occupancy accommodation, common across all participants discussed here was their use of video tutorials as a learning resource independently during the pandemic. While skill is an iterative process, developing continuously over time, even for those who consider themselves experts, we have chosen to focus on novice potters in this chapter. Given their relative lack of experience, they were predominantly learning to handbuild or throw for the first time using these videos, allowing us insight into the challenges and opportunities such resources afford.

While our participants discussed a variety of printed, digital, and social media, which they used to learn, we focus on how our participants used video resources to learn new skills, and how this digitally mediated access to instructors affects novices' learning. The use of video tutorials, or "how to videos", to learn new skills has been discussed more broadly (e.g., Maziriri et al., 2020) and also in relation to craft and embodied learning (e.g., Groth, 2022; Lehmann, 2012; Orton-Johnson, 2014; Pink et al., 2016; Pöllänen & Weissmann-Hanski, 2020). This genre of video can be considered a pedagogical tool, in which the content creator indicates specific actions to be observed and mimicked with narration describing their actions and listing specific tools. However, the learning that occurs using this media is still grounded in the novice exploring the materials and tools for themselves. While the use of digital resources in the learning of craft skills is not new, the novel context of the pandemic caused a proliferation in the number of people seeking to learn from home, outside of the traditional spaces and social structures in which teaching and learning usually occur. Given the need for instructors to facilitate *feeling how*, or what novices need to learn to feel for themselves through engaging in practice, this chapter explores what is gained and lost given tutorial videos' primary focus on visual and audible content.

The visual nature of the medium can be utilized by content creators to illustrate technical or otherwise unseen aspects of the making process that a novice might not be aware of. For example, our participant Amber, who had learnt wheel throwing independently during the pandemic, relying predominantly on YouTube tutorials, said:

> One of the most interesting things I've seen, which I felt really… A guy sliced down the middle of a pot and then showed you, you know when you're pulling up, the position of your hands on either side [Amber gestures hand movements to me].

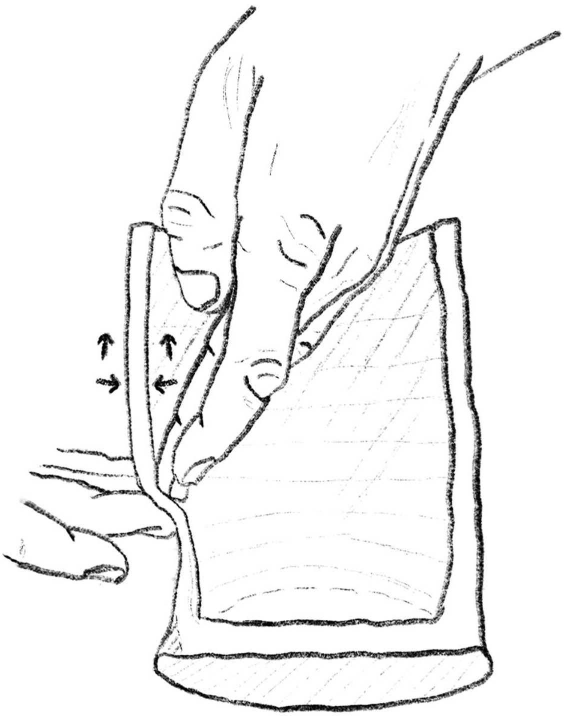

Figure 4.2 Sketch showing the actions and hand positioning conveyed in the YouTube tutorial as described by Amber. Sketch by Catherine O'Brien.

> Because when you watch videos, you don't know where their hands are, do you? … I was like who knew because you can't learn that kind of thing yourself.
>
> (Amber, personal communication, May 28, 2021)

The creator of the video watched by Amber was not just illustrating how to throw but also revealing aspects of this process that relate to feeling the correct positioning of your hands inside the vessel that would not be visible to an onlooker. From the hand movements offered during the interview and existing knowledge of this type of content, O'Brien produced Figure 4.2 to convey what Amber was describing. Here we see how the middle finger on each hand pushes inwards, meeting the clay between them, with the hands simultaneously moving up along the ridges of the wall to pull clay from the base to the top of the vessel. In this way, the content creator utilized the visual nature of video to illustrate a bodily action that would otherwise be inaccessible to someone simply watching the act of throwing alone, unable to see through the thick clay walls of the form. Mimicking these movements, Amber obtained insights into the positions and actions required to pull up the walls of the vessel, allowing her to gain a feeling of and for this engagement with clay that was previously unknown to her. Thus, powerfully, through "seeing" this content, she "felt" something new.

Another point to consider is that although many participants found YouTube a strong source of information for learning specific techniques, their needs for information changed as their skill developed. One participant, Heather, started learning independently before the pandemic after having a few lessons with a local potter but predominantly relied on information she found online.

> I started off watching Jon the Potter … that was a really good starting point for me with YouTube and when I was bored at work, I used to watch him all the time. Um, but since then, I've kind of moved on to more scientific stuff I suppose. More not, "Here's a big lump of clay I'm throwing a mug" and I have moved on to well, "why are you doing that and how are you doing that?" And that's why this channel, Washington Street Studios, I find is much better. Especially, as I'm, you know, I'm going to go into glaze mixing.
>
> (Heather, personal communication, June 30, 2021)

YouTube tutorials are not personalized to individual novices, in a way that an in-person instructor would adapt their plans for a session in line with the level of their students. This meant that the novice participants needed to construct their own progressive learning paths, selecting videos that complied with the skills they sought to learn. However, this also meant that they were seeking out information they thought they needed to learn from different sources when they missed out on the directed learning over a longer period from an expert practitioner. However, common across participants utilizing such digital resources was the experience of coming across content which revealed insights that they did not realize would be helpful to them. An example was the aforementioned content observed by Amber, who had queried "who knew" that that was how the clay needed to be manipulated until she had seen this specific video.

Comparatively, encouragement towards developing *feeling how* can be considered in relation to guided online courses, whereby the instructor directs novices towards practice and experimentation throughout the curriculum. Two of our participants, Leah and Ella, had taken up pottery during lockdown and, in order to develop their handbuilding skills, had used an online course on the home-learning platform Domestika created by the ceramicist Lilly Maetzig (or Mae Ceramics on social media). At the time of fieldwork, 5,898 people from around the world had bought a subscription to this course. The course consisted of 21 lessons with a total of 3 hours and 41 minutes of video. While Ella had been instructed on the wheel by a professional potter whom she was living with during the first lockdown, she started handbuilding when she returned home after this period. Conversely, Leah was new to all forms of pottery during the pandemic. Both were limited in their access to space and equipment. As they had already followed Lilly Maetzig on Instagram, they hoped that the course would help them get started:

> I just thought well I will spend £20 and she'll go through all the basics, and it's just easier to learn. Otherwise, you get a bit overwhelmed. I think you need it all stripped back with handbuilding and you just need to know what's what and then you can take it and run with it. That's been super helpful.
>
> (Ella, personal communication, April 27, 2021)

> Before … because I was kind of just doing it rather than looking at how you're actually like meant to, without actually kind of listening to like the technique. Even something like a pinch pot… [doing the course] you kind of understand what you're doing a bit more.
>
> (Leah, personal communication, April 19, 2021)

Both were encouraged by the idea that they wanted to learn the "basics" and understand the "technique" that they did not feel that they were gaining access to when learning independently, even when using YouTube videos.

To better understand the type of content featured in the course, O'Brien, who was also a self-taught beginner potter since the first British lockdown, undertook the course. At the start of the course, in a video titled *Introduction to Clay and Ceramics*, Lilly demonstrated how to roll a small lump of clay in her hands as she talked. By the end of the five-minute video, the viewer was invited to observe the changes that the clay had undergone by virtue of the handling, and the ways it had dried and cracked compared to its initial moist and plastic state. In this way, the video facilitated bodily exploration of the material, as the instructor (Lilly) instructed the novice (the viewer) to explore the qualities of the material through their own senses. This simple introduction to clay as a material was then built upon across the successive lessons which covered techniques such as slab building, pinch potting, and coil building, as well as explaining kiln firing and basic glazing, before culminating in an independent final project. In this way, the course allowed novices to build knowledge incrementally by directing them to develop a feeling of and for clay. This helped them gain confidence and experience with clay, so as to encourage them to experiment and further explore the material independently.

It is also important to consider how participants used video tutorials to facilitate their learning. While some participants, as expressed by Heather, would watch YouTube while bored at work, and many others consumed video content for satisfaction or leisure, participants would also use these resources to learn specific skills. Many participants watched videos while at the wheel in order to replicate what they observed. This was discussed by Luna, who began their pottery journey through an unpaid and somewhat exploitative internship at a local pottery studio in 2018 and later joined a shared community studio.

> I'll be at the wheel and be like, I don't know how to do that and like watch [a YouTube video] in two times speed, on my phone, being like, hmmm, okay, I guess I get it.
>
> (Luna, personal communication, June 1, 2021)

In this example, observation and mimicry occurred directly prior to engagement with the clay whilst situated in position – Luna could immediately translate what they had witnessed in the video into physical action through engagement with the tools, clay, and environment in situ. Along with the clay and tools, Luna was engaging multi-sensuously with their phone as they watched the screen, listened to the audio, and tactilely engaged with the device to pause, play, and skip the video. The phone became part of the wider cognitive ecology in which Luna was working, attempting to learn this new skill by imitating what they saw on the screen. The portability of the phone and the ease of accessing content through it were central to how the phone could be used as a resource.

Comparatively, Lilian watched YouTube videos on a laptop prior to engaging with clay and consequently found them unhelpful, especially when compared to the communal pottery classes she had been undertaking before the pandemic:

> I don't actually like them [YouTube videos]… you have to watch the whole thing through. And then remember how they've used their hands? And they've moved their hands to create different shapes. And I don't actually find YouTube terribly helpful for that reason … you're watching it end-to-end and you know when you have a teacher, and the teacher is sort of there on your shoulder, and she's saying to you, you know, "move your hands this way", or "put your hands such and this will make a lip" or whatever. You need that one-to-one interaction, a YouTube video doesn't do it.
>
> (Lilian, personal communication, May 25, 2021)

Thus, for Lilian, the issues with YouTube tutorials are two-fold. Firstly, she was unable to translate what she is watching into action due to the limitation of the device through which she was consuming the content; this was not experienced by Luna though. Unlike a smartphone or tablet, which can easily be wiped clean, laptops and computers are controlled by delicate keyboards, which must be kept away from dust and liquid to avoid damage. This renders them vulnerable in a pottery studio, compared to perhaps working in a context with other materials such as textiles. Secondly, Lilian missed out on the real-time feedback offered by in-person teaching, which is well-acknowledged to be central to learning (e.g., Gieser, 2008). While more general feedback, positive as well as constructive, could be offered through engagements with other practitioners in online communities, such as those found on Instagram or Facebook (O'Brien, 2023), the individual guidance on exact timing that Lilian sought was not possible through these pre-recorded video tutorials. Moreover, such media cannot replicate the sensory experience of sharing physical space with others which shapes learning. Thus, she missed not just this feedback but also the physical presence of other potters, novices and tutors, in learning independently.

> I need that interaction? … I miss college for my teacher, definitely. But also, you learn so much from other students … they were all doing different things … And if the teacher was engaged in doing something else, or teaching somebody else, there

> was always somebody, somebody there … I got to know students that knew more than I did. And I could go to them, and equally, when somebody started, they could come to me, so there was that sort of interaction between students as well, which, when you're on your own, you just have to muddle along and read books … I feel that it's a more difficult process on my own.
>
> (Lilian, personal communication, May 25, 2021)

Lilian's dissatisfaction with YouTube tutorials or guidebooks partially came from her comparing it to her previous experience of working among others, which she found integral to her learning. In this way, these resources served to reveal what was missing to her, rather than what they could offer as an alternative path to learning. Moreover, this stresses the importance of learning as occurring through engagements within a wider ecology of interactions, particularly the affective and perceptual dimensions of learning among, with, and from other bodies at work and how this can be lost when learning independently.

Conclusion

Novices experiencing physical engagements with materials for themselves is vital to developing skill. We have considered the role of the materials and tools in learning, as part of this situated activity, with other things and persons, taking skill as a process that is extended and distributed into the world. We have emphasized this by illustrating how teaching and learning interactions need to encourage engaging physically with materials, along with the use of narrative instructions or demonstrations. To do so, we have focused on how instructors might facilitate these material explorations, encouraging *feeling how*, and thus the development of skill.

During the pandemic, with limited access to the environments and social contexts in which we typically understand the learning of skills to occur, the learning process was compromised. We have explored this through focusing on the opportunities and challenges faced by novices using video tutorials as learning resources to develop their pottery skills during such limited circumstances. Particularly, this has been discussed in respect to how video's predominant focus on visual and audible content both facilitates and inhibits the encouragement of *feeling how* in teaching at a distance. We have discussed the different types of information that can be communicated by tutorial videos: first, in respect to the visual nature of video that reveal unseen aspects of the process that rely on tactile sensations, and second, in terms of information and guidance that change over the course of the novice's skill development. We have highlighted that following a more directed course, rather than constructing one's own learning pathway, encourages the exploration of materials and tools and helps novices gain confidence to pursue independent experimentation. We have also considered how the ways in which such content is accessed shapes the experience of the learner. However, we have emphasized how videos cannot offer real-time feedback and guidance which inhibits learning. As well as how for beginners with prior experiences of in-person learning, such as Lilian, digital resources do not offer them an acceptable alternative given the independent nature of such pursuits.

Thus, while the experience of learning amongst other students in the studio cannot be replaced, and certain elements are lost, the ways in which video tutorials can be utilized in respect to its various communicative capacities and accessibility are important to consider in an increasingly digital world. Moreover, as Ihde and Malafouris (2018, p. 198) highlight, as people and things are inseparably connected and co-constituted we must also consider how the pervasive new materialities of the digital, from algorithms and code to glass touch screens or plastic keyboards, shape our lives and thinking. In the same way that MET considers cognition and skill as distributed processes extending the body through materials and tools, this can be extended to consider our engagements with digital materials. As the digital becomes part of the wider cognitive ecology in these contexts, novices must also develop a feeling for how to work with these digital resources in tandem with the clay and other tools in a way that suits their needs.

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5 Embodied craft practices

Mindful flow, creativity, and collaboration as drivers for wellbeing

Kristina Niedderer and Katherine Townsend

Introducing craft practice and its complexities: material engagement, mindfulness, and wellbeing

In recent years, there has been an increase in the recognition and use of craft as a practice to promote mindfulness and wellbeing. We propose that this contribution is rooted in material engagement, the creative act of making, and the social nature of craft. We argue that experiential and social aspects of making foster the human(e) components of creativity and mindfulness through which craft can contribute to emotional satisfaction, social connection, and personal agency, and thus wellbeing.

Wellbeing is key to people's quality of life. Previous definitions of wellbeing have provided insights into different aspects of wellbeing, such as joy, inclusion, confidence among others, creating a number of overlapping, yet different definitions (Kaufmann & Engel, 2016; Kitwood & Bredin, 1992; Power, 2016; Strohmaier & Camic, 2017). Niedderer et al. (2022) have synthesized some of these aspects into one definition of wellbeing, to be developed further in this chapter. This new, overarching definition comprises three key components: *emotional satisfaction* is associated with safety/trust, comfort, feeling well, happiness, and joy; *social engagement* is related to inclusion, connectedness, and attachment; and *personal agency* comprises identity, confidence, optimism, meaningful occupation, autonomy, and growth. Niedderer et al. (2022) further explained that interconnections between each aspect of positive wellbeing beneficially influences the other, e.g., emotional satisfaction enhances the level and quality of social engagement and vice versa. Emotional satisfaction and social engagement are related to personal agency, defined as meaningful intentional action. The experience of having personal agency in one's life is an important determinant of wellbeing that can improve both confidence and optimism, with examples including learning, starting new activities, or decision making (Schlosser, 2015, Zeilig et al., 2019). While Niedderer et al. (2022) and Townsend et al. (2017a) have discussed wellbeing in the context of dementia care and clothing design respectively, their understanding of wellbeing is also useful in the context of this discussion as the aforementioned three components of emotional, social, and personal wellbeing can be identified and refined as key motivators within the crafts as will be demonstrated throughout this chapter.

Whether undertaken as sole or collaborative practices, craft and design require practitioners to learn and employ body-based knowing, i.e., skills developed through working with materials, as an intrinsic part of building their experiential knowledge. Such knowledge relies on embodied cognition (Johnson, 2015; Varela et al., 1991), a paradigm which recognizes that bodily actions play a significant role in how we engage with the

DOI: 10.4324/9781003328018-8

environment and thus how we make meaning. In his material engagement theory (MET), Malafouris (2013) argued for an ontological process that situates thinking in action, influenced by the enactive signs and practical effects of the material world on the extended mind. The idea that thinking is shaped by experience of the external world through our hands has been lucidly expressed by philosopher Elias Canetti (1960, p. 248) in his speculative reflection on the relationship of hands and object. Similarly, in her work with clay, Groth (2017) articulated this acquisition of embodied craft knowledge as a process of "making sense through hands". Ingold (2013) used the example of pottery to illustrate further how "the mindful, or attentive bodily movements of the practitioner on the one hand, and the flows and resistances of the material on the other, respond to one another in counterpoint" (p. 101).

Mindfulness is closely associated with wellbeing and the embodied mind thesis. Building on Merleau Ponty's (1962, 1963) perceptions of the body as intertwined physical (outer) and lived (inner) experiential structures, Varela et al. (1991) acknowledged how these biological and phenomenological aspects continuously circulate back and forth, saying that "we cannot understand this circulation without a detailed investigation of its fundamental axis, namely, the embodiment of knowledge, cognition, and experience" (p. xiv). Varela et al. also made connections between the mindful state reached through pragmatic and philosophical explorations and the Buddhist tradition of meditative practice (p. xviii). Both meditation-based and cognitive approaches to mindfulness are now well-recognized for their benefits to everyday life and mental health, i.e., as contributors to wellbeing. Mindfulness approaches are based on the key concepts of being in the present moment and of non-judgemental acceptance of emotions and events, which can aid relaxation and ameliorate stress and anxiety (Kabat-Zinn, 2003a, 2003b; Langer, 1990, 2010). Besides formal mindfulness training, often in the form of yoga exercises or meditation, arts and craft processes are increasingly recognized for their potential to offer a way to be mindfully "in the present moment", manifest in the experience of a sense of *flow* (Huotilainen et al., 2018). Flow is a phenomenon based on the positive psychological effects occurring in the consciousness of an individual when undertaking autotelic activities (Csikszentmihalyi et al., 2014). Flow has indeed been recognized as being intrinsic to mindful craft practices and outcomes in formal and informal settings (e.g., Huotilainen et al., 2018; Singh, 2018) as we will discuss further throughout this chapter.

To explore the relationship of craft practice and wellbeing in detail, we need to look in more depth at what happens in the craft process. This involves a chain of events arising within often repetitive acts of making, embracing sensory and embodied experience of materials which can foster focus and an "in the moment" experience (Singh, 2018). Through experience of flow, the process itself can support the practitioner's wellbeing. When experiential craft knowledge and activities are shared with others through design initiatives in social settings, it has the capacity to positively impact the wellbeing of groups and wider society (Manzini, 2015; Sennett, 2013). While there are many examples of how craft has been employed to augment the physical body, from fashion design to embroidered implants for orthopaedic surgery to the fabrication of bespoke prosthesis (see Townsend et al., 2020), we are particularly concerned with how the experience of craft practice can contribute to emotional, social, and physical wellbeing.

In this chapter, we explore and unpack the intuitive, sensorial, and socio-emotional nature of craft practice and its capacity for fostering emotional satisfaction, social connection, and personal agency. We explicate this capacity through three examples, one drawn from Niedderer's metalwork and two from Townsend's textile-based practice.

The first case explores the need for material sensitivity within the making process in silversmithing; how craft expertise learnt and wrought through repetitive actions is related to flow and mindfulness. The second case investigates material responsiveness in relation to the performance and aesthetics of the produced outcome, informing a "simultaneous approach" to crafting the textile and garment (Townsend, 2003). The hybrid (hand and digital) crafting methodology (developed in the second case) is discussed through its application in related, participatory research focused on the co-design of emotionally durable clothing in the third case. Using these examples, we reflect upon how hands-on engagement with materials and processes fosters skill development, embodied knowledge, and mindful flow. We further consider how they are related to, and able to embed, the three wellbeing aspects – emotional satisfaction, social engagement, and personal agency – within and through making and collaborative crafting contexts. In the three examples, we focus on these individual aspects despite overlaps between them. Reflection on our own creative practice is expanded by a discussion of selected examples of wellbeing derived from a wider application of craft and design.

Mindful flow in the making: an example from silversmithing practice

Just as a musician needs to practise a piece over and over again to master it technically and to understand each nuance and potential for interpretation, repetition is essential to craft practice, both to gain technical proficiency and to understand the creative potential inherent in the materials and processes involved. Through such repetition, embodied knowledge is formed through a deeper, experiential understanding of the materials, tools, and processes at hand. In other words, with repetition comes immersion, which is the unconditional and empathic attention to the material and process. Immersion without distraction creates flow, a recognized state of mind (Csikszentmihalyi et al., 2014) that can be achieved within and through dedication to, and continual practice of, a (craft) process (Huotilainen et al., 2018, Singh, 2018). The nature of *flow experience* is defined as the subjective state (or feeling) of moment-to-moment activity, when attention is fully invested in the task at hand, and the person functions at their fullest capacity which may include mastery, control, and other forms of autonomous behaviour (Csikszentmihalyi et al., 2014). Flow has further been related to emotional wellbeing, by promoting relaxation and reducing anxiety. Burt and Atkinson (2012) found that "although causality has not been proven, a reciprocal association between enjoyable states of flow and psychological wellbeing has been shown to exist" and that "the more people experience flow the more satisfied they are in life" (p. 58). Anyone pursuing a craft who has entered the state of flow will know the emotional satisfaction flow brings.

Within the practice of silversmithing, the experience of flow for Niedderer is epitomized in the process of planishing silver where the metal is gently tapped with the hammer repeatedly to produce an impeccably smooth form and a characteristic finely hammered surface pattern (Figure 5.1). The rhythmic and repetitive action requires full concentration, i.e., one's entire embodied attention, to hit just the right point with just the right strength to develop the desired shape and smoothness of surface. It involves not only listening to the sound which the hammer makes in striking the silver and the iron stake underneath to ensure they are aligned but also sensing the surface with one's fingertips to ascertain the smoothness of the surface. Since the fingertips have more sensory receptors than any other body part (Johansson & Flanagan, 2009), they tell the practitioner better than the eyes or any gauge whether the shape is well-finished or still uneven and needs more work. Although this process may begin as separate understandings of

Figure 5.1 Kristina Niedderer, four cups, 1994, surface finely planished. Photograph by Gunter Lepkovski, 1997. © Kristina Niedderer.

codified explicit knowledge and of a material's feel and the steps involved in a specific making process, through continued practice, the different aspects of knowledge meld into one holistic experiential understanding – embodied knowledge. As the different aspects become integrated, they create an intuitive understanding of the forces at play, e.g., how a piece of metal will stretch or how far it can be bent without breaking. Due to their multisensorial and embodied nature, such craft processes lead to immersion and to full in-the-present-moment attention, i.e., flow. The experiential process then enables creative development through embracing the tension between repetition and technical challenges which disrupts the flow and requires conscious mediation of the body's actions or conflicting technical realities. Sensory experience further enables the fine evaluation through sensitising and heightening the maker's physical and cognitive discrimination.

The key to achieving flow, from a mindfulness perspective, is the full attention and focus on the task in the present moment – to the extent that the task becomes automated and can move to the background of the practitioner's awareness. In practice, this requires a balance of practical competence (or skill) and challenge: If a task is too difficult, the flow of consciousness is likely disrupted when encountering difficulties, whereas if a task is too easy, this might lead to mindless repetition without full attention. While mindful flow may emerge unconsciously, through the automatic, embodied actions of the skilled practitioner, they may still move in and out of flow states to attend to the progression of the work. This tension between skill and challenge offers the opportunity for new creative interpretations arising from the process.

An example of silversmithing practice that shows how new creative opportunities evolve from immersive and longitudinal making is the work by Hiroshi Suzuki who specializes in raised and planished metal vessels (Schroder, 2010). Through continuous practice, Suzuki has developed his work through incremental change arising from his embodied knowledge. As a process gets practised repeatedly and becomes more and more fine-tuned, masters of their craft learn how to traverse boundaries and, by doing so, achieve new technical and creative feats. This has allowed Suzuki to challenge and overcome established norms of form-giving within silversmithing. In doing so, it has allowed him to perceive new opportunities in the making of his vessels and to create unique shapes that any conventional metalsmith would think impossible to achieve.

The example of Niedderer's experience in silversmithing practice, complemented by Suzuki's mastery of silversmithing, is one of many others that could have been chosen here to illuminate the reliance of creative development on the importance of embodied knowledge and its role within craft making. It was chosen because of the author's own expertise and the experiential processes involved, whereby personal insight is essential to understand them and to recognize them in others' work. This example has demonstrated how immersion into a craft through continual practice is required to build embodied knowledge that leads to skill and expertise as well as creative foresight. At the same time, this immersion into making enables mindful flow to arise for the practitioner within and through the embodied making process.

Huotilainen et al. (2018) traced the physiological and cognitive aspects of arts and crafts making to explain how repetitive making enables the emergence of flow and how it is related to emotional wellbeing. They found that creative making activities can promote psychophysical wellbeing, e.g., through reducing blood pressure and stress, based on complex mechanisms and interplay between cognitive and motor-sensorial processes. This means that creative making can help regulate and balance mental states by providing a way to reach the state of flow. They explain that "the state of flow takes place when the explicit information processing system shifts into the implicit automatic, nonverbal, experience- and skill-based processing system" (p. 11) and that arts and crafts practices can play "an important role in controlling stress and enhancing relaxation" (p. 1). These creative making processes can further instil a sense of control and personal agency, which have an impact on self-perception, and can eventually insinuate feelings such as satisfaction and pleasure. Their work confirms the earlier study by Burt and Atkinson (2012), which investigated mindful flow in relation to quilting and found a reduction in stress and anxiety. Another, more recent study by Singh (2018) sought to investigate how arts and crafts practices support mindfulness and wellbeing, using the example of colouring books. Singh found that colouring activity, even without formal guidance, could enable mindful states and emotional wellbeing, especially the reduction of worry and rumination. All three studies found a positive correlation of craft, or craft-related activities, with emotional wellbeing, because of their ability to create a state of mindfulness, in particular, "flow".

Creative agency in the making: sensorial material engagement in textile practice

This case illustrates how sensorial material engagement supports the acquisition of experiential knowledge and skill, and how this in turn facilitates creative foresight and new expressions in hybrid crafting processes. Working creatively as a textile and clothing practitioner requires embodied craft knowledge, gained through engagement with analogue and/or digital material and technology, and longitudinal experience. Designing and constructing textiles and garments that work in harmony with the animated human form depends upon the maker's theoretical and practical knowhow of diverse fabric qualities and techniques in relation to aesthetics and performance. Gaining textile expertise often begins with formal training in weave, knit, embroidery, and print, each requiring the learning of specialist skills through tactile material engagement in what artist Anni Albers called a "many sided" craft. Using weaving as an example, Albers said:

> Besides surface qualities, such as rough and smooth, dull and shiny, hard and soft, it also includes colour, and, as the dominating element, texture, which is the result of the construction of weaves. Like any craft it may end in producing useful objects, or it may rise to the level of art.
>
> (Albers cited in Coxon et al., 2018, p. 13)

Regarding printed (and surface designed) textiles, Woolley and Huddleston (2016, p. 92) noted that "the purpose of workmanship … [is] to exploit the natural qualities of the base materials, for which an understanding of their underlying physical make-up is an important aspect of craft research and tacit knowledge". Learning how to mix and apply dyeing and printing techniques (cf. Wells, 2000) and devise repeating patterns (cf. Philips & Bunce, 1993) to transpose onto contrasting substrates requires both a technical/rational and aesthetic/intuitive approach to balance colour, motifs, and tactile effects. The printer may experience states of flow in the process of preparing and pinning down a base cloth, screen printing multiple layers of coloured dyes, steaming and washing the cloth, involving precise and repetitive bodily actions. Later manipulations such as transforming two-dimensional textiles into three-dimensional products require a different embodied skillset. As acknowledged by the renowned pattern cutter Winifred Aldrich (1996), to make garments that fit, are comfortable, and work with the body, the designer requires understanding of the fabric's "weight, thickness, drape, shear, stretch" (p. 7). Also known as "fabric hand", this qualitative sensory assessment of a cloth is learnt through the sense of touch (p. 7) and practical, technical, and aesthetic abilities are acquired through sustained sensorial engagement with materials, tools and processes. It can be argued that this embodied knowledge, learnt over time through haptic and tactile interactions, not only informs the crafting of objects but also contributes to the makers' wellbeing associated with the feeling of personal and creative agency and self-esteem due to their accumulated skills.

As with many contemporary craft contexts, the introduction of advanced materials and digital technologies have generated innovative, hybrid methods of making. For example, the performance fabric Lycra had a significant influence on fashion from the mid-1980s, enabling "garments to be cut to fit the contours of the human body" (Townsend, 2003, p. 5). This dynamic substrate, incorporating stretch and recovery properties, presented new opportunities for designers to respond to the material's inherent properties (Ingold, 2013), resulting in the creation of textiles as second skins encompassing "haptic and optical complexity, at once natural and synthetic, shiny and matt" heightening the "corporeal element" (Coxon et al., 2018, p. 28).

In the mid-1990s, computing reinvented the structural processes of textile design and production, calling for designers to develop a "digital hand", to complement their embodied knowledge of physical textile making with "intelligent practices [of] visual thinking, tacit knowledge of tools, experiences and affordances of the media" (McCullough, 1998, p. 271). Computer-aided design and computer-aided manufacturing (CAD/CAM) presented a new interface to experiment with and acquire virtual crafting skills, by

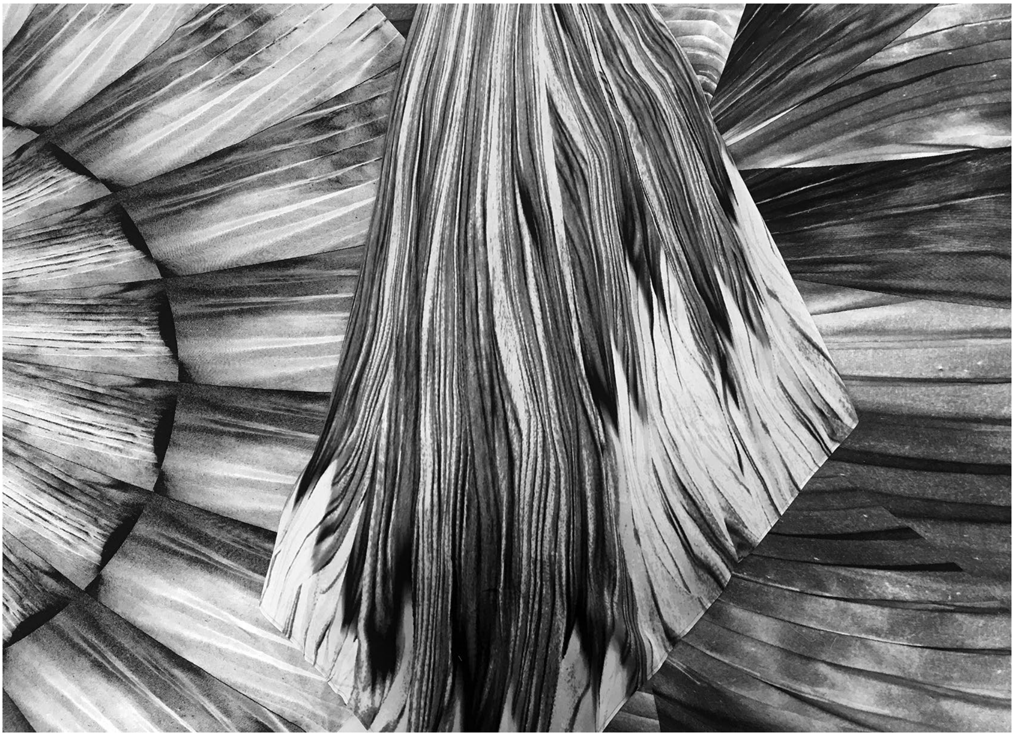

Figure 5.2 Katherine Townsend, inkjet-printed fabric forms featuring *trompe l'oeil* pleats, 2003. Photograph by Katherine Townsend, 2023. © Katherine Townsend.

making connections between traditional and advanced mediums whereby "it can be difficult to say where the tool ends, and the medium begins" (Woolley & Huddleston, 2016, p. 92). An example of this is illustrated in Figure 5.2, which shows three of Townsend's inkjet-printed textiles featuring *trompe l'oeil* pleats, created using CAD to digitally manipulate scans of hand draped, pleated, and dyed cloth toiles.

In more recent research, the ability to draw upon sensorial (analogue) and simulated (digital) material knowledge has informed new methods and three-dimensional forms, such as "composite garments" whereby the tolerances of the textile, garment, and body shape are synthesized in the crafting process (Piper & Townsend, 2016). The use of hybrid technology has extended the parameters of textile making, and in turn the personal and creative agency of the maker. As the following section will discuss, holistic, participatory approaches have reinvented the act of making beyond craft and design problem-solving, by using co-creation to cultivate feelings of agency and capability through shared material engagement activities (Hanssen & von Busch, 2023; Shercliffe & Twigger Holroyd, 2020).

Co-crafting clothing for wellbeing: social engagement and personal agency

The following case illustrates how co-crafting may lead to social engagement and a sense of personal agency in the participants. In craft research there has been a palpable shift from independent creative practice towards using making processes to support "health, wellbeing and happiness" (Townsend & Niedderer, 2020). Between 2015 and 2017, Townsend was able to test her "simultaneous design method" (Townsend, 2003) with a group of older active users of fashion in the co-crafting project, *Emotional Fit* (Townsend et al., 2017b). The participatory project enabled a group of fashion and textile researcher-practitioners to explore the evolving clothing identities of a group of women (n + 40, aged 55+) by sharing and exchanging their "expert" and "diffuse" knowledge of dress (Manzini, 2015). With combined experience of designing, making, wearing clothes, and ageing, the researchers were able to provide an empathetic design response to the group's changing clothing needs, influenced by the impact of their ageing process. A co-crafting model was devised that gave voice to the participants through involvement in a programme of hands-on workshops, with the aim of co-creating a collection of personalized garment prototypes that met their expressed needs and preferences. Qualitative information was gathered through interpretative phenomenological analysis (IPA) of selected group members' "lived experiences" of fashion and fashioning themselves (Eatough & Smith, 2017).

The engagement was supported by a "research through co-design" model, based on three ladders of participation dedicated to (a) gathering information, (b) collaborative making, and (c) disseminating findings and outcomes (Townsend & Sadkowska, 2020, p. 16). The collaborative aspect comprised five steps. *Step 1: Listening and communicating* covered introductions, project aims and objectives. *Step 2: Involving* encompassed interviews, wardrobe studies and workshops. *Step 3: Activating* applied the IPA methodology to analyse transcripts and identify themes relating to the participants satisfaction with clothing, highlighting the significance of textiles as a touchstone for embodied clothing practices and memories (Townsend & Sadkowska, 2018, p. 5). *Step 4: Consulting* invited the participants to feedback on working designs, where their kinaesthetic, bodily sensemaking of the emergent material outcomes informed the ongoing, co-crafting process, as illustrated in Figure 5.3. In *Step 5: Sharing and feedback*, a collection of garments were completed, and presented publicly.

Figure 5.3 Film still showing a researcher helping a participant try on one of the printed garment prototypes to inform the ongoing making process. Photograph by Katherine Townsend. © Katherine Townsend.

Figure 5.4 A group of research participants at the *Emotional Fit* public event, modelling the outcomes from their engagement in the co-crafting project. Photograph by Rebecca Lewis, 2017. © Katherine Townsend.

Fourteen of the women volunteered to model the artefacts at a research event in Nottingham in April 2017, where the project outcomes were shared with an audience of 150 participants, friends, academics, students, and industry (Figure 5.4). The collaborative crafting of clothing represented a "socially valid tool", a notion based on the ideas of craftsman William Coperthwaite, whereby tools used democratically can lead to "socially valid designs" (Hanssen & von-Busch, 2023, p. 59). The benefits of the co-crafting engagement were acknowledged in feedback from the participants and audience as supporting feelings of self-esteem and personal agency, through recognition and activation of their embodied fashion knowledge.

Discussion: crafting wellbeing in the wider context

The first two examples of silversmithing and textile practice have explored the role of bodily engagement with materials for achieving individual aspects of wellbeing, such as emotional satisfaction, creativity, and personal agency. The third example has illustrated how practising craft together can result in social connectedness and the experience of agency. In this section, we discuss the insights gained from these cases and reflect on other examples from the wider field of craft.

Emotional satisfaction through sensorial making and flow

Niedderer's example from silversmithing has demonstrated how craft practice is rooted in the maker's personal experience of their practice and how this experience progresses over time to become internalized in the form of embodied knowledge and expertise (Groth, 2017). Through its simplicity, the process of planishing metal highlights the importance of sensory experience and embodied knowledge in craft making, for both the creative development and the evaluation of the work's quality. The importance of experiential and embodied knowledge towards creative, personal agency and wellbeing is also apparent in Townsend's practice as a textile and garment maker, where she learnt how to embellish and construct fabrics in two and three dimensions. This involved learning both science- and arts-based skills to develop sensory evaluations and craft knowledge (Molander, 2022), from weighing and mixing dyestuffs to print lengths of cloth to measuring, cutting, and manipulating the resulting embellished fabrics into garments.

Niedderer's example has further illustrated how the craft process affords the opportunity for mindfulness and experiences of flow and extends emotional wellbeing and satisfaction (Czikszentmihaly et al., 2014). Adams-Price and Morse (2018) offered an example related to wellbeing and ageing through their review of research regarding the benefits and impact of participating in culturally meaningful, creative activities on older people's quality of life. They found that creative hobbies can have major benefits when practised long-term, and that practising them can improve cognitive performance and social connectedness, promoting life satisfaction and successful ageing. In a different case, Bunn (2020) has investigated basket-making as a vehicle for recovery for ex-servicemen affected by trauma and memory loss. Like Adams-Price and Morse, Bunn (2020) recognizes the importance of flow within the making process of learning basketry skills (p. 39).

Crafting relational interactions towards social engagement and agency

In the third case, the *Emotional Fit* project, the experiential aspect is expanded through social interaction. Here the researcher-practitioners' expertise of making textiles and clothing was juxtaposed with a group of older women's lived experiences of "making themselves" through clothing (Townsend & Sadkowska, 2020). By formally exchanging learnt skills and personal experiences, it was possible to create something beneficial and of shared value to both parties (Sennett, 2013). Using the relational design of emotionally durable clothing as a socially valid tool, the enquiry drew on ideas of how "problem-solving is learnt in practice" by exploring how knowledge exists and can be generated through "communities of mutual learning" (Molander, 2022, p. 227).

With their varying levels of non-specialist knowledge, i.e., learnt from home dressmaking as young women and through lifelong sewing, altering, and repairing skills, the participants' access to and engagement with the co-crafting process were enabled by the presence of the researcher-practitioners with expertise in fashion, textile design, and pattern cutting. In turn, the participants shared their personal and sometimes emotive insights into the rationale or meanings attached to keeping well-worn garments, how they had developed their fashion/ing know-how through sustained material engagement, and their active bodily practice in the world (Malafouris, 2013; Molander, 2022). The workshops engendered mindful working towards a shared goal through relational activities (e.g., textile selection, trying on and fitting sessions, dress rehearsals, filming, and photo shoots), many of which were new experiences for the group.

The translation of discipline-based and emotional knowledge using hybrid and bespoke methods (e.g., the digital scaling of prints within made-to-measure garment shapes) highlighted craft practitioners' facility to uphold human traits through material understanding and practice (Niedderer & Townsend, 2014). This "agency-oriented" approach (Hanssen & von Busch, 2023, p. 66) restored a sense of empowerment to individuals from a demographic who generally feels overlooked by the clothing industry and to some extent society. The participants expressed the positive impact of the project on their sense of personal agency in a documentary film (Townsend et al., 2017a).

Emotional Fit involved participants as both research subjects and co-researchers, demonstrating a "model of practice" that highlights the value of the making experience in and of itself, alongside "learning with" participants (Shercliffe & Twigger Holroyd, 2020; Townsend & Sadkowska, 2020).

Looking further afield, both Rodgers (2018) and Zeilig et al. (2019) have explored co-creation processes regarding the wellbeing of participants, specifically people with dementia in the context of design and arts (music, dance), respectively. Both studies found that the joint engagement in the creative process demonstrates significant wellbeing benefits for those involved. The wellbeing aspect that arises from the social "togetherness" and collaboration within the process comprises social engagement and a sense of personal agency. Zeilig et al. (2019) explained that co-creativity in their study helped to support wellbeing through promoting a relational approach to creativity that nurtures inclusivity and equality:

> Co-creativity for this group was distinguished by a number of characteristic features, including empathic connections, a sense of equality and the generation of a safe space that enabled creative involvement and sharing.
>
> (p. 22)

Zeilig et al. (2019) also stressed the agential nature of co-creativity in that it required participants to take ownership of their feelings within the process and the social group, having to decide how much to disclose and contribute, and whether or when to be an active or passive participant.

The agential and relational nature of craft is further explored by Martindale et al. (2021) and Schnittka (2021). Both studies investigated the phenomenon of sewing face masks during the COVID-19 pandemic by groups of home sewers, including older adults and what led people to make and donate the masks. They explain that craft can act as a catalyst for both creative and social agency as well as relational interactions. The ability to act and do something in the face of the overwhelming feeling of helplessness, especially at the beginning of the pandemic, promoted creative and social agency. Interestingly, for these two studies that due to the requirement of self-isolation at the time, direct co-creation was not possible. Rather, people made masks at home, on their own, as a means of maintaining their emotional wellbeing through feeling (more) in control and empowered in the given situation, and of further gaining a sense of social agency through making something beneficial to the community and helping others. The relational aspect was enacted through interactions of sharing knowledge and experiences of the best materials and ways to make the masks online, and through the gratitude of the community experienced by the makers, as expressed, for example, through "thank you" cards. Satisfaction felt at receiving such acknowledgements added further to the makers wellbeing, or sometimes to the lack thereof if these were not present.

Conclusion: crafting wellbeing through immersion and co-creation

Our examples of craft-making related to metalwork and textiles reveal how craft practice allows makers to develop deep material and experiential knowledge and expertise, and how this may further lead to creativity, personal agency, emotional satisfaction, and social connectedness, thus promoting wellbeing. The examples further demonstrate that mindfulness plays a significant role in relation to the concept of flow, which has been shown to be intrinsically linked to emotional satisfaction. The discussion has highlighted five key points:

- The understanding of how craft practitioners rely on embodied knowledge as the basis for making creative leaps.
- Embodied knowledge and craft expertise, such as sensory evaluations of material properties in the making process, are built over time through practice, repetition, and immersion.
- Immersion, fostered by repetitive action and balance between skill and challenge, allows for the emergence of the flow state that is, in turn, associated with mindfulness and emotional wellbeing.
- Craft and design practices can foster wellbeing by instilling a sense of personal agency and emotional satisfaction through the ownership and self-realization immanent in the process of material engagement.
- Co-creation builds on the wellbeing benefits of making, engendering social engagement and connectedness through sharing not only craft knowledge in the process of making but also the delight and appreciation of the outcomes of craft practice.

We live in an increasingly virtual world where digital technologies become more and more pervasive, on the one hand facilitating creativity, while on the other being recognized for creating stress (Ilstedt Hjelm, 2003). In such a world, it is important to have a counterbalance: craft offers such a compensation and can become a means for promoting wellbeing, through (a) the grounding effects and benefits of immersion through making, (b) the sense of agency that the making process can foster, and (c) the social connectedness that the sharing of craft knowledge and appreciation of the products that craft making can provide.

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Part II

Materiality of materials and non-materials in craft

Part II
Introduction

This part focuses on interaction with a new type of materiality that blurs the boundaries of physical and digital materials in craft. Authors are closely examining how digitization gives rise to the new and changing situations in craft practice and the possible challenges and benefits it brings to embodied making and interaction with materials. As we can see from many of the chapters in this part, similar aspects of embodied cognition can be detected even in processes where interactions happen on a screen or via a robotic arm. Constraints, resistances, affordances, and feelings of flow can be experienced even when the body is not directly involved in a physical way. Practitioner-researcher Flemming Tvede Hansen is opening up this issue when transferring his craft skills to a programmable wire cutter tool in ceramics in Chapter 6 “Embodied Knowledge Integrated in Robotic Wire Cutting of Clay”. In Chapter 7 “Making, Playing, Crafting – Connecting Embodied Practices in Play, Game Design, and Hybrid Making”, digital media researchers Michael Nitsche and Jihan Sherman discuss the embodied interaction of gamers with the games they are playing, but extend the embodied interaction to the *makers* of the games that others play. The game designer’s experiences of envisioning and creating a space for embodied interaction in a digital world is a side of craft and design practice that has rarely been discussed.

Many of the authors in this book describe and analyse their practices when using both physical materials and more immaterial aspects of digital material processes. As the general digitalization in society affects the design and craft practitioner’s task ecology, many making processes get increasingly hybrid. What happens to experiential knowledge of materials and making processes when we move into the digital dimension? Craft practitioner-researcher Justin Marshall investigates in Chapter 8 “*Hand Thought*: Hybrid Practices and a Digital Craft Ethos” the role of hands in the digital era and proposes an ethos for digital crafts.

Additionally, the learning sciences have opened their eyes for the role of bodily actions in students learning and knowing. In Chapter 9 “Grasping Materiality – Digitalization in Light of Educational Arts and Crafts Practice”, arts and crafts educator Lovise Søyland writes about the changed materiality in arts and crafts education and the importance of bodily and concrete physical experiences especially for young children as they draw on these experiences in the translation of concrete materials to the digital realm. The chapter discusses the educational benefits of the co-creative aspects of digital technologies and the space that can connect physical and digital materialities.

DOI: 10.4324/9781003328018-10

6 Embodied knowledge integrated into robotic wire cutting of clay

Flemming Tvede Hansen

Introduction

Digital technologies offer new possibilities for ceramic craft practice. This chapter aims to discuss how digital technologies build on and enhance traditional craft practice in the field of ceramics. As a ceramicist-researcher myself, I explore how interaction with clay through robotic wire cutting holds embodied knowledge. This exploration is based on my own practice-based experiments with the robotic wire cutting of clay. I further discuss the implications of changing materials or processes to virtual or immaterial modalities.

Sennett (2008) has written about metamorphosis in relation to the invention of new tools and technology. The notion of "technology" is wide; analogue tools and machines such as a wheel or a sail may be seen as technologies, some of which have shaped both people and societies despite being quite simple compared to today's digital technologies. Within the field of ceramics, Sennett has described how the invention of the potter's wheel "suggested an entirely new way of building up form than the rope coil; now the potter could raise a wet clay lump" (p. 121). Further, Brinck and Reddy (2020) have described how the invention of the potter's wheel provides an example of how new technology can transform cognition, creating new forms of systemic units and activities.

Digital technologies such as robotics have become common in the practice of craftspeople and designers – I consider them inventions that transform the craftsperson's cognition like the potter's wheel has done. However, digital technologies might generate worries about craftspeople being removed from their practice (Johns et al., 2014, p. 320; Pallasmaa, 2005, p. 12; Sennett, 2008, p. 81). This raises the following question: How can the ceramicist apply their experiential knowledge gained through their traditional ceramic craft practice to working with new digital technologies in hybrid ceramic making? Thus, instead of thinking of digital technologies as something that detracts from craft practice, I rather view them as something that enhances it.

Digital tools enable the ceramicist to work with a high degree of complexity that is not possible with traditional techniques and manual workflows, e.g., 3D modelling software allows the ceramicist to design complex mathematical geometries that are possible to manufacture in clay by 3D printing. At the same time, digital technology creates a barrier to working directly with clay by hand. In the use of digital technologies, the craftsperson typically uses software to design the fabrication method before the material is processed and is not able to make changes while the material is being formed (Willis et al., 2010). Such barriers might prevent the craftsperson from spontaneous decision-making based on experiential knowledge and intuition, where materials act as a partner (Johns et al., 2014). Nevertheless, a range of possible methods for using digital technologies can be

DOI: 10.4324/9781003328018-11

explored in ceramics. Based on my own experiments, I will demonstrate and discuss possible ways of building up a synergy between traditional ceramic craftsmanship and robotics, particularly focusing on utilizing the practitioner's embodied knowledge in experimental processes.

Traditional ceramic craftsmanship

In ceramic craft practice, a dialogue between the ceramicist and material exists as an embodied experience of making, where the physical properties of clay encourage the ceramicist to approach it as a partner in conversation (Brinck & Reddy, 2020). In such reflective conversations with the material situation, the craftsperson reflects-in-action and responds to the material (Schön, 1983, p. 76). This reflective way of interacting with a material resonates well with the idea of an embodied mind. Wilson (2002) described how the embodied mind interacts with the environment and how human cognition has deep roots in sensorimotor processing. In other words, from the viewpoint of embodied cognition, cognitive processes are deeply rooted in the body's interactions with the world.

From a design and craft perspective, Groth and Mäkelä (2016) examined embodied cognition in relation to material exploration. Some of the themes that emerge from Groth and Mäkelä's analysis relate to how previous embodied knowledge supports the craftsperson and designer to overcome challenges that they encounter when working with new materials and the importance of the tactile aspect in the decision-making process regarding materials. While such decision making is based on conscious reflections, embodied skills can become second nature and work in the background of the practitioner's consciousness. Malafouris and Koukouti (2022) have described two levels of the potter's engagement:

> As the potter grows to know clay better the need for conscious attentive engagement drops. Eventually, with practice the nature of attentiveness will be reversed turning into the mode we call immersive attentive engagement. What allows this transformation is the redistribution and re-organisation of the potter's attention among neural, somatic, and material elements that come with increased levels of skill. The initial "mindless", but conscious, attentive engagement is turned to unconscious, but "mindful", immersive attentive engagement.
>
> (p. 14)

Thus, the turn from conscious attentive engagement to immersive attentive engagement reflects how the practitioner gains experiential knowledge and changes the way of working from being conscious of what is going on and controlling it in a conscious way to becoming intuitive and spontaneous.

Furthermore, Adamson (2019) discussed skills as "knowing how to make something" (p. 73), and how skills are key to the creation of any art. In the discussion, Adamson introduced Pye's well-known distinction between the *workmanship of risk* and the *workmanship of certainty*. In the workmanship of risk, "the quality of the result is not predetermined but depends on the judgement, care, and dexterity which the maker exercises as he works" (Pye, 1968, as cited in Adamson, 2019, p. 73). The workmanship of risk is relevant to working with clay in the context of hybrid manufacturing processes, as it reflects an explorative, nonlinear process that includes working with dedicated materials openly and without intermediaries (Brinck & Reddy, 2020).

Craftsmanship and digital technologies

As aforementioned, the introduction of new technologies to traditional craft processes often raises worries about the craftsperson's body being removed from the practice. Sennett (2008, p. 81) identified the machine as the greatest dilemma faced by the modern craftsperson and posed the question of whether the machine is a friendly tool or an enemy that replaces the work of the human hand. Johns et al. (2014) also described how automation, such as robots, is replacing manual tasks to increase efficiency, speed, and precision in manufacturing processes.

In the context of ceramics, automation entails removing the crucial role of clay as a responding material that guides the ceramicist. However, as a ceramicist, I consider the technology that I have utilized in my process an enabling force, following McCullough's (1998, p. 78) idea about the close connection between digital work and craft practice. McCullough considered the computer as a tool that unites craftsmanship with cognitive reasoning, altering the outcome of manual craftsmanship through more sophisticated processes.

Jensen (2021, p. 32) discussed how interactive and collaborative robotic fabrication can contribute to the creative "co-evolutionary" design process and how such creative activities influence cognitive design processes. Thus, I am encouraged to rethink the role of the craftsperson in the design and making process that encompasses digital technologies.

As mentioned earlier, the use of digital technologies in craft practice is typically a two-step process that includes a design process with software and a digital fabrication process. This implies a very detached process and far from the idea of craft practice involving a dialogue between body and material and an embodied experience; such a dialogue is limited when the craftsperson uses digital technologies. Nevertheless, a novel set of design software and technologies creates new ways for craftspeople to explore and develop tools specific to their own projects and to rethink their role in these processes. One example is the 3D modelling software Rhino (Robert McNeel & Associates http://www.rhino3d.com/) and its graphical programming interface Grasshopper, developed by David Rutten (http://www.grasshopper3d.com/). Grasshopper is a visual scripting environment which is used by craftspeople, artists, designers, engineers, and architects to generate geometries for shapes, objects, structures, and complex buildings. The core activity in Grasshopper is to find and encode the generative concept underlying the geometries into custom tools and identify the robotic processes that allow for the investigation of design processes. This includes the search for novel design methods and fabrication processes that support the fusion of human and robotic agencies.

Traditional ceramic craft and digital technology

Digital technology may be utilized in various ways within ceramic craft practice. For example, tools for traditional techniques can be laser cut, such as profiles for plaster sledging, or CNC milled or 3D printed, such as stamps for clay decorating. However, the development of tools for traditional techniques made by digital processes is beyond the scope of this chapter, which is about how digital technology supports and enhances traditional craftsmanship when it is employed as a tool for the making of ceramic objects.

A 3D clay printer is one of the digital technologies that functions as a shape-making tool. The British potter Jonathan Keep has used 3D clay printing in his project *Iceberg Field*. In the project, virtual forms are first generated by a computer code that makes use of an algorithm mimicking the erosion of ice. The virtual shapes are then 3D printed using a clay extruding printer. According to Keep (2019), in some ways, this technique could even be considered a return to the old tradition of coil building in ceramics, as clay is extruded through the narrow mouthpiece of the printer forming tiny coils.

Another example is the wire-cutting robot technology used in the project *Oscillating Wire Cutting and Robotic Assembly of Bespoke Acoustic Tile Systems* by Rossi et al. (2021). The project is a collaboration between architects, engineers, designers, and Strøjer Tegl, a Danish brick producer. It uses a hybrid robotic process that combines robotic oscillating wire cutting of wet clay bricks and adaptive pick and place production of bespoke brick panel assemblies. Rossi et al.'s research bridges the gap between serialized and bespoke production of architectural elements, in which the programming of the bespoke robotic oscillating wire cutting of wet clay is carried out in the Rhino and Grasshopper environment.

A final example is the project *Clay Rotunda* created within Gramazio Kohler Research, Eidgenössische Technische Hochschule (ETH) in Zurich. Clay Rotunda is a free-standing cylindrical structure with a diameter of almost 11 metres and a height of 5 metres; its production combines clay and robotic fabrication. The project makes use of accurate robotic positioning, spatial orientation, and controlled pressing of clay cylinders (Jenny et al., 2022).

These examples make excellent use of digital technologies as tools for making and working with clay; they demonstrate how digital technologies support and enhance the craftsperson's practice in ways that would not be possible in a traditional studio setting. Nevertheless, the human perspective, reflections, skills, sensory evaluations, and embodied knowledge are removed from the loop in these projects. In my present project, I seek to include the embodied experience of making within the design process even when using digital fabrication tools.

Experimentation with manual and robotic wire cutting

In this section, I present my own experimentation and illuminate how I see the human perspective and embodied knowledge as central in connection to 3D design software and digital fabrication tools. In the experimentation, I examined how robotic wire cutting of clay enabled me, the craftsperson, to enhance craft practice in a way that utilized my embodied knowledge and sensory evaluation of the situation.

Wire cutting is a simple traditional technique that uses an ordinary metal wire held between the craftsperson's hands or fixed on a metal frame. The purpose of the technique is typically to divide a lump of clay into smaller pieces (e.g., in relation to brick production) or to release a lump of clay from the potter's wheel. The wire is also a suitable tool for creating shapes, patterns, and textures in clay slabs.

As mentioned in the introduction, the overall aim of the experimentation was to explore and build on traditional techniques, such as wire cutting, with the purpose of exploring the aspect of embodied skills and knowledge in relation to digital technologies. Thus, the experimentation was developed into two interdependent experiments. First, an analogue experiment based on traditional craftsmanship was initiated to explore manual wire cutting as a technique. Second, a digital experiment with wire cutting by robotics was instigated, and here I studied how robotic wire cutting might enhance traditional craftsmanship and utilize the practitioner's embodied knowledge of the situation (Figures 6.1 and 6.2). My research methodology was thus practice-based in the sense that the practice was central to the whole enquiry (Candy & Edmonds, 2018).

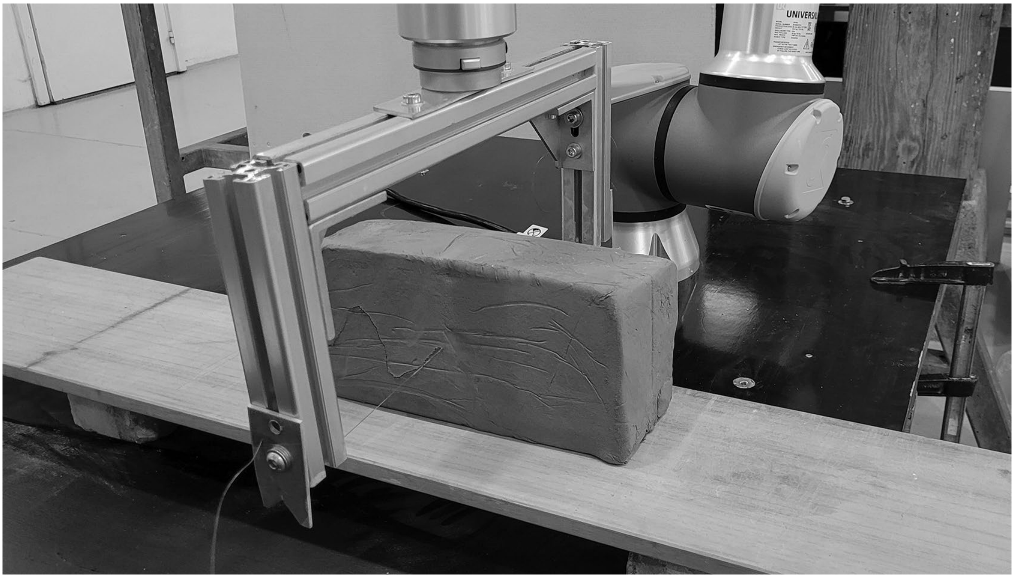

Figure 6.1 Robotic wire cutting in process. Photograph by the author.

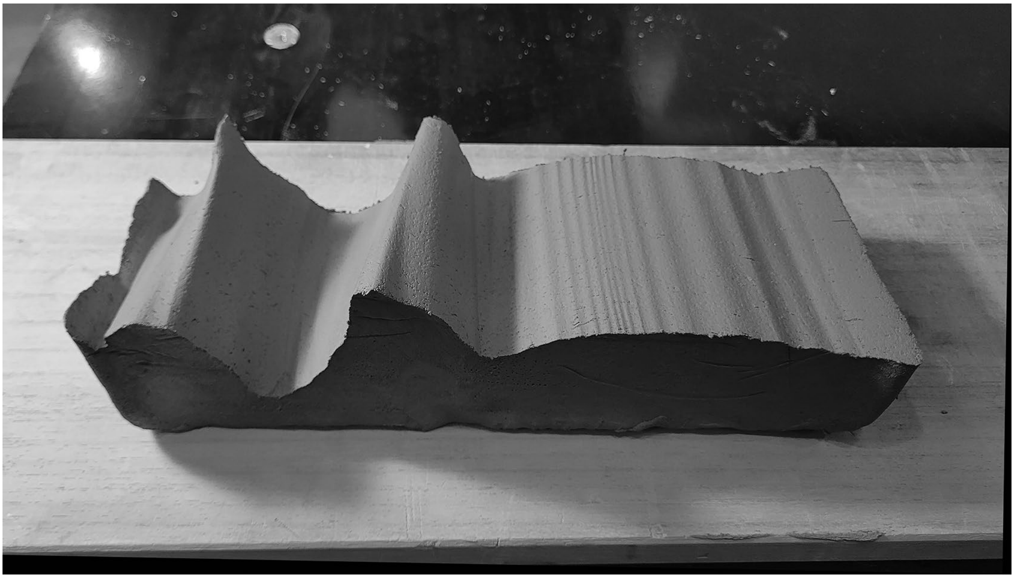

Figure 6.2 Robotic wire-cut object. Photograph by the author.

Experiment 1: traditional wire-cutting technique and manual workflow

The first experiment involved only a traditional technique without digital technology. It was crucial to experiment with the handheld wire, cutting through a lump of clay and becoming familiar with the technique. By doing so, I obtained experiential knowledge of this method that relies on sensorial experiences and embodied knowledge.

In this experiment, I used a 60-cm-long metal wire and a 10-kg lump of clay, which was approximately 10 cm × 10 cm × 30 cm in size. Each end of the handheld wire was wrapped around my hands. I cut away several lumps of clay from the original shape. I explored different kinds of cut curves ranging from soft and sharp curved areas and from very detailed to longer curved areas. Furthermore, as I was cutting, I felt the friction between wire and clay in my hands. When cutting in the middle of the lump, I experienced a stronger resistance in the clay than in the outer areas. The cutting was intuitive and spontaneous based on the dialogue between my hands and the resistance of the clay to the wire. The cutting was not precise but reflected my wish to express myself artistically with a personal curve, executed at a particular moment, with a particular degree of skill (McCullough, 1998, p. 8). When opening and turning up the slice of clay, it became visibly clear how my movements had affected the hidden surface inside the clay. The surface featured curvy lines, which reflect how the wire had made a U-shape instead of a straight line between the positions of my hands because of the resistance of the clay and ways in which I either kept the wire tight or not while cutting. The relation between my hand movements, the felt friction through the wire, and the resulting shape were examples of the experiential understanding that I gained through this process. Several tests helped me obtain various sensory experiences and embodied knowledge of how to manipulate the wire to achieve certain effects, and the result was reflected in the cut slices of clay.

Furthermore, this process of acquiring experiential knowledge also included a turn from conscious attentive engagement into the mode that Malafouris and Koukouti (2022) called *immersive attentive engagement*. Such immersive attentive engagement only appeared after I had gotten used to the technique and felt comfortable using it; it became second nature to me. The internalized embodied skill would later help me overcome challenges in the decision-making process when utilizing robotic wire cutting.

Experiment 2: robotic wire cutting and hybrid workflow

On the basis of the introductory analogue experiment and the obtained experiential and embodied knowledge, this section introduces the overall workflow in the experiment with wire cutting using a robot arm – a UR10 in this case. The overall workflow followed a recording of my hand movements simulating wire cutting through a lump of clay by a Kinect (Figure 6.3). A Kinect is a motion-sensing input device developed by Microsoft originally as a motion controller for gaming that maps depth; it can be used to perform real-time gesture recognition (Caruso et al., 2017). The recording was based on the settings I programmed in the graphical programming interface Grasshopper. In this case, the recorded movement was reflected as two curves that generated a surface in Rhino by Grasshopper (Figure 6.4). Angled points were created in the middle and along the surface of a curve. For this purpose, we can call these points "cut-points". The angle of the cut-points reflected the angle between the positions of my hands at a certain point in time. The different distances between the cut-points reflected the speed of my hands. The faster I moved my hands, the longer the distance between the cut-points and vice versa. An additional curve was applied throughout all the cut-points according to speed. The additional curve was, in this case, a *sinus curve*, but could be designed as I wanted it. A sinus curve is a mathematical waved curve that oscillates between similar negative and positive values, in a curve that repeats itself. The additional curve was stretched according to the cut-points and their angles, corresponding to the cutting path of the robot arm and its wire-cutting tool (Figure 6.4). Furthermore, with Grasshopper, I was able to

Figure 6.3 My movement recorded by a Kinect v2. Photograph by the author.

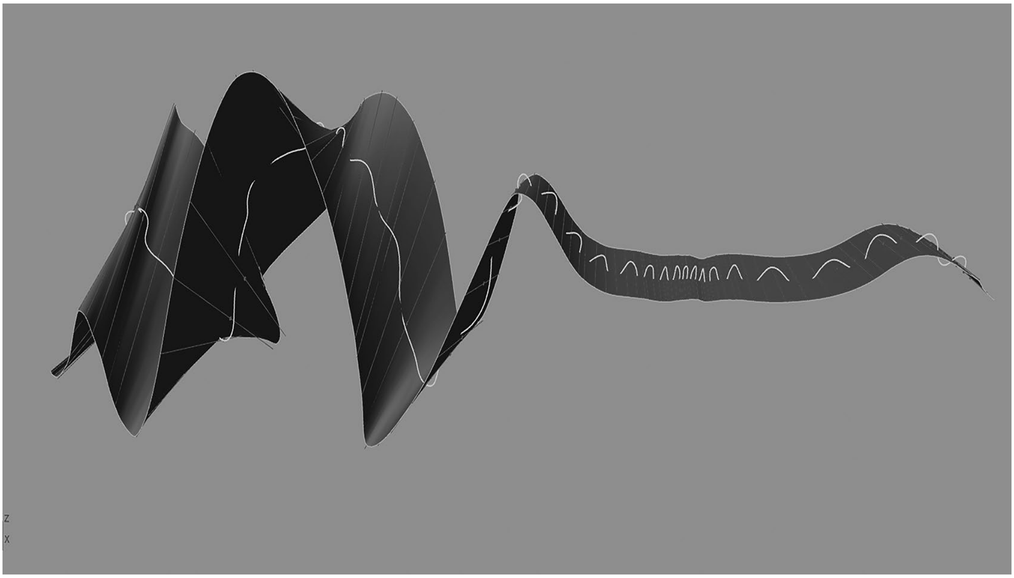

Figure 6.4 The recorded movement reflected as two curves that generate a surface. An additional sinus curve is applied to the recorded curve points in the middle of and along the surface according to speed.

scale the recorded curve in height, length, and depth. Finally, the UR10 robot arm with the attached wire-cutting tool executed the cut through a lump of clay (Figure 6.1). An example of a wire-cut object is shown in Figure 6.2.

The robotic wire cutting was explored in various ways in an overall workflow that reflected an iterative loop shown in Figure 6.5. The results of the robotic wire cutting were

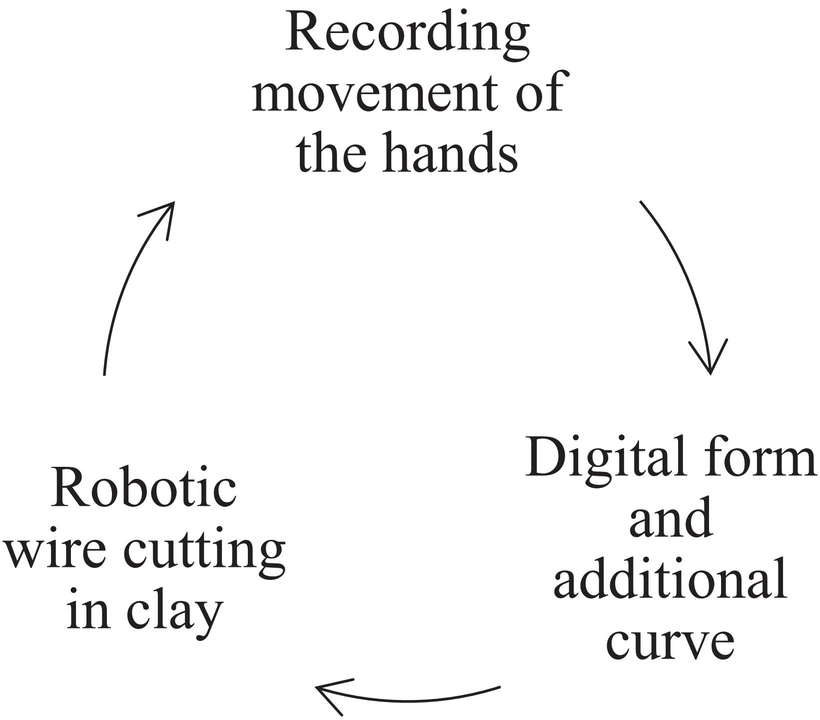

Figure 6.5 The overall workflow of robotic wire cutting as an iterative loop. Diagram by the author.

the feedback from the movement of my hands that encouraged the dialogue between me and the clay. I could thus respond to the feedback from the clay and so on. First, small shapes of clay were cut with the purpose of identifying the relationship between the recorded movements of my hands and the scale of the movements of the robot arm. These initial experiments were approximately 10 cm × 10 cm × 30 cm in size and demonstrated how the flow of my hand movement could be scaled down in a compressed expression emphasized by the additional curve as in the example in Figure 6.4. Second, shapes were cut by the robotic arm in sizes that were the same as the dimensions of my hand movement, approximately 90 cm × 20 cm × 20 cm. Finally, the robotic wire cutting was increased in scale beyond my hand movement, approximately 170 cm × 25 cm × 25 cm in size. The three sizes of robotic wire cutting were executed using the same recorded hand movements, showcasing how this method allowed me to extend my craft practice by leveraging my embodied knowledge across different scales. Through these experiments, I could work on a smaller or larger scale beyond what my hands could accomplish.

An important finding was the relevance of the recorded speed of my hand movements. By recording my entire hand movements, I was able to express myself through a curve and enhance my craft practice by scaling the wire cutting up or down. The inclusion of speed in the recording enabled me to refine the curve even more by stretching the additional curve according to the cut-points. Thus, I was able to concentrate on the overall curve and deal with details by changing speed, which was beyond what was possible for my practice solely with my hands.

Another finding was the relevance of encoding Grasshopper in relation to the scale of the robotic wire cutting. The number of cut-points had to be right according to the chosen scale. Otherwise, the applied curve would either be invisible or be messed up. The sinus curve in the Grasshopper setup required a specific number of cut-points to oscillate between negative and positive values within a defined timeframe and scale. For example, if the robotic wire cutting was scaled up, the applied curve demanded more cut-points; otherwise, the oscillation would diminish. Conversely, if the robotic wire cutting was scaled down, the applied curve necessitated fewer cut-points, or else the oscillation would intensify, potentially resulting in intersecting loops. The number of cut-points had to be balanced and harmonized in relation to the scale of the hand movement like the musician needs to tune the instrument before playing.

Discussion: enhancing ceramic practice by robotic wire cutting of clay

The overall workflow of the robotic wire cutting in question is relevant to the discussion of and arguments for how digital technology brings new possibilities and enhances traditional craft practice while incorporating aspects of the craftsperson's embodied knowledge. Next, I will especially discuss three aspects emerging from the experiments that I find important, including (a) the ceramicist's sensorial experiences, (b) the role of the ceramicist's hands, and (c) the explorative nature and workmanship of risk that projects involving digital technologies facilitate.

Robotic wire-cutting workflow relying on the ceramicist's sensorial experiences of traditional tools and techniques

The experimentation shows how the robotic wire-cutting workflow can be explored and built upon traditional tools and techniques. Through the first experiment with the hand-held wire cutter, I have obtained experiential and embodied knowledge of the relationship between the movement of my hands and the friction I feel between the wire and the material. When getting familiar with the technique, I experienced a turn from conscious attentive engagement to immersive attentive engagement (Malafouris & Koukouti, 2022). This experiment relies on sensorial experiences, and the tactile aspect involved in carrying it out helps me utilize the movement of my hands within the digital realm in relation to robotic wire cutting in the second experiment. With the obtained embodied knowledge, I have developed an awareness of the friction between the wire and the clay, and the challenges and opportunities that such material interaction would bring.

Recorded movements of the ceramicist's hands creating robotic wire-cutting workflow

The overall workflow of robotic wire cutting is generated from the recording of the movements of my hands. Though the movements might be without friction, they are based on my awareness of the material's affordances and the experiences that I have gained during the manual wire cutting experiment. While moving my hands, I experience the interdependent relationship between the movements of my hands, the wire as a tool, and the friction of the surface of the clay when cutting through it. Two particularly interesting aspects emerge in relation to the recording. The first aspect is how the recorded movements of my hands augment digital shaping. The fact that the recorded curves are based on the recording of my hand movements and not digitally drawn in 3D software by a mouse, for example, is crucial (Jensen, 2021, p. 23). The decision-making process when drawing a 3D curve with software is mainly based on the eyes, which has the risk of turning the design process into a passive visual manipulation and creating a distance between myself and the curve (Pallasmaa, 2005, p. 12). In contrast, the recorded curves reflect an intuitive and spontaneous expression, since they are based on human performance. The distance between the cut-points based on the recorded curves reflects the speed of my gestures while the angle of the cut-points reveals the positions of my hands. Thus, the interdependent positions of the cut-points indicate a high degree of complexity that is realized intuitively over time and based on embodied knowledge gained in the introductory experiment with the handheld wire cutting. The distance and angle of the cut-points emphasize and accentuate a personal artistic, sensitive, humanistic, and intuitive expression made through the movement of the hands to which the sinus curve is applied and, in turn, enhanced.

The second aspect is how the use of robotics enhances the traditional wire-cutting technique. The sinus curve, which is applied to the recorded curves, augments the captured movements in relation to speed. The application of the sinus curve to the recorded curve corresponds to my hand movement. The applied sinus curve is periodic and precise according to the speed of the hands. The applied curve enables me to deal with small details and repetition beyond what is possible when practising with my hands. Through the applied curve, I am able to concentrate on the overall curve and also deal with details and repetition solely by changing speed. Dealing with the combination of the overall curve and highly detailed and repetitive small curves is beyond what is possible for me when exclusively working with the handheld wire. In addition, I was able to up- or down-scale the power and range of the recorded curves of my hand movements in height, length, and depth. Thus, I can base my work on my embodied knowledge of the material and the process and, at the same time, make use of the advancement of the robotic tool that enriches my traditional craft skills.

Workmanship of risk involved in robotic wire cutting

The overall workflow with robotic wire cutting is built on the idea of workmanship of risk (Pye, 1968, p. 7). The applied curve based on speed deals with uncertainty. As I move my hands, I am aware that the recorded curves are to be transformed. However, the quality of the result is not predetermined but depends on the judgement, care, and dexterity (Pye, 1968, p. 4) which I exercise when exploring my hand movements, based on the feedback gained from the earlier results of the recordings and the robotic wire cutting. While I experience the relationship between my hand movements and the applied curve, I utilize my newly acquired embodied knowledge with regard to the workflow. As a ceramicist, I am used to working with uncertainty, which refers to the process that involves the physical properties of clay, thereby encouraging my approach to it as a partner in conversation (Brinck & Reddy, 2020). Thus, the workmanship of risk is relevant to all processes when working with clay, including throwing, hand building, wire cutting, the drying process of the clay, and last, but not least, the firing process where clay and glaze undergo a chemical process at high temperatures.

Reflection

Through the above-mentioned aspects, reflection on my overall workflow and the programming of robotic wire cutting can be made to build on and enhance traditional craft practice within the field of ceramics. As the second experiment shows, the robot does not replace human performance; the human element is not removed from the loop, and the robotic fabrication process supports the fusion of human and robotic agency (Jensen, 2021, p. 167).

As mentioned in the introduction, the invention of the potter's wheel provides an example of how new technologies and tools can fundamentally transform practices and even have a bearing on cognition, creating new forms of units and activities (Brinck & Reddy, 2020; Sennett, 2008, p. 121). The workflow with robotic wire cutting is an example of such transformational technology. Reflecting on the idea of enhancement of traditional craftsmanship using robotics for wire cutting, I emphasize that a ceramicist should access this hybrid process without a detachment from traditional craft and that prior experience of manual wire cutting is essential. One could start the robotic wire-cutting process by recording the hand movements without a previous experiential learning process that involves touching the matter, i.e., clay. Nevertheless, in this case, the craftsperson cannot reconnect to any memories of friction and sensory experience while performing robotic wire cutting. Through the embodied knowledge gained during the first experiment that involves traditional wire-cutting techniques and manual workflows, I develop an understanding of the friction between the wire and the clay, as well as the potential challenges and opportunities inherent in this material interaction. This process highlights the unique capabilities of the human hand compared to those of a robot and vice versa. To prevent the digital design process from becoming passive visual manipulation, I consider it crucial to rely on the judgement of the results as well as those derived from the capabilities of the human hand, perceiving the manual and digital workflows as evolving interdependently and in parallel. Furthermore, I emphasize the aspect of applying an additional sinus curve to the recorded curves according to the speed of hand movement. As aforementioned, with this aspect, I could design the behaviour of the applied sinus curve as I want. From my viewpoint, it is an open-ended possibility for designing dynamic behaviours for interaction based on traditional craftsmanship. I consider this representative of how a craftsperson might utilize digital technology to achieve an entirely new way of building up form.

The aspect of real-time interaction is important and challenging throughout the overall robotic wire-cutting workflow, as it builds on a two-step process. The movements of the hands are recorded and developed by the additional curve as a path for the robot's movement. As discussed earlier, the applied curve deals with the workmanship of risk, which reflects the overall process of working with clay. Nevertheless, the feedback is not immediate and does not happen in a continuously interactive workflow, which is central in traditional craft techniques, such as throwing clay on the wheel or the first experimentation with manual wire cutting presented in this chapter. Furthermore, such traditional craft techniques and workflows also include the tactile aspect of materials. Thus, the aspects of immediate feedback and the tactility of materials could be a topic for further exploration and discussion in the future regarding the overall workflow of robotic wire cutting in question.

Conclusion

This chapter has demonstrated how digital technologies can build on and enhance ceramic craft practice, more specifically how interaction with clay using robotic wire cutting can develop embodied knowledge that is brought into the programming by the recording of the craftsperson's hand movements. The two interdependent experiments exemplified in this chapter include: first, an analogue experiment that examines wire cutting as a traditional crafting technique; and second, a digital experiment that explores wire cutting by robotics and how this enhances traditional craftsmanship and utilizes the craftsperson's embodied knowledge gained from traditional craft practice.

Based on these experiments, I identify three important aspects that enable new possibilities given by digital technology for enhancing traditional craft practice and facilitate ways in which digital technology can be utilized to realize such possibilities through the integration of embodied knowledge of the craftsperson. The first aspect relates to how material engagement determines the movements of the craftsperson's hands when recorded by the Kinect, leading to the development of the workflow and process of robotic wire cutting. Here, I emphasize that the craftsperson's experience of traditional wire cutting is essential to access this hybrid process. The second aspect is the importance of the recording of the hand movements with a Kinect device since the recorded curves reflect human performance, which is impossible with a digitally drawn curve in 3D modelling software. The quality of the hand movement is applied to the recorded curves according to the moving speed of my hands. In this way, the applied curve reflects the path of robotic wire cutting of clay, enabling the practitioner to deal with small details and repetition beyond what is possible with hands. The third and final aspect is the concept of workmanship of risk, which refers to the applied sinus curve. Since the applied curve is employed according to speed, it involves uncertainty and risk, which the craftsperson has to accept. Such risk and uncertainty reflect the overall working process with clay, by hand or a robotic arm alike. The workflow of robotic wire cutting builds on traditional craft practice and is easily obtained as an approach for the craftsperson. The experiment demonstrates how the use of advanced digital technologies to work with materials can sustain and enhance traditional craft practice.

Acknowledgement

I am grateful to architect and programmer Tom Svilan, PhD, who has been a great support in the programming and development of the robotic wire-cutting tool.

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7 Making, playing, crafting – connecting embodied practices in play, game design, and hybrid making

Michael Nitsche and Jihan Sherman

Video games: playing and making

Video games draw players into simulated worlds where their input controls map onto any sort of virtual body. This kind of play depends on enaction and physically operating controllers, keyboards, and gamepads, but it seems far from a direct material engagement with the virtual worlds or bodies that one encounters in these mediated experiences. Players might traverse large game worlds, craft virtual objects, or mine virtual resources, but lack the material experience of the represented worlds and their depicted objects. Turning an entire pixelated tree into materials and translating them into virtual objects in *Minecraft* takes a player mere seconds. During this process, *Minecraft*'s "wood" remains a reference for gameplay options, not a material to be experienced. At the same time, players physically operate controllers to achieve such results and the play remains embodied overall. Dealing with *Minecraft*'s "wood" requires muscular engagement and coordination with the virtual world. Players remain embodied through interface operation and cognitive engagement. This chapter steps into the space between these two conditions, physical and virtual. Within this space, we do not focus on the way crafting mechanisms are adapted into digital game worlds. Instead, we draw connections between various forms of craft, video gameplay, and design. We build on the notion of embodiment to discuss differences and similarities in these connections. With this, we aim to engage the challenge posed by digital mediation of crafting practices and physical embodiment of gameplay and design. How does the play activity and the design of digital games relate to the practices of crafters and makers?

Huizinga (1949) defined play as detached from production, "playing is no 'doing' in the ordinary sense; you do not 'do' a game as you 'do' or 'go' fishing, or hunting, or Morris-dancing, or woodwork-you 'play' it" (p. 37). Huizinga's play is performed in the *magic circle*, described as "temporary world[s] within the ordinary world, dedicated to the performance of an act apart" (p. 10). But the concept of the magic circle has been debated (Consalvo, 2009). How unproductive is play, really? While video game play remains rooted in the digital, these roots certainly do not mean that it is unproductive. Bertran et al. (2019) suggested that "playfulness moves beyond, or extends, the magic circle of a pure game, instead weaving itself into everyday life and activity" (p. 1266). Playful interaction with purely digital worlds might have started by recreating simple game boards like *Tic-Tac-Toe*'s grid in *OXO* (1952), abstracted real-world spaces like a tennis court for *Tennis for Two* (1958), or fixed virtual worlds such as the maze of *Pac Man* (1980), but it has quickly outgrown such limitations. Today, players can participate in game worlds that allow them to turn into makers of items, media, game performances,

DOI: 10.4324/9781003328018-12

and even whole worlds. Play produces more than fun. Not surprisingly, game studies as a research field has looked at play as craft (Brock & Fraser, 2018) and taxonomies of crafting in games (Grow et al., 2017). Pearce (2006) suggested a form of *productive play* or "[a] dynamic, two-way medium in which the 'audience' has just as much power to create content as the 'producer' [...] More important, productive play also challenges traditional capitalistic notions of 'productivity' versus 'leisure'" (p. 19). Yee's (2006) exploration of *the labour of fun* asserts "the staggering amount of work that's being done in these games is often gone unnoticed" (p. 68). Furthermore, player production facilitates "the blurring of work and play", as de Peuter and Young (2019) outlined, and is "a lucrative source of game industry productivity" (p. 3). Play and the productive labour of creating the game world become intertwined as players make content and game components during their game interactions.

This kind of productive play depends on embodied engagement in public arcades or private living rooms, constructing new social fabrics, new digital objects, and novel forms of expression. Games, much like other media and practices, bring forth cultural constructions. This play as exploration of social human action might appear "toylike" (Gee, 2008, p. 261), and the discussions often emphasize the purely digital domain, like visual representation, sounds, network features, or computational advances. However, it is also productive in the way it generates digital manifestations, which can claim their own cultural space that reaches from game artefacts to new digital ecologies. Within this production, we focus on the play engagement through specific interactive access. Games only operate when played and the play depends on players' muscular and mental engagement. It involves mind and hand in a practice of cultural production framed by the game and its context. Not only does this define play and game experiences as embodied by design, like sport or dance, but it also highlights the challenges of the material encountering. The mind of a player seems to extend into the virtual game world and engage with its ingredients through mediation without direct contact. Although other media, such as film or literature, have already established such a projection, video games differ in their need to be acted upon. Code performs in relation to player participation and the text emerges only in a constructive collaboration of such shared agency (Murray, 2012). This first section builds on the effects that such agency and enactment have and draws parallels to traditional crafting approaches to connect play and making.

A growing understanding in cognitive sciences suggests that we extend our cognition through our actions into the world and the objects we encounter. There are different arguments within the idea of extended cognition. Distributed cognition looks for a kind of extension of humans' cognition outwards into other systems such as social set ups or objects (Hutchins, 1995). Emphasizing the role of materials even more, material engagement theory (MET) (Malafouris, 2013) argues for an extension of the human mind into objects and acknowledges the inherent agencies of these materials and objects. According to MET, we think with and through things as these things actively contribute to the exchange. Thinking, in this approach, includes the tactile encounter with the materials at hand and the material feedback from the thing. Malafouris and Koukouti (2022) suggested the term *thinging* to describe an active and productive conversation between multiple partners. A woodworker is thinging in direct conversation with wood, with the way its surface feels, its grain resist, and its colour changes. This direct encounter is typical for craft, and we can trace parallels to craft research and concepts such as Adamson's (2007) *Thinking through Craft* or Richards' (1966) focus on a potter's centring of the clay as "more-than-physical processes" (p. 33). How can a video game support the kind of thinging that MET calls for? There is very little tactile encounter with the material qualities of wood in the moment a player approaches a tree in *Minecraft*. In *Minecraft*, wood cannot speak back.

To build this first connection, it helps to realize that the connection between traditional handicraft and digital production has been argued for multiple material practices, such as working with textiles (Nimkulrat, 2020), sculpting (Masterton, 2007), or architecture (Mulder, 2022). As production techniques adjust to the impact of the digital revolution, practitioners adjust their techniques. Crafters have started to integrate modern fabrication tools and digital control mechanisms into their practices. Today, using a CNC mill is not uncommon in woodworking, decals for ceramics can be produced on inkjet printers, and embroidering machines can be programmed. More broadly, McCullough (1998) discussed digital making, like operating a computer-aided design (CAD) programme, alongside more traditional craft practice. The digital interaction remains an embodied act, "hands are performing a sophisticated and unprecedented set of actions. These motions are quick, small, and repetitive, as in much traditional handwork, but somehow they differ" (p. 19). The activities during a CAD session might differ but remain an embodied performative practice. McCullough invited us to focus on the concept of "workable construction" and to think about the making of digital projects as a form of craft. The digital and its focus on play is not a barrier for such productivity. In fact, McCullough emphasized that "it is a distinct advantage of computation to introduce play; this is a natural consequence of working in bits" (p. 221) and this play is empowering and positioning the digital maker. "With today's technology, we can acknowledge the role of the individual as someone more than a 'user'. We can suggest that the most important aspect about how to use a computer is how to *be* when using a computer" (p. 271).

Being with a computer is supported by control mechanisms – from keyboards to tablets to game controllers – and their mapping onto the virtual worlds. These worlds differ in video games when compared to CAD programmes. The virtual bodies of Pac Man (in the *Pac Man* game series) or Mario (in the *Super Mario* game series) or Aloy (in the *Horizon* game series) are cultural projections of women, Italian plumbers, pizza-objects, etc. They are operational entities with particular movement speeds, action abilities, and collision boundaries that function in a pre-designed game context. These facilities are part of the overall design of the virtual world. For example, Aloy's jump-height abilities in the *Horizon* games relate to the design of the fictional game world and her ability to climb virtual walls is defined by conditions within this virtual world. In *Horizon Forbidden West* (2022), the player can enter a visual mode that highlights markers of climbable walls. These virtual representations not only carry meaning as avatar figures reflecting particular social roles but also are part of the operational game-rule world and the player can see these relations. The encoded correlations between the world, props, and characters position the player in relation to the game environment. Wilhelmsson (2006) suggested the term *Game Ego*, defined as

> a bodily based function that enacts a point of being within the game environment through a tactile motor/kinesthetic link. As a player you incorporate an agent, a Game Ego function, within the game environment. This exertion of control is an extension of the player's own sensory motor system via a tactile motor/kinesthetic link, why it is not only the controlled and perceived motion on a screen but also the experience of locomotion within an environment that is the result of this control.
> (p. 67)

The locus of operation is a virtual character and a digital world. The specific forms of how players exert control differ based on a game's underlying design. Movements map differently, visualization of the world varies, and rules differ widely across games and game genres. Despite what the individual game design conditions might be, accessing a virtual character through an interface always affects the player in return – it creates a linked Game Ego. Through this work, players can evolve into masters of interfaces and game worlds. One extreme example for these conditions of play is eSports. In eSports, highly qualified video game players compete against each other, mirroring traditional sporting competitions. Part of their qualifications are specific motor skills concerning how fast and precise they react to situations in the virtual world (Hilvoorde & Pot, 2016) and how they can improvise successful solutions on the fly within the game world and in relation to the actions affected by other players. This helps to clarify that embodied play through the controller can be learnt and that it generates new outcomes based on the acquired skills. This might be most obvious among eSports professionals, but it applies to all gamers. The interaction is embodied, and differences can be measured in skill and performance. Proposed by Dourish (2001), *Embodied interaction* is an area within human-computer interaction that combines social and tangible interaction and is expanded into other domains such as virtual environments and virtual reality (VR). Embodiment "denotes a form of participative status. Embodiment is about the fact that things are embedded in the world, and the ways in which their reality depends on being embedded" (p. 18). For virtual environments and VR, their "world of interaction is the world of the computer" (p. 38).

We connect gameplay to embodied practices and craft. First, it establishes that playing a video game requires a form of embodied participation in these worlds by the players, who produce contextual actions within these game environments through gameplay. These interactions are skill-based and can be learnt as they emerge in relation to varying game encounters. Expanding on these activities, we argue that the results of these play actions can be productive within game worlds and offer their own form of embodied making through interfaces. Building on this first step, the next section will draw connections between craft and game design through embodiment.

Game makers and crafters

Above we draw connections from playing to making within designed game worlds – here we will approach the making of these game worlds as a crafting exercise. Game development has already been described as a form of crafting (Westecott, 2013) with game making as producing "a cultural artefact through mediated, embodied, and material means" (Keogh, 2022, p. 375). The interface remains a central component in this construction. Notably, the designers of the virtual worlds co-shape the design of the material controllers, which have proven central for the embodied play of the player. The development of the Nintendo 64 system coincided with the design of a key game for that console: *Mario 64* (1996). The design of the game and the patent for the physical controller for the console are co-authored by legendary game designer Shigeru Miyamoto.

> The first time Miyamoto played with the controller, because he's working most of the time on Mario 64, he would have seen Mario 64 with it. It wasn't so much that controller dictated Mario 64, it was just that was the game he was working on, Mario, was the way of testing it out.
>
> (Nintendo coder Giles Goddard as cited in Green, 2010)

Game design itself turns beyond the technical manifestations into an embodied practice for Miyamoto and this extends beyond the interface technicalities. Miyamoto was trained as an industrial designer, not as a programmer and his practices focused on elements such as character and world design.

> When a game was nearly completed, he spread out its blueprints across a room full of tables that had been pushed together. The blueprint was the map of a game's pathways, corridors, rooms, secret worlds, trapdoors and myriad surprises. Miyamoto lived with it for days, travelling through the game in his mind.
>
> (Sheff, 1993, p. 92)

His encounter with the game world, data, and design decisions was not limited to digitally mediated computer graphics but also unfolded in a lived experience within the physical space. Game design is not only designing "for" embodiment but also embodied practice in itself. Indeed, the world of the designer is re-structured to support game design as an embodied practice.

Gaming literacy – not only of the player but also of the designer – is enhanced through such practices. Combining game design, play, and learning in its overall concept, *Gamestar Mechanic* aims to teach game design within a STEM curriculum through its functionality as an online game. It situates "the making of games within a larger game world, where the making and modding of games is not only the primary play mechanic or mode of interaction, but also the means by which game design thinking and practice are modelled and performed", said Salen (2007, pp. 303–304) who is its lead designer. This is achieved by creating a game world where players alter objects to learn the basics of game design. Game design is taught as a virtually embodied practice within this world. Such practice can support empathy through game design (Shultz Colby, 2022) and related approaches have been realized in commercial productions such as the *Little Big Planet* (2008) game series. In *Little Big Planet*, each player controls a virtual character that can decorate, alter, or even construct a completely new game world. The characters of *Little Big Planet* were envisioned by their designers as "not just residents of this wacky world, they also help to build it. They are natural architects" (Wired, 2008). Driven by the interaction from the player, they alter existent worlds or build entirely new ones. In this case, the game design pushes the player into the role of a designer through a craft-based making within the world. Notably, *Little Big Planet* also uses a craft-like aesthetic to immerse players into this operation.

The role of embodied design becomes even more pressing in the design of experiences using VR and motion-capturing technology. Robin Hunicke, the co-founder of the game developer *Funomena*, noted in Bye (2018) for her practice that

> there is a lot of things we do physically in terms of theater [sic], dance, play, even cocktail parties, you know, watching people interact with one another and the way that they move when someone interrupts a conversation or when they see someone that they want to talk to and they turn their body towards them. There is so much that we can learn from physical interactions in space that we can now put in our games because they're no longer just about touching the pads on some controller that's in your lap.

According to Hunicke, the goal in her projects "is to really understand how the physicality of the medium is impacting those aesthetic outcomes" (Bye, 2018). In this case, social and embodied actions inspire new game designs. Designing for embodied play is not only part of the historic practice and technical condition but also an aesthetic challenge for new designs in VR where enaction finds new importance.

Enaction builds on the concept that any sense of one's own body and embodiment is not a given but a constant negotiation with the environment (Stewart et al., 2010). If the environment is virtual, its virtuality does not stop this negotiation. The player of a VR game positions themselves in the virtual space, locating themselves in the time and space of that digital environment. The digital nature of this new environment does not stop the constant construction process that is enaction but changes the conditions. Designers and players learn to work with these changes and can form new habits and behaviours from them, which can lead to new interdependencies of media and cognitive processes (Fingerhut, 2021). Parisi (2021) built on Hansen's (2006) work to argue for a form of ecomedia of VR that creates a *body-in-code*, which emphasizes the entanglement of the human experience with the mediated world – particularly for VR (p. 20). For Hansen, one's experience "has *always* been conditioned by a technical dimension and has *always* occurred as a cofunctioning of embodiment with technics" (p. 9). The resulting body-in-code is "a body submitted to *and constituted by* an unavoidable and empowering technical deterritorialization—a body whose embodiment is realized, *and can only be realized*, in conjunction with technics" (p. 20). From this, Parisi (2021) argues for the "primacy of bodily activity over body perception" (p. 248). In this case, the activity enacted upon the virtual world trumps the limitations of the body perception and the technical challenges of VR. Some of these limitations are by design – like varied depth perception or spatial cognitive thinking – others are technical conditions that gradually shift – like image resolution or tracking precision. Either way, game designers like Hunicke provide the means so that players actively work with them, "cofunctioning" through them via their play activity.

A different relation to a craft-based game development approach is found in Juul's (2019) discussion of the independent game developer scene. Juul connected independent game makers' practices to craft in terms of design, visual style, content, and criteria. In particular, he associated Morris' (1888/2010) call for "authenticity" of the handicrafts to the claim of many independent game developers, that their works "embody values of authenticity, honesty, and personality" (p. 35). In the 1880s, Morris mourned a loss of individuality through industrial production and advocated for a "life of handicraft" (p. 148) that aligned with his socialist values. One of his key critiques regarded the division of labour in industrial production that hampered an authentic craftsmanship. The disappearance of handicraft, for Morris, directly leads to a "degradation of life" (p. 151). Juul's (2019) argument projects the ethical stance of this historic craft revival onto the position of independent game makers today. They are able to sidestep the commercial shackles of large production houses and instead push niche and personal preferences in their games. Large-scale production studios depend on huge commercial successes of their games, while independents rely on much smaller teams and budgets and can produce for smaller audiences. This allows them to emphasize values that might speak to those communities and this freedom allows them to realize non-conforming stories, worlds, characters, and designs. A trademark of indie games are small teams and a Do-It-Yourself (DIY) attitude that counters the big teams of large game industry studios and bears resemblance to the small workshops or individual workspaces of crafters. This community of "indie game development involves a broader spectrum of skills that is considered similar to DIY making but focuses on creativity and experiential qualities even more" (Freeman et al., 2020, p. 4:5). The experience of production for these makers and small teams is not yet fragmented by an optimized division of labour, where design, art, marketing, and technology are left to designated specialists within each team. Instead,

> we all have to be highly flexible and wear multiple hats. We may have a team leader but he/she is also your co-worker. We may all be team leaders because we equally contribute. Today you may be the level designer and tomorrow you may be the AI engineer. Due to the lack of specialized producers, in order to support proper communication we all have to learn things beyond what's our nominal job.
>
> (Indie game developer quoted in Freeman et al., 2020, p. 4:14)

This section emphasizes three connections between game design and craft practices. First, the embodied nature of the interface design enables designers to shape the ways players engage with the game. In this case, not only do game designers provide the tools for embodied engagement with a virtual world to stimulate productive play, but they also either co-construct the interfaces or experience their virtual worlds through them as designers. This becomes even more prevalent in VR titles that draw on and include social embodied practices. Second, Juul (2019) recognized that indie developers follow an arts and crafts movement–inspired "authentic" ethos as an alternative to industrial-commercial game development. In this case, the ideals of past craft revivals, such as Morris' (1888/2010), call for social responsibility, honest individual work, and beauty, are adapted by game makers countering the hyper-capitalized world of commercial game producers. Third, the actual process of game making in small teams requires a pre-industrial sharing of labour due to the lack of specialized sub teams. In this case, game making requires each creative to manoeuvre between different tasks and learn new means of production and collaboration. All three parallels – embodied interfaces, values, and practices – connect game development to embodied craft through technology, ethics, and process, as seen in examples of hybrid games combining physical making with digital designs portrayed in the next section.

Hybrid makers and hybrid games

The third connection bridges games and hybrid maker practices. Hybrid craft reconnects digital and physical materials within making practices through the "merging of digital technologies with traditional ones" (Zoran & Buechley, 2010, p. 285). Hybrid practices extend embodied experiences through digital technologies such as personal fabrication. Tools and interfaces occupy the intersection between the maker and materials and they facilitate these experiences. The nature of these tools can be criticized as distancing and lacking fine-tuned haptic probing, but while they can separate the human body and the material-at-hand, they can also extend and connect the encounter. Ingold (2009) describes the textility of making as a process through which "the forms of things arise within fields of force and flows of material" (p. 91). Makers, then "bind their own pathways or lines of becoming into the texture of material flows comprising the lifeworld" to explore them as "wayfarers" (pp. 91–92). The texture of the world is both technical and "textilic", using Ingold's description of the distinctions made between technology and craft. This binding relates to Malafouris and Koukouti's (2022) thinging – both are explorative and constitutive through the material encounter. Hybrid makers engage and "bind" material flows that are both digital and non-digital. Cole and Perner-Wilson (2019) described an approach to hybrid making that considers electronics in terms of materials and offer an opening for overlapping computational and digital technologies. This includes a "getting lost with the materials" in Perner-Wilson's e-textile practice, in which hierarchies collapse through her explorative and "wandering" process of making – for digital as much as non-digital components (p. 110). Not unlike the discussion on game interfaces, part of this wandering depends on tools and the design of control mechanisms.

Much like the interfaces that define and embody play practice, hybrid craft practices have a range of tools, such as 3D printers, laser cutters, and CNC milling machines. But to support a closer material encounter and specific practices, practitioners often generate their own tools. These can utilize standardized machines – like Zoran's (2013) 3D printed frames supporting the construction of novel baskets through engrained complex weaving patterns within the frame. Others focus on easier integration of the computational side, like the LilyPad developed by Buechley (Buechley & Hill, 2010), which provided a microcontroller optimized for use in e-textiles. In a combination of established craft practices and novel technologies, Jørgensen (2015) worked with adjustable pin systems to shape glass and foam structures. Focusing more on the aforementioned "textility" of making, other tools can be hybrid in themselves. For example, Perner-Wilson's "Ohm-hook" allows crafters to check for the resistance of a conductive fabric while crocheting with that very same tool (Plusea, n.d.). Tools like this live in both digital and analogue worlds and shape the emerging communities of practice that use them (Posch & Fitzpatrick, 2021). They lay foundations for future embodied practices.

The emergence of tools for hybrid practices follows a craft-like evolution in which standardized machines and bespoke tools shape emerging practices. Game design can turn towards the same kind of hybridity of material and digital practices and integrate craft-based or hybrid activities into videogame gameplay using different approaches. Through such a design, crafting itself can become part of the gameplay and thus encourage an embodied experience, where the materiality of the craft practice is part of a hybrid game design. *Loominary* is a digital *Twine*-based game in which players explore an interactive story by operating a small loom and gradually weaving a piece of cloth as they play the game (Sullivan et al., 2018). The loom is a custom-built controller, not unlike Perner-Wilson's Ohm Hook; it detects colour choices of the threads used in the weaving, which map on gameplay decisions.

> To make a choice in the game, the player weaves a row in the artifact with yarn the same color as the choice they want to make. In this way, the player's choices are literally woven into a physical record of their play session.
>
> (p. 444)

Weaving is the gameplay, and the outcome is a digital play experience on a screen as much as a gradually emerging fabric. The digital mechanics are text-based and deal with the story of the Greek Fates, themselves mystical weavers and spinners. Players make their choices in this interactive story through an embodied crafting mechanic that relates in theme and operation to the theme of the depicted interactive fiction.

Another hybrid design approach is to combine digital components with physical materials and emphasize their physical agency. *Primal Clay* combines a digital narrative game about world creation with Hydrostone, a fast-drying plaster often used for detailed model casting (Stricklin & Nitsche, 2020). *Primal Clay* players encounter prompts in the digital narrative that force them to act with the Hydrostone as they make their choices. Embodiment includes players having to stick their hands into the Hydrostone, move objects around in it, and interact with the computer as much as the physical components. As the game unfolds, the Hydrostone gradually hardens and eventually resists further manipulation, which ends the game session. In *Primal Clay*, the material itself is integrated into a hybrid game design, and the material agency of the Hydrostone unfolds as much as that of the player or the computer through the gameplay. The game design highlights the contributions of the material as it gradually hardens, forms final shapes, breaks, or interacts with other materials around it. Hybrid making and a textility of making that emphasizes the forces of the materials are integral parts of this game that stages Hydrostone as an active participant.

A third hybrid design approach focuses on the production of tangible results from digital play sessions through hybrid fabrication tools. The difference from the first two approaches is that the fabrication method might not include a direct encounter with the material (e.g., thread, Hydrostone). Instead, digital gameplay maps onto fabrication tools that then generate tactile objects integral to further playing the game. *Generation* is an experiemental game centring on the theme of evolution. It offers players a first physical game piece unto which players digitally construct subsequent pieces that need to assemble to an emergent interconnected form (Grasse & Melcer, 2020). Each piece is 3D printed as the play unfolds. Players can select upcoming pieces, but this selection is limited by the game interface and its rules. The goal is to generate increasingly complex structures that illustrate the effect of emergence in evolution. The complexity of the growing interconnected object-bodies mirrors the emerging variety in a game about evolution and growth. Players still construct a physical object but can do so only through a game-based digital design and the 3D printer as fabrication tool connecting the two.

All three approaches show different concepts for hybrid game designs that touch on craft and maker practices. While the examples presented here are all experimental games and lack a commercial launch, they still highlight the opportunities at hand. Some of these practices already spread into wider communities, including custom-built controllers for Twitch shows, 3D-printed figurines for hybrid role-playing games, or DIY-printed *Pokemon* cards. Through developments like these, the original notion of productive play gains a new dimension.

Conclusion

We have traced connections from the productive practices of video game players to the embodied and value-driven approaches of game makers and to the emergence of hybrid practices. The focus has been on ways that support embodied engagement specifically in play and design. The tools and interfaces play a central part in this engagement. For a video game player, the game interface is the access point for an embodied form of play in the digital world. Its mastery remains crucial for their identity as player within their communities. For game designers, the interface design can become part of their making practice. Their work includes structuring the productive engagement with their game world and this design work can be an embodied process itself. Hybrid makers and hybrid games stand in-between these positions. They highlight opportunities of conceptual overlap and dependencies. All three approaches remain centred on the body and its engagement with the materials at hand through tool-like mechanisms – whether they are physical, digital, or hybrid. The results are interwoven with other craft-based criteria. The player's engagement blends into facets of digital production, the designer's contributions deal with craft-informed ethos, and the emerging hybrid practices combine the material agencies with digital designs. With the parallels we outlined in this chapter, we do not want to equate the three main areas of gameplay, game design, and hybrid practices. Each of them still offers unique opportunities and constraints that should not be ignored. For example, the player still depends on the designs implemented by the game maker; game designers rely on their own tools, game engines, and associated practices; and many hybrid makers build on standardized fabrication mechanisms. However, each of them performs embodied practices to position themselves as player/game maker/hybrid. Whether this is a game designer stepping through the game world they create, a player mastering an interface to perfection, or a hybrid maker melding digital and physical practices, what turns them into the designated player/designer/maker is a productive embodied practice that relies on a performative construction. Exploring these kinds of embodied practices brings design closer to material making and invites us to reconsider our approaches to the tools and interfaces that facilitate this production/performance. This encourages designs that might require that productive tools be designed for more playful engagement. Reconnecting digital design spaces, e.g., video games play and fabrication design, to material-based lineages, e.g., craft, has the potential to re-centre the body and re-form how we consider game design, game play, and the interweaving interaction design between them.

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8 *Hand Thought*

Hybrid practices and a digital craft ethos

Justin Marshall

Introduction

The integration of digital tools into craft practices is now well-established within the UK and beyond, with over 30 years of research and practice in the field (e.g., Harris, 2012; Johnson, 2017; Nitsche, 2014; Shillito, 2013). The work described in this chapter continues my and other designer's and craftspeople's interest in investigating the aesthetic opportunities offered by computer numerically controlled (CNC) production technologies and associated software, e.g., metalworker (Masterton, 2007), ceramic and glass designer (Jørgensen, 2013), woodworker (Neal, n.d.), and product designer (Grimshaw, 2017). Much of my practice-based research, including this ongoing project, has been underpinned by a consideration of not just the role but also the significance and implications of integrating digital technologies into craft practice (Marshall, 1999; McCullough, 1996; Zoran, 2015).

In still one of the few extended works in this field, McCullough (1996) argued for computers to be regarded as a medium, rather than a tool, and as such believed that the most important question is not "how to use a computer" but "how to *be* when using a computer" (p. 271). He recognized that using digital technologies is not merely a matter of instrumental application, but one of experience, i.e., it has an impact not just on what we do, but what we think. While McCullough was writing at the time when the use of computers, especially those for digital production technologies within craft practices, was still relatively rare, Zoran's curation of *Hybrid Craft: Showcase of Physical and Digital Integration of Design and Craft Skills* (2015) came at a point when a broad constituency of practitioners had experimented with digital making technologies. Zoran is not the only, or first, researcher to use the term *hybrid craft*. For example, Buechley and Perner-Wilson (2012) emphasized aspects of digital interactivity in their definition of hybrid craft. However, for the purposes of this chapter, Zoran's (2015) broad definition of hybrid craft as a practice in which digital and analogue tools and processes are integrated into a single practice is most appropriate.

In this chapter, I reflect on such a hybrid crafting project through my practitioner-researcher's lens. Through discussing the making of a series of wooden tableware and associated drawings, that used both traditional carving tools and CNC technologies in their creation, issues related to the ways in which makers frame their expectations of engaging with digital tools are illuminated.

I would emphasize that neither the digital craftworks described later in this chapter are intended to be recognized as an illustration of a theortical propostion, nor the making process as a form of theory testing. At its foundation, this chapter is built on a "thinking

DOI: 10.4324/9781003328018-13

through doing" approach (Schön, 1983), which, I would argue, aligns with a craft practitioner's experience of a creative practice and relates to the concepts at the heart of embodied cognition theory, i.e., that thinking and doing, the mental and physical, and mind and body are inextricably linked (Newen et al., 2018). Through this exploratory making process, inspired in part by Wallace's (2014) "Unpicking of the Digital", I propose a digital craft ethos which aspires to: (a) fidelity *not* accuracy; (b) sensitive making *not* efficient manufacturing; (c) affective *not* effective technologies; (d) uniqueness *not* infinite replicability; (e) augmenting existing practices *not* replacing established ways of working; and (f) continual "hands-on" interaction with tools *not* full automation. This ethos seeks to encapsulate a situated and embodied pragmatic characterization of technology, which can be aligned with craft-oriented methods and mindset, as distinct from an instrumental characterization of technology, which I associate with industrial design/engineering practices and thinking.

I recognize that the distinctions that I propose have some parallels with those that have been rehearsed previously within design theory, e.g., Dorst and Dijkhuis (1995) who differentiated the philosophical traditions of constructionism/phenomenology from those of positivism in the development of design methods. However, in aligning a set of attitudes and approaches to craft, rather than to a particular mode of design practice, I am seeking to (re)assert the value and significance of craft as both a practice and lens that can be brought to the world.

Before describing the pragmatic and instrumental characterizations of technology and to ground the references made to craft theory later in the chapter, I will briefly describe some of the ways in which key writers in the field have discussed and defined craft that are relevant to my argument.

Characterizations of craft

As recognized by Pye (1968), craft has been notoriously difficult to define and the quest to do so can often complicate and obfuscate, rather than clarify. Pye therefore promoted *workmanship* as a more precise term (p. 7), and one that is more useful as the foundation for reflecting on the broad practice of making things. He split making into two categories: *workmanship of risk* and *workmanship of certainty*. He aligned workmanship of risk with craft and defined it as

> using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgement, dexterity and care which the maker exercises as he [*sic*] works. The essential idea is that the quality of the work is continually at risk during the process of making.
>
> (p. 7)

Pye then associated workmanship of certainty with industrial production and automation, defining it as a process of production in which "the quality of the work is exactly predetermined before a single saleable thing is made" (p. 7) and as such the results are entirely predetermined and risk is minimized. I will return to this distinction when I draw parallels between analogue and digital making in the Hybrid Making section.

The notion of care as a core aspect of craft is taken up by Sennett (2008), who as a sociologist wrote about craft as a mode of practice that can be found across all fields of endeavour, rather than craft as an economic or materially specific sector. He argued that craft embodies a basic human instinct and desire "to do a job well for its own sake" (p. 9), i.e., to be a care(full). In addition, he maintained that in craft "thinking and feeling are contained within the process of making" (p. 7). He opposed the tradition where thinking and acting have a distinct and hierarchical relationship (e.g., Arendt, 1958) and asserted that "for craftsmen labour is not simply a means to an end" (Sennett, 2008, p. 20). The means-ends relationship and its implications for how we conceptualize the role of tools within a making practice will be extended in the section on the pragmatic characterization of technology.

In his book *Making* (2013), Ingold drew a distinction between the Aristotelian concept of hylomorphism and the biological concept of morphogenesis when discussing how things are made. He described hylomorphism as a scenario in which "practitioners impose forms internal to the mind upon a material world 'out there'" (p. 21). Parallels between this conceptualization and the design engineering mindset with its instrumentalized view of technology will become apparent in the next section. In addition, a critique of the separation between internal cognition and external physical action will be developed further in the section on embodied cognition and the extended mind.

Ingold argued for making to be considered a morphogenetic process, more akin to growth than manufacture. Making is a process in which materials are active rather than passive and the maker "joins forces with them" (p. 21) rather than seeking ultimate control and dominance. Ingold's work utilized craft practices to explore and extend his argument recognizing the intimate and reflexive relationship that craft practitioners have with materials they use, and the active, evolutionary, and situated nature of the way they work within (rather than with) the world. I will discuss these active material relationships in the Hybrid Making section when reflecting on the negotiation between digital and analogue spaces.

Narratives of technology

The instrumental characterization of technology

Instrumentalism considers technologies in terms of functional means to predetermined ends, a way of achieving a particular task. Tools, digital or otherwise, are aligned to objective measures of speed, efficiency, productivity, accuracy, and interactions that are procedural, effective, and deterministically repeatable. Anecdotally, I have often heard this view encapsulated in ethically neutral aphorisms such as "they are just tools", "they just help get the job done", and "it's all about efficiency".

This framing has a simple and powerful logic that neatly sidesteps the need to fully recognize the complexity of real-world situations in which distinguishing and isolating causes (means) and effects (ends) are often difficult, or even impossible. It is a characterization of technology that sits broadly within the positivistic scientific tradition and aligns with the aspirations of modernity manifested through an industrial production model that has dominated western culture for more than two centuries (Susskind, 2020). However, it would be disingenuous to argue that this way of framing the role, application, and value of technology has not been hugely successful and economically beneficial to many individuals, communities, and societies. Although it could be, and has been, argued that this has been at the expense of other populations, environments, and ecosystems (e.g., Escobar, 2018). The distinct role of design was born out of the industrial revolution and the division of labour into specific tasks and job specialization that is at the core of the mass manufacturing model. It is therefore unsurprising that industrial designers tend to bring an instrumental understanding to the use of digital tools, as this mindset is in many ways caught up in their very definition.

The pragmatic characterization of technology

In contrast, pragmatism provides a theoretical framework situated in human experience. It provides an alternative characterization of technology that recognizes, and seeks to understand, the wider implications and significance of technologies in practice (Hickman, 1990). Drawing on the pragmatic philosophy of Dewey (1916), McCarthy and Wright (2007) argued that we do not just use technology but also live with and experience it; it has emotional impact and significance in our lives. As such, technologies are affective not just effective. Their work explores the felt experience of, and through, technologies. From a pragmatic perspective, knowing, doing, feeling, and making sense are inseparable. "Dewey's perspective on human action—the key to understanding felt experience—is that action is situated and creative. There can be no separation of means and ends" (McCarthy & Wright, 2007, p. 17). Furthermore, Scheffler (1974) emphasized that: "means are not merely neutral ingredients of a plan; they have inherent values and disvalues. … The choice of means, in short, enters into and qualifies the nature of the end" (pp. 230–231).

More specifically in relation to the production of design, art, or craft work, Hickman (1990), suggested that

> in the production of every successful artefact, which is to say in every stage of a successful inquiry, means and ends so interpenetrate that they can be sorted out only in retrospect. Every process of free art proves that the difference between means and ends is analytic, formal, not material and chronological.
>
> (p. 73)

Paralleling Sennett's (2008) position on the means-ends relationship, this revaluation challenges the neutral instrumental perspective and creates space to think more broadly about the implications of taking a particular course of action with technology.

Technology as practice

Taking the pragmatic recognition that technologies are situated and value-laden one step further, Franklin (1999) argued that we should consider technology to be a "practice" not just devices, machines, and processes. This means that cultural and social arrangements are core to her considerations of technology. She asserted that the instrumental lens of deeming technologies to be equipment or devices only would encourage us to focus myopically on the "close" impact of their use, instead of seeing further and farther at the bigger socio/political consequences, ethical implications, or the wider impact on the structuring of work. As such, she argued for technologies to be thought about in terms of "principals" (i.e., an ethos) as well as processes. Making explicit connection to craft practices, Franklin framed her discussion around notions of *holistic practices* which are characterized by individuals having control over the whole process and the nature of outcome (p. 10), contrasting this with *prescriptive practices* which are characterized by splitting creation of artefacts/products into a series of processes (p. 12). However, she argued that prescriptive practices were amplified by industrialization and mechanization, rather than being founded within it, and that examples can be identified as far back as 1200 BC (p. 12).

The implication of Franklin's argument is that all machines should not simply be considered prescriptive technologies within themselves, but ways in which they are deployed and integrated into infrastructures of power and control (i.e., how they fit into technologies of "practice") that define their role and significance at both personal and societal levels.

Embodied cognition and the extended mind

Central to pragmatic theory is action, and the derivation of pragmatism, like practice and practical, is "pragma", the Greek word for action. We come to know through doing, through being in the world. Pragmatism positions action as inextricably linked, not as a subsidiary activity, to thinking. This broad position can be aligned with the theories of embodied cognition (Newen et al., 2018). For example, Malafouris' (2013) work challenges the computational view of mind as an internal representational engine and argues for a model of cognition that is embodied and rooted in the inseparability of thought, action, and the material world. Providing a broad definition, he stated:

> The general idea of the embodied mind is quite simple: The body is not, as is conventionally held, a passive external container of the human mind; it is an integral component of the way we think. In other words, the mind does not inhabit the body; rather, the body inhabits the mind.
>
> (p. 60)

It is clear to see why this theory has found such resonance within the craft community. Its focus on the physical body and its interaction with the material world as the site of cognition articulates the experience of makers whose practices are defined by an intimate engagement with materials and the tacit understandings gained in thinking through doing (Schön, 1983) and working things out in the situation (Coyne, 1995). Luscombe (2018) argued, "tools and techniques can be understood not only in terms of their capacity for achieving goals, but also according to the ways in which they inform processes of design" (p. 5), i.e., tools and techniques affect the way we think.

Clark and Chalmers (1998) took this theory a step further and proposed their concept of *extended mind*, which argues for a recognition of a complex entanglement between brain, body, and the external world (including tools). As such, tools cannot be regarded simply as neutral instrumental aids to achieving pre-defined goals. As Luscombe (2018) suggested in the discussion of the role of tools in design:

> The theory of extended mind promotes the idea that actions are performed not just to advance toward a goal, but also to help work things out. Rather than seeing tool use as a means by which to transcribe predetermined forms onto paper, screens, or three-dimensional materials, an extended approach to cognition recognizes that there are occasions when tools are used to find out what these forms should be.
>
> (p. 10)

This recognition that actions are not always procedural, and that goals are not always predefined and are rigidly fixed, can be related back to the pragmatic assertion that means and ends are active and inseparable in what Dewey (1939) phrased "the continuum of ends-means" (pp. 40–47). This is not to argue that any inquiry (or form of creative practice) is without intentions or plans, but that these were articulated by Dewey as "ends-in-view", rather than fixed goals. "Ends-in-view are dynamic and active throughout the process of an inquiry. They are never remote, but imminent through every stage in a process" (Hickman, 1990, p. 73). Therefore, "ends-in-view" are continually under review, in a reflexive relationship with the processes employed (i.e., the means). I would argue that this also maps onto a craft-oriented way of thinking about tool use. Craft practitioners recognize the role and significance of tools and processes within their creative practice, not as a means of making manifest fixed predefined aspirations (i.e., fixed ends), but as means of exploration, discovery, and articulation. Tools extend the mind, not just facilitate its intentions (Baber, 2015).

The understandings from this and the previous sections on how technologies can be characterized will be drawn on in the next section, which will describe the creation of a series of hybrid craft works that have been pivotal in the development of my digital craft ethos. The section will describe and reflect on the development process and how aspects relate to, and make manifest, distinctions between a craft-oriented approach and an industrial design one when engaging with digital tools.

Hybrid making: the *Interference-Integration* series

Started in 2018, the *Hand Thought* project is an ongoing exploration into combining digital and analogue tools and techniques. Within this timeframe, I have developed a range of prescribed ways of using the digital toolset, strategies, and approaches that seek to disrupt expectations. The *Interference-Integration* series that sits within the wider *Hand Thought* project, and is described here, is the most recent collection of work. This set of wooden pieces, and associated digitally augmented hand-painted watercolours, combines established handcrafting techniques (i.e., hand carving and painting) with digital production processes (i.e., CNC milling and digital plotting) to create hybrid analogue/digital artefacts.

In order to develop ambiguous visual and surface characteristics that combine and contrast analogue and digital aesthetics, I sought to create a conversation between hand carving and CNC milling in the 3D works and between hand painting and digital plotting in the 2D ones. And so, through this activity, the works begin to articulate an aesthetic language that is recognized as neither quite handmade nor machine manufactured.

The creation of the hybrid 3D work started, not with a virtual computer-aided design (CAD) model as might be assumed within a digital making project, but by sourcing green (unseasoned) wood and using traditional techniques and tools (i.e., axe, adze, spoke shave, and chisel) to carve bowl and platter forms. The hand-carved forms were then scanned using a white light scanner to produce highly detailed digital models that captured not only the form, but also the cut marks and other surface texture of the bowls, which are the characteristics and the traces of the analogue process and natural materials used (Figure 8.1).

The scan data was only used to create partial surface models of the physical forms. There was no need to address the challenge of creating accurate and cohesive full 3D models of the bowls. To create toolpaths that fit to the bowls' surfaces, partial surface

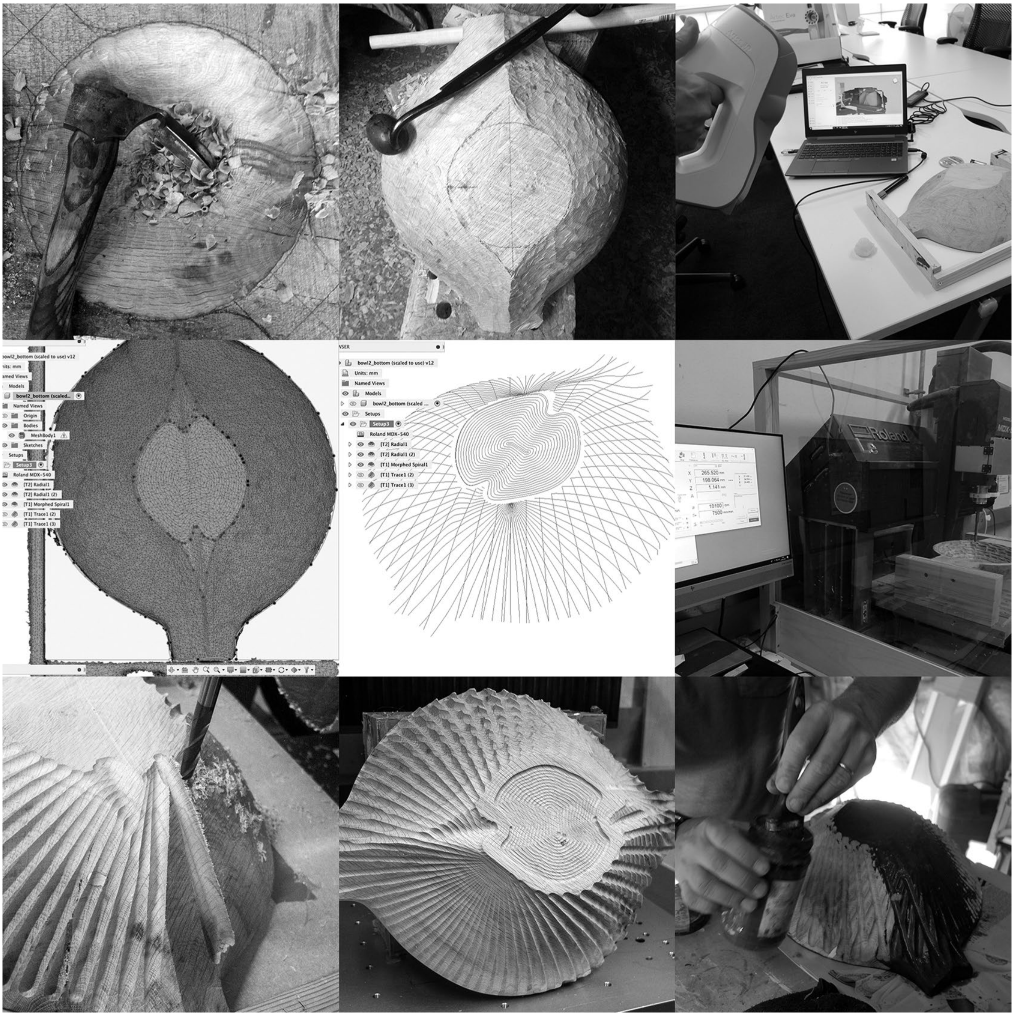

Figure 8.1 The process of development for hybrid work. Traditional green wood tools and techniques are used to carve a bowl. The bowl is then scanned to produce a digital model onto which toolpaths are mapped in preparation for CNC milling. Photographs by the author.

models of the topside or underside were required. This strategy exemplifies the distinction between an industrial design mindset and a craft-oriented approach. An industrial designer aspires to a direct correlation between the virtual CAD model and the physical world, and hence they would strive to produce a perfect full scan of an artefact. In contrast, a more pragmatic digital craft approach is to identify strategies to achieve a particular task, with no aspiration or need to produce a complete correlation between the digital and physical.

Working in computer-aided design and computer-aided manufacturing (CAD/CAM) software, a variety of cutting regimes were explored to create toolpaths that produced complex surface patterns and textures and that mapped onto the scanned bowls' surfaces.

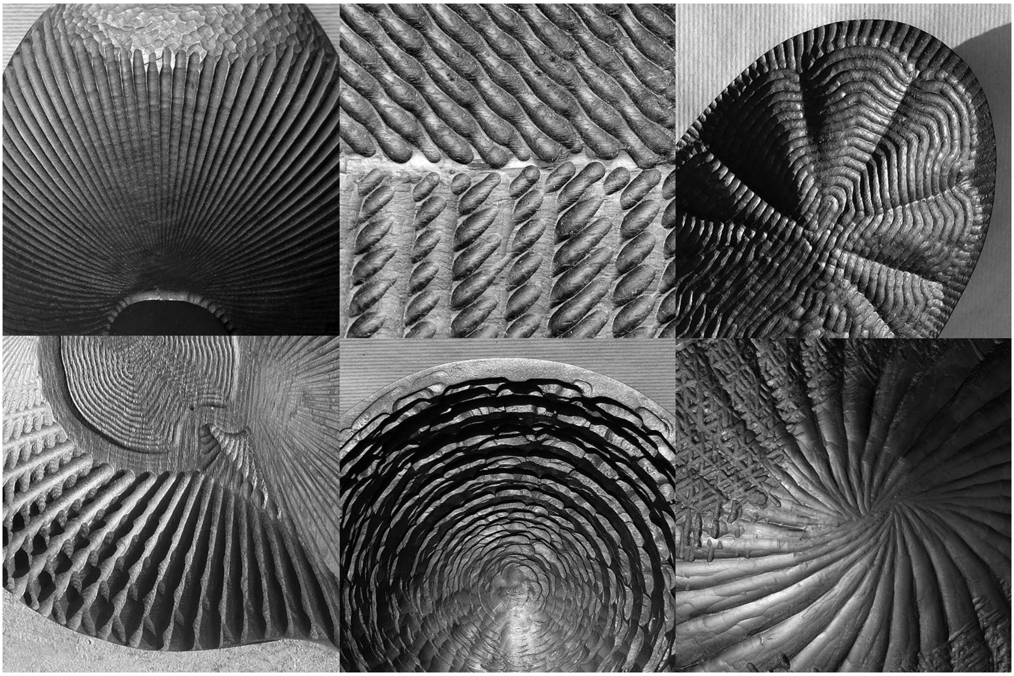

Figure 8.2 A selection of hybrid digital/analogue surfaces and textures from across the *Interference-Integration* series. Photographs by the author.

Hence, when the position of a physical form was aligned with a virtual model, patterns could then be milled onto the surface of a bowl. The patterns did not eradicate the hand-carved surface but followed and overlaid it. Thus, the physical characteristics created using hand tools were retained, while deploying and celebrating the possibilities that the digital processes afforded (Figure 8.2). This process was consciously distinct from industrial design engineering approaches that seek to reproduce a digital design as accurately as possible in physical form.

Furthermore, this approach explicitly aimed to subvert the software's mission to create optimum toolpaths to reproduce CAD models efficiently and accurately. A range of techniques were used to achieve this, including deceiving the software by mismatching software settings with the actual tool shape and sizes used. In addition, tool "step over" settings (i.e., the amount a tool moves across once one pass of cutting has been completed) were used. Such settings emphasized, rather than concealed, the way in which the tool moved over the surface of the forms (Figures 8.2 and 8.3). Making the means of production visible rather than invisible is another distinction I would highlight between craft production and industrial manufacture. In this way, the strategies developed sought to produce physical artefacts that integrate the analogue and the digital, and so be truly hybrid in nature.

To reflect on the way in which this hybrid process aligned (and misaligned) with established understandings of a craft practice, while I recognized that the workmanship of risk (Pye, 1968) was still unquestionably present in the early stages of hand carving, it does not exclusively lie in this stage of the making process. The risks that were distinct and worthy of recognition in this hybrid method are situated in the practical and conceptual

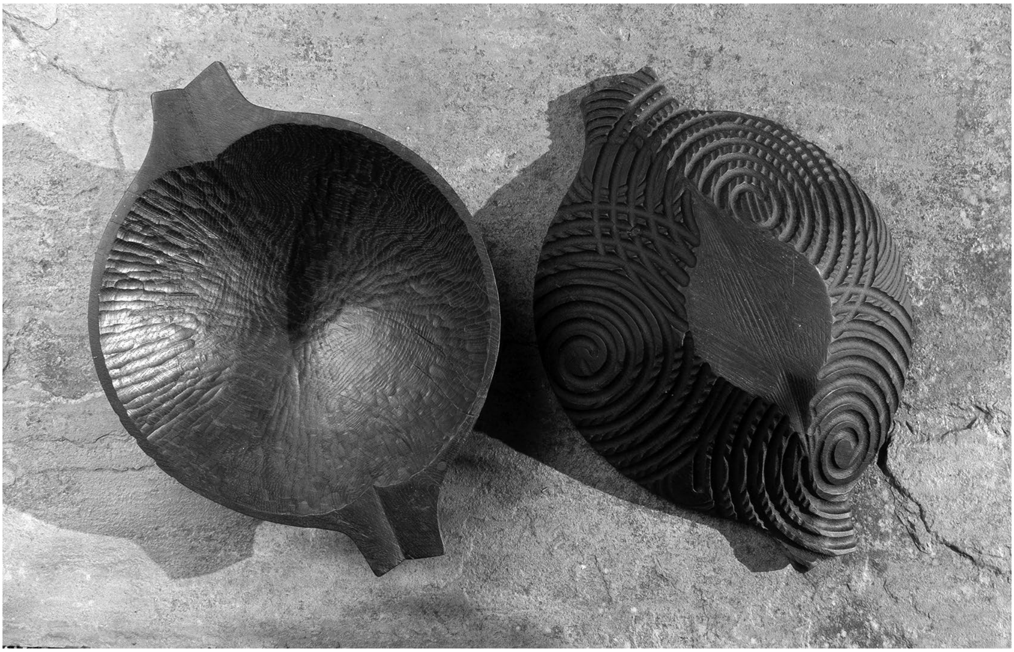

Figure 8.3 "Large hybrid spiral bowl", rust stained oak, 420 mm × 310 mm × 110 mm, 2021. Photograph by the author.

aligning of the digital with the analogue. At this boundary where the static digital world of ideal forms met the material variabilities of living wood, there was a negotiation in which aspirations of accuracy and the exact reproducibility of a digital form gave way to seeking fidelity and sensitive synthesis. So, although aspects of the digital were at play, there were no undos and no option to start over – risk was still present. Each piece was therefore a one-off, bringing together a particular piece of wood uniquely carved, with a toolpath that maps only onto that form, in a particular way, at a certain point in time. Assumptions of speed and efficiency in the use of digital tools were confounded by the strategies used here. It is not that there is always an accelerated pace to a craft practice that integrates digital technologies, but that the rapid and more time-consuming aspects that make up the composition of the whole design and production process are often re-orchestrated. Continual engagement and presence are also necessary in this re-orchestration in order to respond to outcomes as they unfold, not only as one would expect within the analogue carving and shaping processes, but also in the CNC milling processes. None of the pieces created in this series were completed with a single deployment of a set of predefined cutting toolpaths; they all required iteration, adjustment, tweaking, or even significant rethinking, in response to the particularities of the work as it evolved. This iterative, actively engaged process was contrasted with aspirations in industrial design engineering to create efficiencies of production through minimizing the need for human engagement beyond a divorced design phase and the setting the initial parameters of manufacture. The logical corollary of this industrial design engineering is full automation and the use of robotics coupled with artificial intelligence (AI, machine learning) to completely remove human input from manufacturing processes.

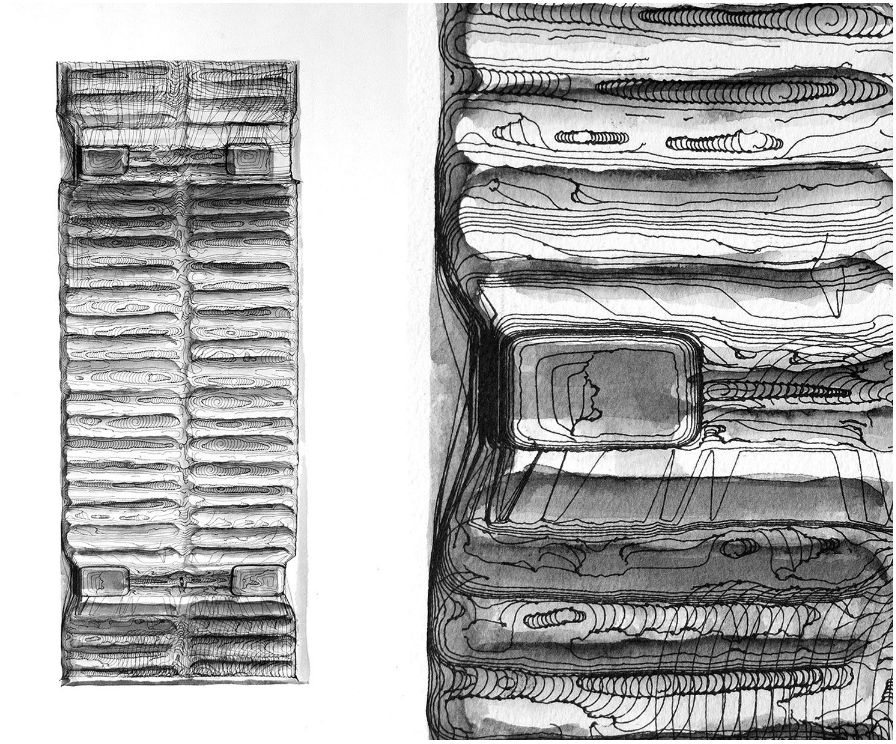

Figure 8.4 “Long platter hybrid drawing” (and detail), A1 watercolour and pen plot, 2021, demonstrating toolpath complexity and irregularity. Photographs by the author.

A hybrid drawing accompanied each of the wooden pieces produced. The starting point was the creation of traditional watercolour drawings which were then overdrawn using a digitally controlled plotter/cutter which was adapted to hold a variety of pen types and sizes. The digital aspect of the imagery was based on the toolpaths generated by the software to control the milling machine for each of the 3D pieces. The intention was not to create direct representations or illustrations of these toolpaths, but to explore the visual language that the software generated in its mission to compute complex cutting paths. In this way, I was interested in qualitative fidelity, not quantitative accuracy, and the interplay between digital complexity and the hand painted image (Figure 8.4).

In the following discussion, I will analyse these processes in the light of the previously presented theoretical orientations.

A pragmatic and embodied digital craft ethos

Earlier in this chapter I sought to highlight the differences between a craft and an industrial design-oriented mindset, relating them to two distinct theoretical frames that I call: *situated pragmatism* and *rational instrumentalism*. Building on this understanding, and as an attempt to offer a distinctly craft-oriented approach to using digital tools, I propose a digital craft ethos which has the following aspirations and characteristics:

- Fidelity *not* accuracy.
- Sensitive making *not* efficient manufacturing.
- Affective *not* effective technologies.
- Uniqueness *not* infinite replicability.
- Augmenting existing practices *not* replacing established ways of working.
- Continual "hands-on" interaction with tools *not* full automation.

I would emphasize that I am not claiming that the characteristics cited here are all original. Many will be recognized as present in existing discussions/debates concerning the values and aspirations for digital making. For example, within the Fablab and Maker movements (Anderson, 2012; Gershenfeld, 2005) that responded to a desire for people to make things for themselves and to create unique personally meaningful items using both digital and analogue tools. However, for all the value and benefits these movements have created, I would argue that they have limited interest or focus on critiquing the nature of how people engage with digital tools themselves. I would argue that digital craft has a slightly different set of concerns and aspirations, which I am seeking to pull together and articulate as this ethos.

In the following subsections I will explain what these digital craft characteristics infer, drawing both on the theory discussed earlier in the chapter and reflections on my practice.

Fidelity not accuracy

Pragmatism and theories of embodied cognition focus on our situatedness in the world. In seeking fidelity rather than accuracy, the digital craft ethos recognizes that there can be a disjuncture between the nature of a CAD design, defined through precise mathematical computation, and the variabilities and complexities of the material world. Instead of striving to rigidly impose the precision and accuracy that CAD provides on material outcomes, it is more inclined to seek outcomes that have the fidelity of a negotiation between the digital and physical realms. This concept was explored in the *Interference-Integration* series in which the precision of digitally generated toolpaths were mapped onto, rather than eradicating, the irregular hand carved surfaces.

Sensitive making not efficient manufacturing

As previously argued, an instrumental understanding of technology and the industrial model of production that instantiates can be aligned to a computational model of cognition, in which thinking and acting are separate, hierarchical, and distinct. In contrast, and as Groth (2017) acknowledged, embodied cognition theory and pragmatism understand thinking and acting as contiguous, and this can be recognized and is reflected in the holistic making practices of craft. Unlike the role of digital tools within an industrial model of production (driven by a competitive market economy) that is centred on efficiency facilitated through speed, accuracy, reliability, and consistency, digital craft often assuages efficiency and aspires to a sensitive making practice through prioritizing extended and nuanced engagement with materials and processes. Although the hybrid practice described in this chapter puts digital design and production technologies to work, in no way can this argue to increase efficiency or speed of production. When I described the lengthy sequence of hybrid processes involved in the creation of a bowl to a colleague who is a traditional woodcarver, she rather acerbically noted, “I could have finished five bowls in that time!”. In addition, there is no distinct and finalized design (thinking) stage, followed by a carrying out (doing) stage. Whether using a CNC mill or an adze, the maker has a continual dialogue with the material in the emergent process of bringing a piece of work to completion.

Affective not effective technologies

Pragmatism promotes the idea that there can be no simple separation of means and ends, and that knowing, doing, feeling, and making sense are inseparable. Therefore, engaging with tools and devices can be affective (i.e., a “felt” experience) rather than only instrumentally effective (i.e., just a passively more efficient way of getting something done). As Luscombe (2018) and Baber (2019) argued, and I recognized in the creation of my hybrid works, our engagement with tools impacts how we feel our way forward in a creative making process. Therefore, the making process is not one of simply inscribing fixed ideas into material form through appropriate technologies; making is an embodied process, where the tools we use mediate our experience of the world.

Uniqueness not infinite replicability

The aspiration to be able to infinitely reproduce a product to predefined standard is core to the mass production model, and the tenets of an instrumental framing of technology are key to achieving this. The notion that things are “worked out in the situation” (Coyne, 1995, p. 39) and that context is significant are key to pragmatic theory. Often attuned to place in terms of both material resources and culture (i.e., context), alongside making processes that promote variability, craft practices incline to create one-offs and/or works that are bespoke to people, place, or unique application, rather than standardization and infinite replicability. I would argue that the use of digital tools, especially within a hybrid practice, does not preclude this approach and provides opportunities to create variety and uniqueness through exploring opportunities within both hardware and software, and at the interface between the digital and the physical. The works presented here, alongside others in the wider *Hand Thought* project (see Marshall, 2021), provide examples of this. The interplay between the processes of hand carving (or painting) and the digital milling (or plotting) do not aspire to replicability, but inevitably lead to one-off works and begin to create a new hybrid aesthetic vocabulary.

Augment existing practices not replacing established ways of working

Both Dewey (1925) and Franklin (1999) recognized that ethics and human values are core in any consideration of technology development and application. Franklin argued for the development of appropriate technologies that benefit wider society, rather than just a few elites. One aspect of their ethical positioning is the belief that tools, instruments, and devices should extend and augment people’s existing skills and practices, instead of seeking to substitute or replace them and so devaluing human labour. This can be contrasted with the ethically neutral instrumental framing, which has a tendency towards a belief in the “technological imperative”, i.e., what can be developed, will be developed (Chandler, 1995).

Continual "hands-on" interaction with tools not full automation

Such a belief in the technological imperative has resulted in the rapid move towards the replacement of skills through full automation and minimizing the need for human engagement (or even presence) beyond a design phase that is divorced from making. The nature of hybrid digital/analogue practices that have helped define my digital craft ethos seeks to embody a commitment to continual interaction with the materials and tools of a situation, and the use of technologies to extend skills and capabilities. An efficient industrial design and production scenario is where a set of fixed instructions can be uploaded to a CNC machine and then left to run unmonitored and unfettered by possible human interference (and so possible error). In contrast, I am always present during the machining element of the making process, continually reviewing, amending, and assessing the work as it is developing, and so this experience has meaning and value for me beyond that of a machine attendant.

Conclusion

The *Hand Thought* project has provided a foundation for generating, and a sounding board for testing, new propositions and exploring technology at both a practical and conceptual level. To summarize my argument, I am proposing that the more rational and instrumental characterization of technology can be linked to the industrial model of production, where means and ends are separated, where there is a division of labour, a splitting of design and production – thinking from doing, the mental from the physical, mind from body – and so inevitably separating the cognitive from the corporeal. In contrast, the more pragmatic and embodied characterization of technology recognize the dynamic relationship between means and ends – the unity of designing and making, the integration of thinking and doing, the synthesis of mental with the physical – and so the inseparability of the cognitive and the corporeal. This characterization aligns with both key defining features of craft practice and the theory of embodied cognition. From this position, it can be recognized that the use of digital (and any other tools) is not a mere "carrying out", but intrinsic to our cognitive landscape, at personal and societal levels, as Franklin (1999) would maintain, and so the way we choose to organize work and labour. I would argue that this pragmatic characterization provides a framework that is distinct from the dominant industrial model and brings humanness into a consideration of people not only as consumers, but also as valued makers/producers.

To conclude on a utopian note, I would emphasize that thinking more carefully about technologies as both "practice" and "tools" could lead to different avenues of development and provide opportunities for richer, embodied, and pragmatically oriented relations with our future digital tools. To achieve this requires the mindset of the craftsperson carefully directing us along a path of sensitive, appropriate, and humane technology development, adoption, and use. One line of inquiry could be more and richer "hybrid practices" as alternative modes of production that are valued as much for their human-centred process (the making) as for the final outcomes (the products).

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9 Grasping materiality – digitalization in light of educational arts and crafts practice

Lovise Søyland

Introduction

Making involves handling material knowledge through bodily interaction and hands-on engagement. Embodied cognition (EC) theories have become important for understanding the essential role that materials and making has in the development and application of such knowledge. EC theories, often related to as the 4Es (embodied, embedded, extended, and enacted) (Newen et al., 2018), explain how our embodied minds are shaped by, and how we think through, interaction with our surroundings, meaning that our cognition is deeply entangled with the materiality of the world. These theories have implications for education as they show how children's explorative practices with their surroundings are central to their learning (Kiefer & Trumpp, 2012).

As the digital realm has become part of the materiality of the world (Pink et al., 2016), the educational context too is rapidly facing a change in materiality. The rapid growth of digital technologies is prevalent in Norwegian early childhood education, as can be seen in the recent introduction of handheld touch devices with software programs to children's learning environments since 2011 (Letnes et al., 2016, p. 6). Creative learning activities which have previously been materially engaging experiences, such as drawing, are partially replaced with activities on digitally enabled surfaces, such as tablets. The change in materiality may affect how children make sense of the physical world. Therefore, a better understanding of the implications this change has for education is necessary.

As an educator in the Norwegian arts and crafts early childhood teachers' education (ECTE) at the University of South-Eastern Norway (USN), my teaching emphasizes material practices that involve bodily, haptic, and sensorial experiences generated through explorative and creative making activities. I see an emphasis on craft traditions in education as a way of introducing the value of embodied learning and multi-sensorial experience to young learners.

EC theory underpins the making and thinking through materials (Groth, 2017). Human beings make sense of, are affected by, and develop meaning through interaction with materials and environments (Gibson, 1979; Gulliksen, 2017; Kiefer & Trumpp, 2012). The embracement of material tradition, creativity, and craft practice that require embodied sense-making is key to not only education in general but also arts and crafts education (Fredriksen, 2011a; Groth, 2020; Gulliksen, 2017). This tradition highlights close encounters with materials and knowledge acquisition through handling and exploring materials, i.e., knowing through a material practice (Nimkulrat, 2021). Crafting material directly by hand is a way for a person to negotiate meaning related to their abilities and limitations and get closer to making sense of the world (Groth, 2020).

DOI: 10.4324/9781003328018-14

Young children's making is primarily about creating imprints and expressions, and bringing something new to life (Waterhouse, 2021, p. 7). Explorative and playful interactions with materials and tools and their properties, affordances, and constraints are crucial for young children's learning (Fredriksen, 2011a; Søyland, 2021; Waterhouse, 2021). In the Norwegian context of early childhood education (ECE), young children's making processes are not so much about creating products, but rather the experience and experiential learning that grow through their embodied entanglement with materials (Fredriksen, 2011a; Waterhouse, 2021). Children's making activities are constitutive of a way to be in, to explore, and to make sense of the world. While exploration can be seen as a strategy to make new discoveries and to identify new perspectives, it requires action and is closely connected to play and bodily interaction with the child's surroundings (Fredriksen, 2011a). This chapter explores the phenomenon of a changed materiality through an interactive workshop, in which children, an ECE teacher, and I explored different modalities of natural materials through iPads, projectors, and flashlights in a large project room.

The material paradox of digital technology

Materiality refers to our perception and experience of our surroundings (Ingold, 2007), including materials. Both physical and digital materials have materiality that can be experienced and sensed, and they are not separate but entangled elements of the same processes (Pink et al., 2016, p. 1). Digital materiality is made available through software, which can be understood as a digitally mediated material. Such a material must be seen in relation to how it has become digital and been made available, e.g., through hardware. The digital material brings with it a paradox of materiality; while it is often described as immaterial or intangible, it requires the physical, e.g., a touch device, in order to be perceived and sensed. The digital also generates a haptic dissonance (Gerlach & Buxmann, 2011), as shown in Figure 9.1, when an ECE teacher explores different materials in a workshop, there is a distance between the physical leek flower and the handheld device showing the leek flower on its screen.

My PhD dissertation "Grasping Materialities" (Søyland, 2021) identifies how sensorial dimensions of materiality can bridge the gap between the understanding of the physical material and that of the digital, and how they fundamentally entail knowledge gained through making processes. Bodily interaction with materials, whether digital or physical, are connected to exploring material knowledge, which again is important to the development of arts and crafts education. This has sparked my interest in examining the potential of combining physical materials with digital technology in children's exploratory arts and crafts activities; it is to develop new understanding of ways in which children learn through the entanglement of the modalities of materials. Figure 9.2 shows an example from the same workshop mentioned above where the ECE teacher explored the intermeshed space of blending materials.

Exploratory practice with digital technology and materials

The introduction of digital technologies in educational contexts brings both challenges and opportunities. Jenkins et al. (2006) described a creative participation gap related to digital media and children as experienced technology users and consumers who mainly employ technology for entertainment rather than as part of a creative, participatory

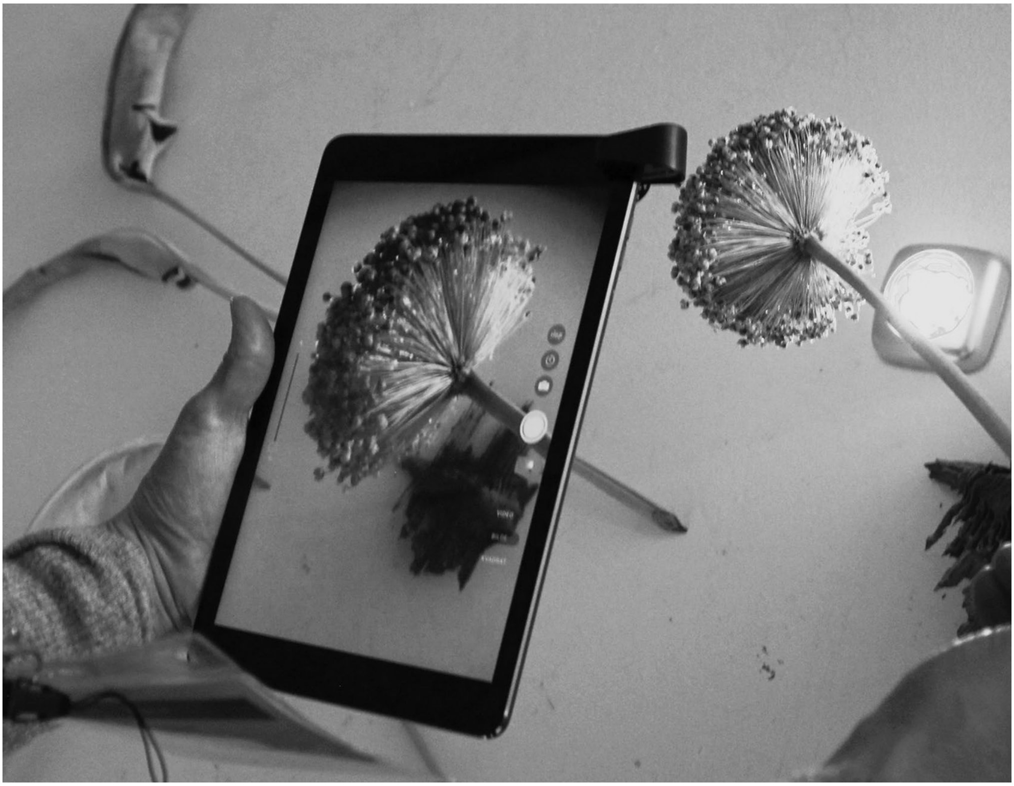

Figure 9.1 An ECE teacher's exploration of a natural material – a leek flower – through the camera of a touch device. Photograph by the author.

learning process. This perspective sheds light on the need for an explorative practice with digital technology which potentially can contribute to bridging the described creative gap in education. Several studies from the Norwegian context have confirmed that early childhood education needs to move away from linear instructions and reproductive learning tasks towards active and engaging activities through exploratory and open-ended processes with digital technologies (Bølgan, 2018; Letnes, 2014; Waterhouse et al., 2019). In addition, Norwegian governing documents for both kindergarten and primary school highlight that children and pupils should gain experience with the exploratory and creative use of digital technology (Norwegian Directorate for Education and Training, 2017, 2019). As an educator, I consider exploration to be central to arts and crafts education and to the ways in which digital technology can become an active part in open-ended learning processes. The shift towards active learning with digital technology leads me to examine children's exploratory activities with physical and digital materials.

In this chapter, I draw on a case of children's material engagement conducted in 2018 to discuss the aspects of how children explore and make sense of different materials and how arts and crafts education can make strategic choices and build informed practices based on this knowledge. I employed an arts-based research methodology (Barone & Eisner, 2012), including qualitative case study (Stake, 2010) as well as video and photo documentation. The case study method allowed me to study young children's

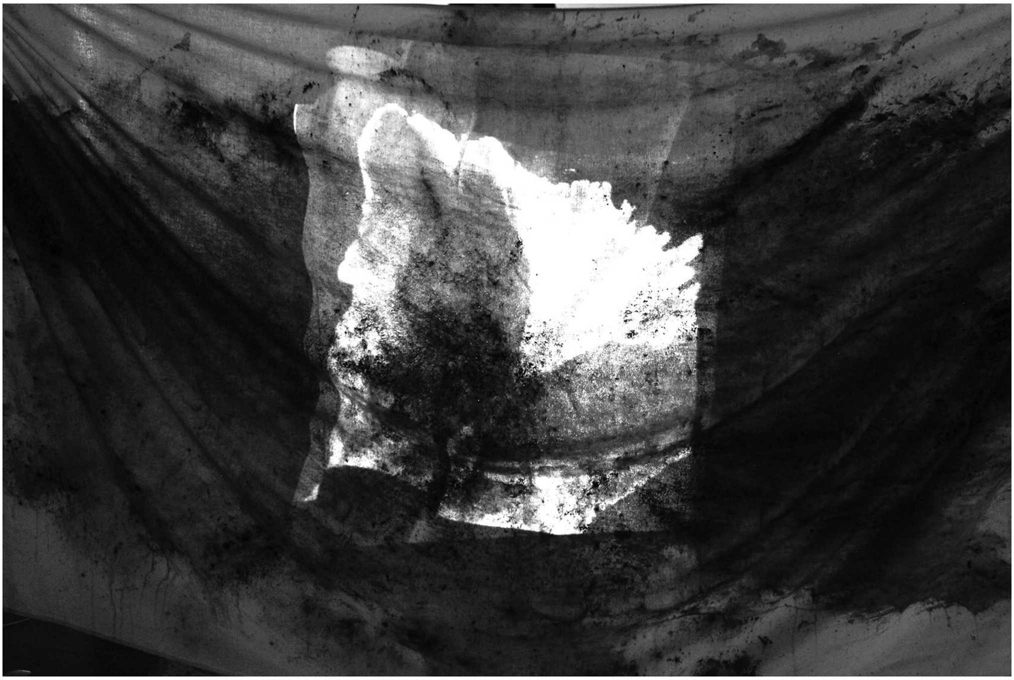

Figure 9.2 An example of a new expression that appears when the physical and digital materials are interlaced. A photo of dried leaves is projected onto a hanging cloth. Photograph by the author.

sense-making through their exploration of different materials. Six children aged 5–6 and their ECE teacher were involved in the study in which I used touch devices and projectors, technologies that are largely available in Norwegian ECE. The selection of photography and mobile projectors was expected to support engagement in the explorative activity, the embodied dimension, and the three-dimensional space. In the study, I took an active role by joining the young children and their teacher in the exploratory processes. Before I describe the case example in more detail in the next section, I will discuss the knowing and sensing body in material exploration in relation to EC, to ground an understanding of how humans make sense through material exploration.

Embodied cognition – the knowing and sensing body in material exploration

Educational sciences have slowly accepted the idea of EC as relevant and important (Korsmeyer, 2007; Kiefer & Trumpp, 2012). EC theory further shares similar foundations with the theoretical directions of educational arts and crafts. Some directions of EC theory are influenced by Merleau-Ponty's (1962/2005) phenomenology of perception and others connect with Dewey's (1934/2005) pragmatism, both arguing for the knowing body. Embodied knowledge also has some of its roots in Gibson's (1979) theory of human environment interaction and others draw on the field of philosophy and neuroscience, such as enactivism (Noë, 2006; Varela et al., 1991).

The idea of the embodied mind is exemplified through the 4E cognition (Newen et al., 2018, pp. 3–8). First, cognition is embodied, not dependent solely on the brain but involving the whole body. EC underlines sense-making as a bodily phenomenon, in which the body is always included. Second, cognition is embedded in structures of the social and material surrounding, such as in an explorative process. Third, cognition is extended, meaning that thinking is extended beyond the body, e.g., through tools and materials that people use and think with. Tools and materials therefore are extensions of a person's sense-making. Fourth, cognition is enacted; what goes on in a person's mind is revealed in their actions. This may be seen in skilful craft making, when tacit knowledge largely involved in practical knowing is acted out in practice.

In arts and crafts education, the close connection between action and perception is natural. From an enactivist perspective, Noë (2006) examined action and perception together as the starting point for cognition and described how the human mind is in constant interaction with its environment. Noë wrote, "what we perceive is determined by what we do" (p. 1). This means that a child's opportunity to actively explore can be seen as crucial to sense-making. This is because their senses, like all humans, are interrelated in an ongoing activity and, thus, fundamental to their ability to make sense of themselves in relation to their surroundings.

In material exploration, physical interaction with materials and three-dimensional environments activates and creates the neural networks that facilitate a person's abstract thinking and imagination (Gulliksen, 2021, p. 147). This suggests that it is hard for a person to imagine something that they have never experienced, and that exposure to physical material interactions gives a broader repertoire of experiences to use in one's imagination when encountering the digital.

Developing sensitivity to materiality

In addition to material engagement, time is a key aspect of developing sensitivity to the materiality of our surroundings. Carlsen and Clark (2022) expressed a concern about the accelerated world of education that also affects ECE and a speeded-up working culture as a result (p. 203). According to Clark (2020), *slow knowledge* is vital when it comes to education and society in general. Clark pointed out that while fast knowledge is often linear, abstract, and theoretical, slow knowledge tends to be more profound, complex, multi-sensorial, and therefore not afraid of drawing on tradition. She continued to argue for the necessity of a slow pedagogy to accommodate children's learning and give them opportunities to develop slow knowledge. Carlsen and Clark (2022) also highlighted that the exploratory and open-ended learning processes are vital to facilitate children's development of sensitivity to their surroundings. Carlsen and Clark's thinking can be seen as a counterpart of the inherent effectiveness of learning technology.

Grasping physical and digital materialities: case study of children's sense-making through exploration

The case involved six children aged 5–6 years and their ECE teacher. Divided into two groups of three, the children were invited to a large project room at the University of South-Eastern Norway, where I had arranged for them to engage in a three-day exploratory and interactive workshop with different technologies, such as iPads, projectors, macro lenses, and flashlights, and physical materials, such as a cod skeleton, gum arabic, moss, bark, a piece of wood, and bubble wrap plastic etc.. The children did not get a task ahead of the workshop; the room was presented to them as an open invitation to explore what was available in the room. With some photography experience, they were asked to only take photos of the things and materials in the room, and not of each other. They could move and explore things with their hands but were told to handle those things gently, such as some glass objects and a buck skull. During the three-day workshop, I collected empirical data, including 600 photos and a six-hour video, which I transcribed and took screenshots from. These visual data were combined into a 70-page document. The qualitative content analysis focused on the children's sense-making interpreted through their explorations of different materialities and their modalities, during which I examined their facial expressions, gestures, movements, and verbal utterances. The focus was placed on situations when one or several children became very engaged and occupied in an action or when they showed surprise or joy by making new discoveries or expressions. The two most interesting such sense-making instances of children exploring a leek flower and leaves were selected for an in-depth analysis and developed into photo collages and thick descriptions (Stake, 2010). Thick descriptions in the context of this study are detailed descriptions that I expressed in poetic language (Stake, 2010) of the short moments of children's interactions and engagement with materiality.

Thick descriptions and photos of children's explorations of different materialities

Leek flower

The children enter the room and spend some time walking around, looking, touching, and moving the various materials and things that are available. One of the children spots the dried leek flower, runs to it, lifts it up to his nose to smell it, and says: "It smells good – like water and forest". He holds the leek flower against his cheek and lets it rest there for a while. It looks like he is focusing on how it feels on his skin. The other two children stand and watch. One of these children says: "The flower is dead. It has no colours anymore and it does not flourish".

As we have moved into a new phase of the workshop, the children have now received one touch device each. The children explore the materials in different ways by photographing them from different angles, and by using a macro lens they come even closer to the leek flower. They make sounds that I understand as a sign of them making new discoveries of the materials and the transformation of the materiality from the physical object to its digital materiality on the screen. They oscillate between holding the materials in their hands, feeling them, and returning to taking photos.

I project one of the children's photos of the leek flower into the room. One of the children runs to the podium where the flower lays, grabs it, runs towards the projection, and throws the flower into the air. The light from the projector hits the flower and brightens it up as it spins in the air and then falls onto the floor. As the other children's attention is shifted from this child and the flower on the floor to the projection on the wall, they move towards the end of the room where the photo of the flower is projected.

The child puts his hand on the wall and makes a sound that shows that he is excited – I understand this as a reflection and discovery of the difference in size between the physical and the projected leek flower. The child wonders about this transformation of the physical leek flower that he has held in his hands and has touched his skin on the cheek. Now the leek flower has changed form, as its photo is projected onto a piece of hanging translucent white cloth and other surfaces in the room. One of the other children moves towards the projection, puts her hand on the wall, and then quickly grasps it again, as if she is

Figure 9.3 Children's exploration of materials, projected photos, and the emerging of new expressions. Photographs by the author.

pondering the tactile surface of the wall and the projected materiality. Maybe she is feeling that something is there, but at the same time is not there. I also hold the flower directly under the photo app while projecting it into the room. The projected leek flower becomes a moving landscape in which the children move, and that they shape with their bodies by creating shadows and setting the hanging piece of white cloth in motion (Figure 9.3).

Leaves

A piece of translucent white cloth hangs from the ceiling and a pile of dried leaves is on the floor. The light is turned off and a photo of leaves on the touch device is cast from the projector onto the cloth. The light is mixing with the surface of the room, the materials, and the projection of the leaves. The children move their bodies, interacting with the light, which creates fluid shadows and expressions in the room. The whole room is transformed and set in motion. The children move fast and make sounds, enjoying themselves. They stop between the wall, the pile of leaves, and the cloth (Figure 9.4).

One of the children sits down by the dried leaves on the floor. He grabs a handful of leaves, slowly squeezing them between his left-hand fingers while lighting them with a flashlight held in his right hand. After a while, the same boy moves his flashlight from left to right, creating lines of light on the projection of leaves. He holds the flashlight still for a moment, then brings it closer to the digital leaves, and makes a large spot of bright light within the projection. He stands still for a moment, looking at the spot of light. A while later the children head towards the cloth and the projection with their flashlights in hand,

Figure 9.4 The children explore the materials by hand and by moving into the projected materiality of leaves. Photographs by the author.

expressing excitement. The light from the projected leaves hits their bodies. Their bodies shine in orange, white, and reddish hues. The children utter sounds of amazement. Two of the children shout, "I am big, I am big", while they look at their shadows. They move their bodies in different directions as if they are dancing in front of the projection and the multi-coloured light, and various shadows appear as they block the light. They aim their flashlights at the projection and their own shadows. Fluid visual expressions appear in the room when they do this. The atmosphere of the room changes as the children use their hands and feet to arrange the leaves in different ways.

Discussion

Based on the in-depth analysis of the two selected instances of children's exploration, three main themes were identified: (a) sensorial aspects of transforming materials and their materialities; (b) multi-sensorial experience of grasping and exploring physical and digital materials; and (c) educational benefit of the co-creative aspects of digital technologies and the intermeshed space between physical and digital materials.

Sensorial aspects of transforming materials and their materialities

Learning as a bodily phenomenon can be acknowledged by taking the material craft tradition within arts and crafts education seriously. The importance of exploratory aspects of learning is evident in the case study described above since gaining experience is something we do rather than something that happens to us (Noë, 2006, p. 1). From the case study, it can be implied that a learner's perception depends on their activity and that material exploration is a process emerging through embodied sense-making. Sensorial interaction is needed to experience how materials change. A close interaction between the person and the constantly changing material provides the experiencing person with an embodied understanding of the material (Nimkulrat, 2021, p. 49). The case study demonstrates the ways in which physical material engagement facilitates children's learning through haptic exploration, e.g., when the surface of a leek flower is felt against the skin or when leaves are squeezed between fingers. In such a direct material engagement, I would argue that no distance exists between the world and the learner's body and senses.

As the case study has shown, explorations, through active engagement and movement with the material and their diverse modalities, enable children to experience different transformations of the material in their hands, from its physical substance to digital materiality on screen. By using a macro lens, the children come closer and experience not only the transforming material that the bare human eye cannot see but also the changing environment when the macro photos are projected in the room. When the children experience these transformations, their sounds, words, and body languages express their excitement and deep engagement in the exploration. These examples of children's experiences of material transformation and related bodily engagement with materiality exemplify how digital technologies can extend and facilitate learners' sense-making, in line with how cognition is extended through tool use (Kiverstein, 2018, p. 22).

In educational arts and crafts, exploring how a material changes and is mixed with substrates is central to material engagement, not only with tangible materials but also with intangible ones and the combined materiality of the two. As observed in the case study, one child uses his left hand to grab and slowly squeeze leaves between the fingers repeatedly and his right hand to turn on and aim the flashlight at the leaves to illuminate them. In this way, light, as something that can be understood as intangible, is employed to explore the material's properties and transformations. The child uses light to "touch" the leaves slowly and repeatedly and transforms the beams of light into the projection of the materiality of leaves. This case has shown that attentive and sensorial exploration can bring about a flow of mixing materialities and the intertwinement of the physical and digital materials. An activity like this offers potential for experiencing new materialities, and modalities of materials, than what is possible without digital technologies.

As Noë (2006) described, experience is a temporal extended process of skilful probing that comprises the mind and the world (p. 216). In my understanding, this indicates that the passage of time links to deep and lasting learning. Haptic, slow, or deep knowledge is complex and multi-sensorial (Clark, 2020); repetition and time are key factors in exploratory processes that can lead to gaining such knowledge. Similarly, the activities, which I have described in this chapter, connect the exploration of materials and that of digital technologies and may have great potential for developing different blended materialities in three-dimensional space. They enable children to be close to physical materials, and to "touch" and explore digital materiality, e.g., the projections of the leek flower on the wall and the cloth, with their senses. I argue, in line with Carlsen and Clark (2022), that such open-ended exploration is vital in facilitating the development of children's sensitivity to their material surroundings. The case study reveals ways in which combined modalities of materials offer children new opportunities to explore visual expressions and touch interaction that can potentially transform and shape their experience of the world through sense-making processes.

Multi-sensorial experience of grasping and exploring physical and digital materials

Material engagement is central to children's learning because it enables them to gain multi-sensorial experiences of different types of materials and surroundings and to negotiate meaning through their grasping of materialities. Through the case study, I can identify how children are able to combine their past sensorial experiences of materials (see Fredriksen, 2011b) with related emotions and imagination emerging in their current exploration. An example of this is the child who carefully lays her hand on the projected image of the leek flower on the wall. I understand this action as her testing out if she can feel the leek flower that she has just touched by hand. She uses her embodied experience, such as the tactile feeling of a similar material and the leek flower, to explore and imagine the digital materiality of it (see Gulliksen, 2021, p. 149). In other words, previous bodily interactions with physical materials are here connected to the person's sense-making of digital modalities of materiality. The surface of a touch device or a projected materiality of a leek flower provides less sensory information than the physical leek flower. In such a digital experience, a distance between the illusory digital materiality and the person can be described as haptic dissonance within digital technologies (Gerlach & Buxmann, 2011). The digital version of an organic form in space will not make sense to a person without multi-sensorial experiences with physical materials and three-dimensional surroundings. This example underpins the importance of first gaining material experience to later make sense of the digital. In addition, it demonstrates how material and digital activities can be facilitated and how such activities can afford new explorative potentials.

The children in the study grasp and explore materialities and the digital modality of these materials in multiple ways, e.g., affecting and exploring them through their bodily movements, hands, and the use of objects in the three-dimensional environment. The children interact with the space and the projections and experience how they could alter the images with their flashlights. Moreover, by adding other types of materiality such as light, new experiences and expressions could be created. The children interweave different materialities in motion through their senses and moving bodies. Through projection and children's interactions, the digital materiality of the leek flower changes from being perceivable as a representation of it to being blurry colours and abstracted shapes, like an abstract painting in motion. Children gains rich opportunities to influence their surroundings, to express themselves, and to make their own choices in relationship to, and in interaction with, different materialities in their surroundings as well as with one another and adults. This understanding is supported by Tollefsen and Dale (2018) who argued that cognition is embedded in structures of the social and material surroundings (pp. 266–268).

Educational benefits of co-creative aspects of digital technologies and the intermeshed space between physical and digital materials

It is crucial to acknowledge learning as embodied action (see Kiefer & Trumpp, 2012) and the importance of embodied understanding of the material in education. Since the digital dimension distances children from the concrete experiential exploration of material constraints and affordances, it is vital that educators, when facilitating children's sense-making processes with digital technology, consider how sensorial aspects of materiality can potentially connect the understanding of the physical material to that of the digital. Sense-making is a phenomenon that always includes the body (Noë, 2006), so it is important that educators develop an understanding of how children make sense of the digital. In this context, I think it is indispensable to bring sensorial experiences from the material world into the exploration of digital materialities and vice versa.

I find it important to adopt open-ended digital technologies and strategies to education to provide children with explorative learning opportunities. In order to do so, educators need to use digital technologies in co-creative and explorative processes to expand the learners' understanding of the world by bringing something new to life through creating expressions and discovering new aspects of materiality. Through collaborative exploration, some of what goes on in the different learners' reflections and understanding can be shown through their actions and shared among the learners (i.e., cognition is enacted, Tollefsen & Dale, 2018, pp. 266–268). This implies that the co-creative aspect is important when children and adults actively explore materialities and digital technologies. I find it important that educators explore how technology can potentially extend children's cognition through practical engagement, and educators need to strategically use digital technologies by involving learners' embodied minds. In other words, it is necessary that children get an opportunity to use technology that enables them to act and to influence the outcome of their interaction with the technology. When digital technologies are used in this way, or in a similar hands-on activity, learners can embody digital technologies and use their senses to develop deep knowledge in a complex and multi-sensorial way.

Exploring materiality of the physical, digital, or the space in-between the two is a non-linear process that requires openness or a mindset of "not yet knowing" the outcome. Digital technology can be a medium that transforms children's experience and makes them understand other aspects of the world than the materials alone can do. The digital offers another modality to explore different dimensions of the same materials. Craft making is based on responsiveness to materials and various tools and technologies; it is about trying out and making experiential discoveries. Dewey (1934/2005) criticized the tendency to avoid resistance in learning and claims: "Resistance is treated as an obstruction to be beaten down, not as invitation to "reflection"" (p. 46). Material resistance, which is central to crafting, is an integral part of the reflective process and a driving force in exploratory making processes that requires sensitivity to the environment. I recommend educators to lean on material-based educational traditions developed in creative practices and ask how deep knowledge can be developed through digital tools and media that present different affordances. Practical activities in workshop environments, including different kinds of technologies and materials, are fundamental in hands-on learning. Arts and crafts processes, which are open-ended and exploratory in nature, have a lot to offer in this context. When educators select materials and digital tools for making and learning activities, their responsibility is to define how children can be challenged to interact, explore, and think. In this context, it is important to use technologies that initiate active open-ended bodily interaction with materials and environments, and to give learners opportunities to co-create with one another.

Closing remarks

I conclude by urging educators not to downplay experiential knowledge in relation to materiality in education and to value and acknowledge children's multi-sensorial experiences and hands-on activities in schools. When replaced, the digital experience is, in many ways, a poorer embodied experience than the physical, material one, and I would argue that the nuances of sensory experience are in danger of disappearing due to an extensive use of digital technology in education. Both physical materials, and manual and digital technology are needed in education, and the material-based educational craft tradition can potentially provide opportunities for intertwining them in explorative open-ended processes in which children can engage actively. This could also contribute to bridging the creative participation gap in education described by Jenkins et al. (2006). Educators, in particular arts and crafts educators, must embrace the co-creative aspects of digital technologies and invite learners to explore the intermeshed space between physical and digital materials. It is important to continue to develop learning strategies that engage and invite children and young people to actively grasp diverse forms of materiality.

Acknowledgement

This research is funded by the University of South-Eastern Norway. I thank the editors for their expertise and assistance throughout all aspects of writing the chapter.

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Part III

Artefacts as material extensions of craft experience

Part III

Introduction

In this part, artefacts are scrutinized as material extensions of craft experience. The chapters illuminate various roles that artefacts can play in human perception and action during interaction with materials and tools. In Chapter 10 "Traces of Craft Experience in Artefacts", textile practitioner-researcher Nithikul Nimkulrat discusses the traces of making that can be seen in the artefacts resulting from her attentive material engagement. The artefact can reveal the maker's intentions and interactions with the materials, tools, and environment, even if the process of making involves digital tools and takes place in a virtual space. Expert practitioners can read traces in the artefact and follow the processes of other craft practitioners, their actions, and tools used. The author argues that these are traces of human thoughts that demonstrate the inseparable process of making and thinking in the haptic engagement with materials.

Imagining what something might look like in a material is one central aspect of any designing or making in a material. Experiential knowledge of materials' properties and how they behave is important for being able to make realistic plans and choices for what materials to choose and how a material might behave when manipulating it. Craft practitioner-researchers Marte S. Gulliksen and Camilla Groth write about mental imaging in Chapter 11 "Scaffolding Visualization and Mental Rotation in Designing and Crafting", particularly focusing on mental rotation, i.e., an ability to imagine what something might look like from another angle, and how to scaffold this ability when the process is challenging. By utilizing "mental aids" such as paper templates, Gulliksen was able to externalize her mental rotation when her ability to do so in her mind was limited due to an illness.

While craft is seen as a means to reach wellbeing and flow states, craft can also be frustrating and painful, especially when being a novice and material affordances have not yet been internalized and bodily actions have not been drilled to perfection. As arts and crafts educator Anniken Randers-Pehrson describes in Chapter 12 "Making Bumps and Jumping Hurdles: Understanding Resistance in the Processes of Raising Aluminium from a Novice's Perspective", her experiences of learning to handle aluminium in metal forming was far from smooth, and she experienced several hurdles on the way to gaining experiential knowledge and expertise. However, as a teacher educator in arts and craft, she appreciates the benefits for learning through overcoming material resistances and challenges.

When a designer's imagination is not enough, designers and makers use externalization as a tool for handling the situation. Drawings and modelmaking are ways to project ideas and concepts in a physical way. Often ideas are changed when they are externalized, and the material resistance plays a part in what the outcome can be. In any case, the prototype extends the workings of the mind outside the brain and thus exemplifies what

DOI: 10.4324/9781003328018-16

in EC theory is meant by the extended mind. Physical props and tests further scaffold thinking so that images that were not possible to create in the mind can be visualized. Especially 3D modelling in CAD and now also AI can help ideation in a never-seen-before manner. Chapter 13 "Making Sense with Things in Participatory Design" by cognitive scientist turned design researcher Jelle van Dijk touches upon the sharing of ideas through prototyping in participatory design projects. Designer-researchers Stefano Parisi, Venere Ferraro, and Valentina Rognoli further examine tactile and physical experiences of designers who work with smart materials and design for materials experiences in Chapter 14 "Interactive Connected Smart (ICS) Materials Experience: Collaborative Embodied Knowledge Through Material Tinkering". Embodied materials experience emerges through collaborative tinkering practice with hybrid materials embedding bioplastics and electronics to generate interactive artefact concepts. The chapter shows that the hybrid material samples, recipes, and tutorials resulting from such tinkering practice can be used to expand and transfer experiential knowledge of the new materials to other people through an education design workshop that promotes experiential learning and critical thinking.

10 Traces of craft experience in artefacts

Nithikul Nimkulrat

Introduction: craft practice, design thinking, and embodied cognition

In 2009, I proposed *materialness* as a concept of craft practice that demonstrates the entirety of the creation of a material artefact, both its form and meaning, informed by qualities of the material with which the practitioner chooses to work in response to the environment and time in which the practice takes place (Nimkulrat, 2009). Back then, I developed this concept in an attempt to understand my material practice and resulting artefacts as well as my audience's reception of the artefacts, featured in a specific manner in a specific exhibition space. The concept emphasizes that "making is expressing" (Nimkulrat, 2009, pp. 212–216). While making involves the hands, the mind, and the eyes working in concert, the bodily movement in the act of making in an environment influences the craft practitioner's feeling and thinking, turning material into a meaningful artefact. With this concept, the role of a craft practitioner shifts from making artefacts to creating an experience for the audience viewing the work.

Looking back to the materialness concept and craft practice in general, I can now recognize their connection to *embodied cognition* (EC) – an approach in cognitive science which understands human cognition as grounded in the interaction between body and environment (Varela et al., 1991; Wilson, 2002). EC, often explained through the 4Es (embodied, embedded, extended, and enactive cognition), describes how cognition is not only happening in the brain but also facilitated by a person's active participation in, and interaction with, the physical and social environments (Newen et al., 2018, pp. 3–7; Rowland, 2010). EC and the 4E concept have lately been more and more adopted also to examine skilful creative practices (Baber, 2021) – "Humans, as cognitive agents, are *embedded* in environments in which they *enact* their *embodied* skillful coping in response to the scaffolding of artefacts that allow for the *distribution* or *extension* of cognitive activity" (p. 2). Cognitive processes, as understood by the stronger flank of the theoretical spectrum, can thus reach beyond an individual's body to their physical and sociocultural environment (Clark & Chalmers, 1998). As per Clark and Chalmers's *extended mind* thesis, the mind is extended out into the world and consistently incorporates the environment into the cognitive process.

Phenomenology and perception-action coupling are fundamental to EC (Chemero, 2021, p. 135). Perception-action coupling is formed by "the relationship between a person's prior experience, the actions that they can perform, and the environment in which they perform these actions" (Baber, 2021, p. 134). According to Gibson (1979/2014), perception and action work together to enable individuals to interact effectively with their environment, which offers opportunities for action, also called "affordances".

DOI: 10.4324/9781003328018-17

Therefore, cognition is situated in a dynamic organism-environment relationship that is constantly activated according to the needs, interests, and values of these organisms, including humans (Johnson, 2017, pp. 68–69). Such an understanding resonates with the materialness concept and can be recognized in craft practices in which the craft practitioner interacts with the environment, including materials and tools, in order to conceive an artefact; it is the concurrent making of form and meaning and the inseparable coupling of perception and action of the practitioner's "living, skilled, ready-to-act body for the very having of experiences" (Chemero, 2021, p. 138). The more experiences that craft practitioners have, the more skilled and ready-to-act they become in their dialogical material relationship, so that they can respond to situations arising in their practice (Brinck & Reddy, 2020). Rietveld (2008) called the act of a skilled practitioner *unreflective skilful action* (p. 976). In the process of acquiring a skill, the practitioner is attuned to an environment and, through time, starts perceiving the nuances of their making process and eventually responding unreflectively yet effectively to the new situations arising through relevant affordances offered by the environment. In other words, what turns a practitioner into a skilled one is their ability to "[respond] adequately and appropriately to the actions [that] a particular situation invites" (Rietveld & Kiverstein, 2014, p. 334) and to discern different types of actions applicable to the details of the situation.

Many theories of design thinking, or design cognition, mainly focus on problem-solving which is not the only cognitive activity that designers or craft practitioners do (Rowe, 1991; Simon, 1988). For example, Peter G. Rowe (1991) suggested that the design process involves a sequence of situated actions in which designers define problems and seek solutions through heuristic reasoning. Such an approach of "design thinking as a cognitive style" is one of Lucy Kimbell's (2011, 2012) three ways of describing design thinking. The other strands are: "design thinking as a general theory of design" and "design thinking as an organizational resource". Kimbell (2011) recognized that design thinking separates doing from thinking and designers from the world in which they design (p. 289) and recommended shifting its focus to "situated, embodied material practices" (p. 300). Such emphasis affirms that EC theory contributes to design practice and research beyond problem-solving (Groth, 2017). It can explain design thinking and inform design practice "by providing [not only] a theory of what people do with artifacts" (Baber, 2021, p. 1) but also a theory for understanding the reflective, or even unreflective, practice involved in the creation of those artefacts.

Following from the above, it can be implied that EC may be used as a lens through which designers and craft practitioners can reflect on how they engage with materials, tools, and artefacts in their creative practices. In this chapter, I examine how an artefact can embody and reveal the process of its conception. The chapter sets out to answer the following questions: Can *experiential knowledge* of a craft practitioner be grasped through observing visible traces on an artefact? If so, how and by whom? And why is it important for the practitioner to trace back their own experiential knowledge embedded in an artefact? Experiential knowledge, as opposed to declarative knowledge, includes not only material knowledge but also more implicit procedural knowledge and knowledge about cultural and social meanings that one gains through experience.

The answers to these questions may extend the materialness concept to encompass the haptic engagement in the transitional moment of a material being crafted into an artefact. Gibson (1966/1983), who studied the senses as sensory systems, coined the term *haptic* and explained it as "the sensibility of the individual to the world adjacent to his body by the use of his body" (p. 97). Included in this concept is the person's deliberate and active movements, balance, and orientation, as well as proprioception, which is the awareness of the position of one's body parts in relation to one another and the kinetic movement and position of the limbs (pp. 36–37). Distinctive traces identifiable on a completed artefact may evidence what happened in its making process. This is to illuminate the process of *thinking through making* (Ingold, 2013; Mäkelä, 2007; Nimkulrat, 2012), in which the craft practitioner expresses their thoughts through specific actions, that may be recognizable in the artefact. Thinking through making follows the idea that making facilitates thinking and that making constitutes knowledge creation (see also Brinck's chapter in this book). Through two examples of crafts, one analogue and one hybrid, I argue that traces of a practitioner's experience perceptible on artefacts not only embody and reflect skill and time but also evoke memories and give the artefact meaning for the practitioner.

Knowing *through* and *in* making: haptic engagement with materials and tools

In the situation of making an artefact, the material is not in a static state, but part of a transformative interaction with the maker and the environment. To study the nature of relational transactions of humans and things and the role of things in shaping the mind, Malafouris (2018) proposed the *material engagement theory (MET)* and situated thinking in action:

> By engaging the things that surround us we get to know about touching and seeing and learn about their phenomenal properties. … [W]e come to feel and know our bodily senses by engaging the world. Material engagement is the basic process by which we discover the feel and functions of our senses and through them the capacities, limits, and boundaries of our bodies. This is also how we discover affordances, enact possibilities of action, and appreciate the varieties of consciousness by which we apprehend and come to know "reality". Those processes are of course inseparably social, cognitive, and material.
>
> (p. 755)

According to MET, understanding the way in which people interact with physical artefacts is necessary for recognizing how the embodied attributes of such interaction support ongoing, mutual engagement. In other words, MET considers materiality as mediating cognition and thus extends the domain of cognitive science to incorporate the material domain (p. 755). As Malafouris and Koukouti (2022) pointed out, the dialogue between the maker and the material can be better understood with the help of the temporality of touch and the tactility of making, i.e., through different sensory modalities, such as hearing, sight, and touch, in an *attentive material engagement*. Attentive material engagement is

> the state of bodily involvement or attunement characteristic of human skilled practices and modes of creative engagement. … It involves the skilled positioning of the whole body (e.g. through posturing, gesturing, active touch or anticipatory sensing) in a given material environment.
>
> (p. 266)

Similarly, Ingold (2013, 2017) emphasized making as a process of *correspondence* in which the maker and the material actively and continually meet each other as a form is being generated.

When it comes to material engagement in the field of crafts, skill makes a difference as many craft processes are complicated and it takes many years for a craft practitioner to acquire necessary skills. Ingold (2000) defined skills as "capabilities of action and perception of the whole organic being (indissolubly mind and body) situated in a richly structured environment" (p. 5). According to Sennett (2008), all skills begin as bodily practices, the knowledge of which is gained in the hands through touch and movement (p. 10). However, Baber (2021) pointed out that skilled practitioners may not perform different actions or complete tasks more quickly than novices, but their skill enables them to effortlessly organize tasks in a sequence and to "rapidly adapt performance of a task to suit context or the ability to anticipate the needs to a subsequent action and adjust a current action accordingly" (p. 149). Rietveld and Kiverstein (2014) added that as practitioners' skills are accumulated their sense of how and when to act becomes increasingly refined (p. 334).

Through two examples of my own craft practice, I will in this chapter discuss the understanding of thinking *through* and *in* making and the imprint it makes in the artefacts. The first example is a material practice that sheds light on how I, who have knotted three-dimensional artefacts from paper string for more than 15 years, organize the making process and foresee what actions are needed in order to continue the process. The second example is a hybrid digital-analogue material practice that illuminates my learning through the feeling *of* and *for* materials and the role of prior experiential knowledge and procedural memory in such learning. Both examples reveal how my experiential knowledge becomes visible in the resulting artefacts.

Example 1: analogue material practice

The first example presents my engagement with a tangible material (i.e., paper string) in hand-crafting an artefact. This artefact was created within a knotted series of artistic work that is a commentary on my everyday experience of working from home during the COVID pandemic in 2020. During this time, it became evident that several things around us, such as computers and coffee cups, were inevitable for our daily lives; we simply could not live comfortably without them. The artefacts in this series were not meant to serve any practical functions; they were created to stimulate contemplation and reflection. They represent generally relatable experiences during an extraordinary time.

My longitudinal experiential knowledge of my craft enables me to intuitively perform the process of knotting the lacy structure that I commonly use in my work. The process begins with tying four strands of paper string – two active and two passive in the middle – into an individual reef knot (Figure 10.1a). Multiple individual reef knots are then connected to one another using the same type of knots to construct a lacy structure (Figure 10.1b). However, for the knotted lace to turn into a particular three-dimensional form, I need to outline certain aspects prior to the entire knotting process, such as the length of the strands and the workflow (i.e., a series of steps or actions) necessary to complete the form.

Intending this artefact (later named *The Laptop*) to be in the form of a 13-inch laptop, I started the making process by looking at my physical laptop to comprehend its overall shape and details that could help determine and organize the overall workflow of the knotting process. Since I would have a "real" laptop in front of me while knotting, no sketch was made to guide the knotting process. I envisioned that the keyboard part would be constructed of two layers of a lacy knotted structure, while the screen part would be

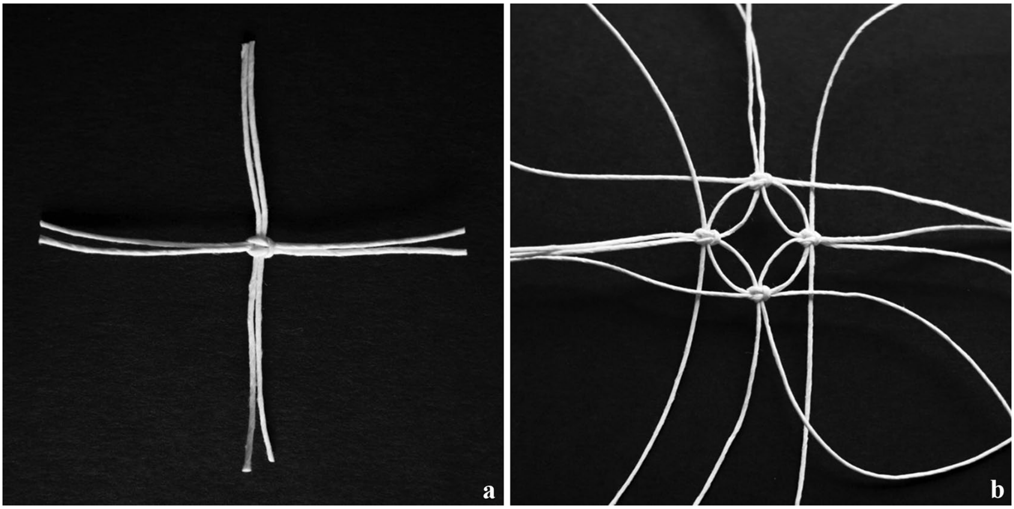

Figure 10.1 A single reef knot with two middle strands (a) that allow for more knots to be connected to form a circle shape and eventually a lacy structure (b). Photographs by the author.

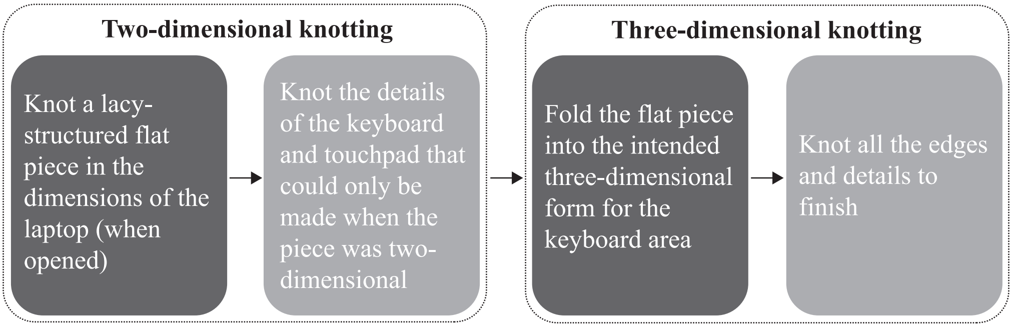

Figure 10.2 The workflow of the knotting process of *The Laptop*. Diagram by the author.

in one layer. Figure 10.2 shows the organized workflow in two main stages of two- and three-dimensional knotting: (1) knot a lacy-structured flat piece in the dimensions of the laptop (when opened) and the details of the keyboard and touchpad that could only be made when the piece was two-dimensional; (2) fold the flat piece into the intended three-dimensional form for the keyboard area and knot all the edges and details to finish.

To begin the actual creation, I cut the 1-mm paper string following the diagonal measurement of the laptop from edge to edge, approximately 45 degrees, multiplied by two. Informed by my prior experience, this length of paper string would be long enough to knot the lacy structure in the intended dimensions. The knotted piece was gradually expanded, and I constantly checked its size by laying it onto the real laptop. This exemplified how I could extend my thinking process by using an object in the environment to think with in my iterative making process.

After this, I wrapped the knotted piece around my laptop to figure out in which direction the piece would be folded to form the keyboard part. I marked on the piece where to

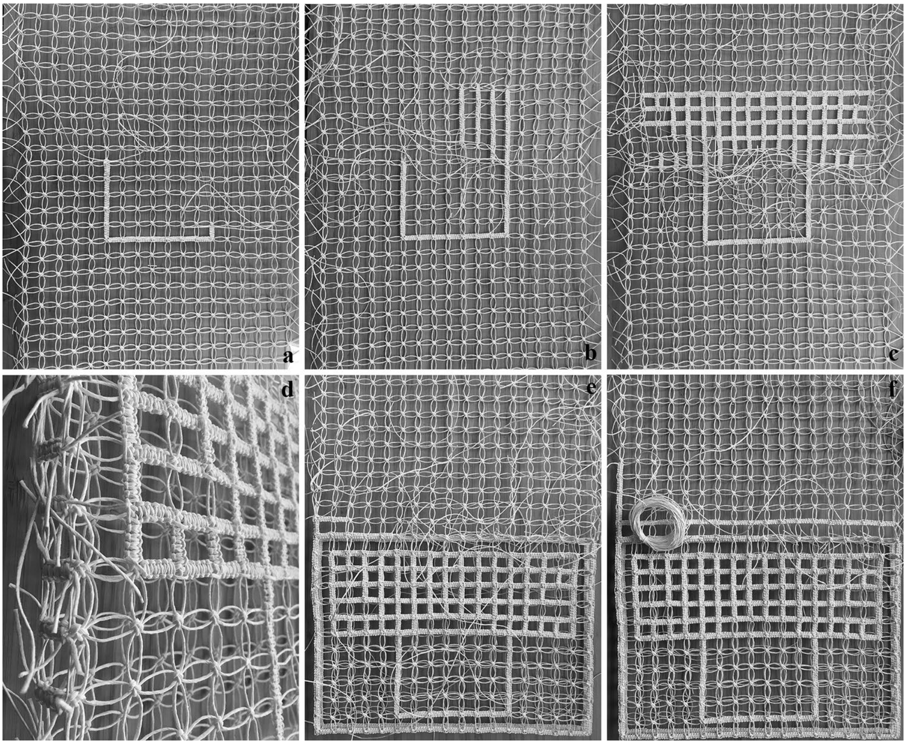

Figure 10.3 The knotting process of *The Laptop*. Photographs by the author.

knot the details portraying the touchpad and the keyboard. I then knotted a continuous line to form three sides of the touchpad (Figure 10.3a). I stopped multiple times to scrutinize the ongoing work and reflect on how the knotting should continue. Instead of finalizing the fourth side of the touchpad, I continued knotting all vertical lines of the keyboard and returned to knot all horizontal ones to complete both the keyboard and the touchpad (Figure 10.3b–c). After that, I folded the flat lacy-structured piece so that the keyboard area became three-dimensional. I knotted several vertical lines, forming "pillars" to support and elevate the keyboard (Figure 10.3d). To strengthen the overall artwork, I added 0.4-mm wire along the edges as the middle strand hidden under the knots. The knotting of the edges started from the bottom corners of the keyboard and then continued to the two vertical sides. The knotting of the vertical sides did not proceed to the screen part but stopped to allow for the completion of the horizontal lines and the insertion of a small circle depicting the built-in camera first (Figure 10.3e–f). As I was knotting the edges, I gradually tidied up the paper string tails left from the knotting of the lacy structure base and other details. These string tails were bent and knotted over, thus working as central, inactive strands hidden inside the knotted edges. Since I had previously used this technique to create other artworks, whose edges needed tidying up too, I knew exactly how the tails could be concealed and in which order the knotting should progress in order to achieve clean edges.

While my hands were manipulating the paper string, I was constantly transforming the material into the intended form and details. As the work progressed, the number of

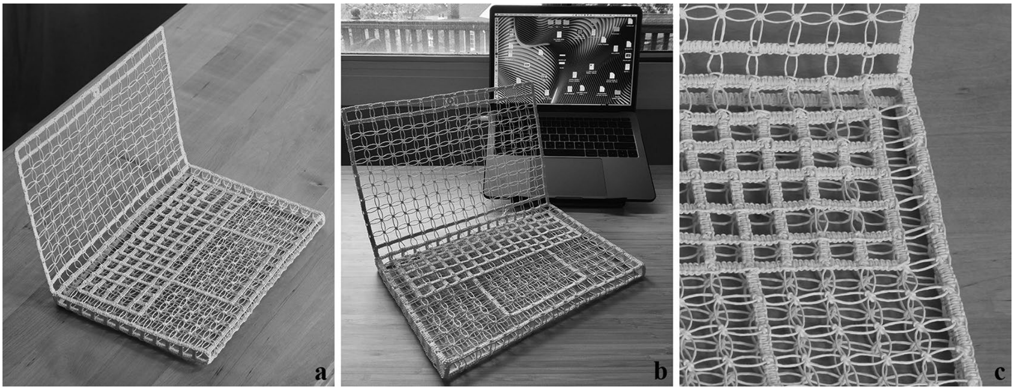

Figure 10.4 The Laptop, 2020. Photographs by the author.

separate strings was reduced which made the work-in-progress less messy and more in control. The number of strands and tails gradually became fewer and fewer until no tail was visible when the work was completed (Figure 10.4). Composing the artefact using this technique and material was essentially about attentively engaging with the material, envisioning the needed parts and their architecture, and managing the complex workflow in the correct order. Such handling of the material and technique and the organization of the workflow can be considered "knowledge born of sensory perception and practical engagement, not of the mind with the material world … but of the skilled practitioner participating in a world of materials" (Ingold, 2007, p. 14). The traces seen in the completed artefact (Figure 10.4c) reveal a specific order of making to me. This specific order is a result of how I perceived and engaged with the material and the environment and how I was informed by my prior experience of working with the material and technique.

Example 2: digital-analogue material practice

The second example demonstrates my process of familiarizing myself with digital manufacturing tools and the translational process of crafting with both digital and analogue materials. The artefact was created in the final stage of a ten-week project in which I explored how hand-crafted artefacts could be translated into another modality and material using 3D modelling technology (see also Nimkulrat, 2020). The project started with the creation of a hand-knotted paper string artefact in the form of a coffee cup (Figure 10.5a) that was used in the experimentation with various digital modelling and fabrication platforms.

From my previous experience of learning to use digital tools, I recalled their limitations regarding the amount of data and file size that can reduce their effective operation. For this reason, I utilized the idea of abstraction to simplify the degrees of complexity of the hand-crafted artefact before attempting to translate it into a digital version (Campbell, 2016, p. xxi). I first photographed the artefact, transferred the photograph onto a WACOM tablet in Adobe Illustrator, and then freely drew on it with a stylus. After that, I used a section of the freehand drawing to produce a simplified 3D model on Cinema 4D (Figure 10.5b). In this practice, my mind, through my sense of touch and the digital tools such as the stylus, was extended into the virtual space. Such handling of digital tools to interact with software resonates with the extended mind thesis (Clark & Chalmers,

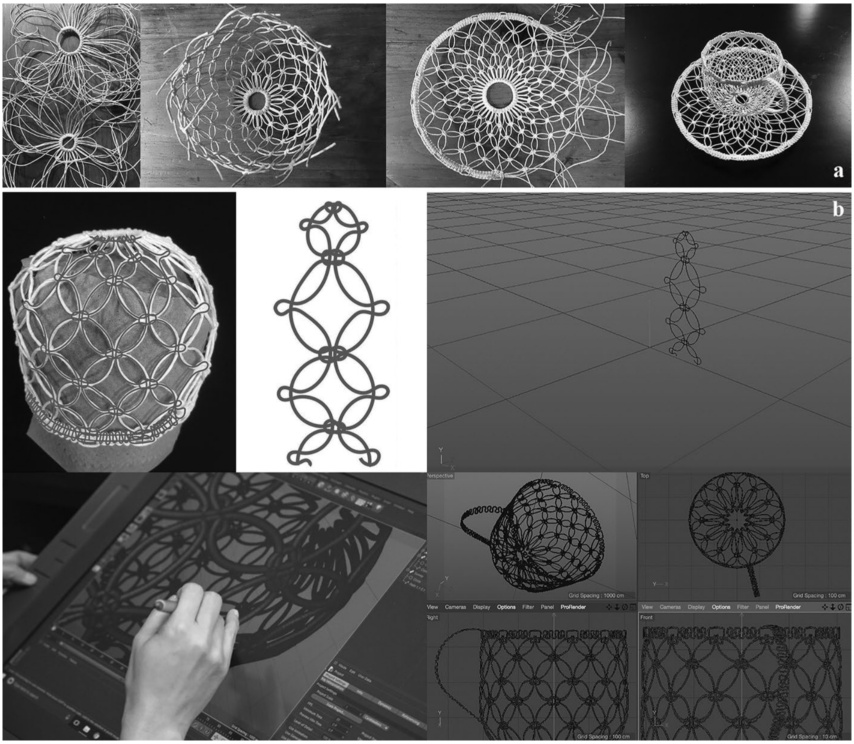

Figure 10.5 A hybrid process of translating the hand-knotted cup into the digital realm. Photographs by the author.

1998) which emphasizes that the mind is not necessarily contained within the physical body but can extend to elements of the environment, even the virtual in this case.

After having managed to translate my tangible artefact into the virtual space, I was free to manipulate it further and change its materiality and function even more. At this stage of the project, I had experimented with all digital tools available in the research lab where I was working except the Zcorp 310 printer. Using powder- and binder-based printing technology, this printer can be employed to manufacture moulds for castable materials, such as metal, glass, and clay slip. The materials used in this 3D printing process combined Hydroperm (i.e., gypsum-based plaster), calcium carbonate, and maltodextrin (i.e., a fine-grain sugar used in the brewing industry) (Robbins et al., 2014, pp. 134–135). According to Robbins et al., the combination of the powder components of Hydroperm and calcium carbonate produces good spreadability and relatively high resolution, while maltodextrin acts as the binder that diffuses through the combined powder to create mechanical strength to withstand further operations. As my experimentation with digital modelling and fabrication up to this point dealt with the non-functional, lacy-structured cup, I had not seen the relevance of this 3D printer to my hybrid craft practice. However, after having gained proficiency and confidence in handling various digital tools, I started to recognize a new opportunity offered by this printing technology for giving function to the lacy-structured cup and bringing the making of it back to the analogue world. This printing technology and material that were new to me inspired the next stage of this project to utilize the 3D model in Figure 10.5b as the base to continue working in the digital space towards the creation of a 3D-printed mould for slip casting my virtual cup in clay (Figure 10.6).

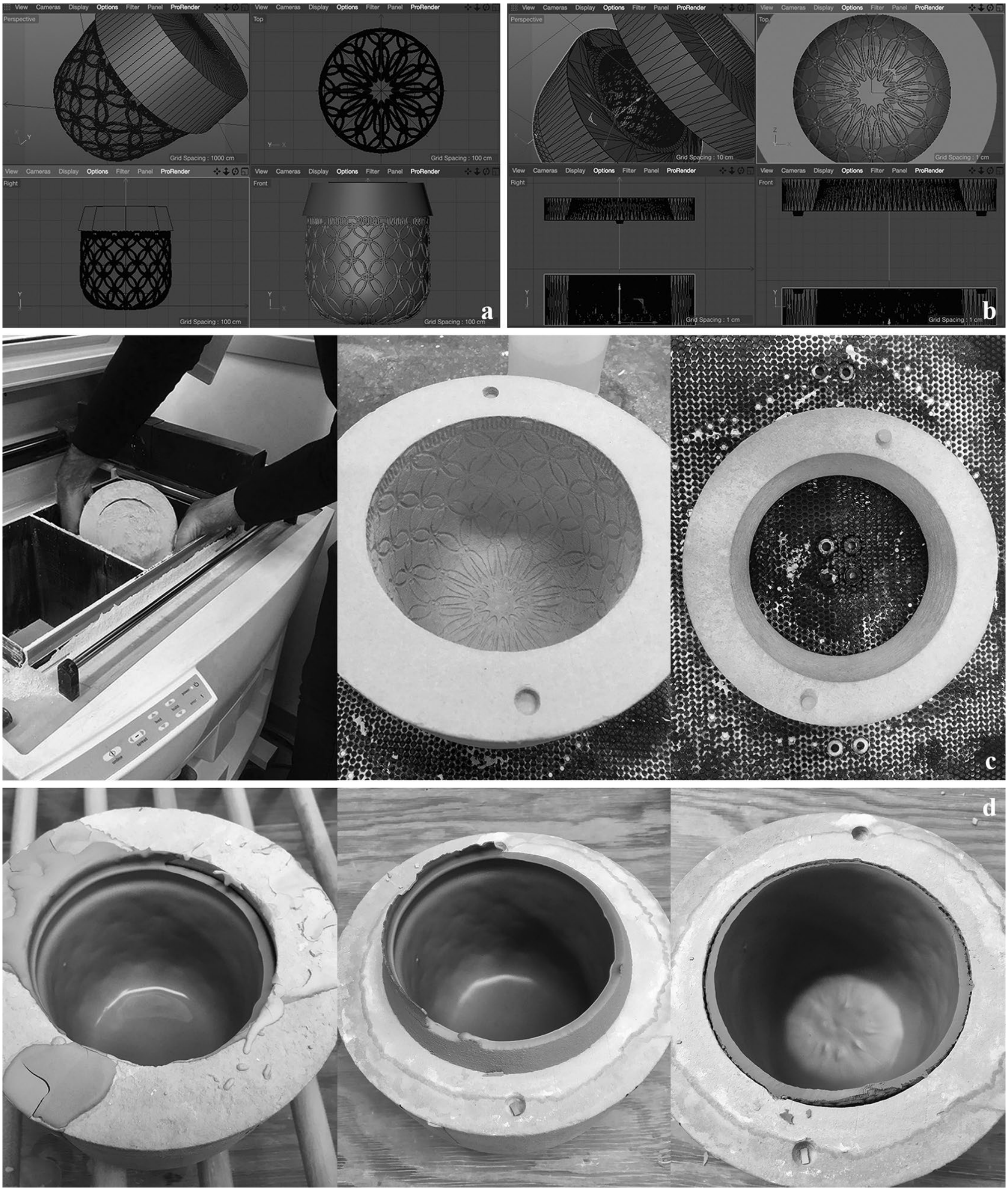

Figure 10.6 A hybrid process of translating the digital model into a 3D-printed physical mould, which is then used for slip casting to create a ceramic cup. Photographs by the author.

The 3D modelling of the positive cup shape and the eventual mould for slip casting required not only my newly acquired skills of 3D modelling but also my prior knowledge of mould making for prototyping and traditional ceramics. I obtained such knowledge more than 20 years ago in my bachelor's studies in industrial design but had not practised making moulds or ceramics at all since that time. I now applied my experiential knowledge of ceramic practice into the digital realm; instead of working with plaster like in traditional mould making for ceramics, I first created a two-piece, one-inch-thick mould on the virtual screen. To do so, I first removed the cup handle from the 3D model in Figure 10.5b and used it to digitally make a positive, solid cup shape with an additional one-inch-thick top part (Figure 10.6a). I left the lacy structure as the cup's surface relief pattern. Next, I created a one-inch wall around the positive cup (except on the top), parted the mould into two pieces at the rim of the cup, removed the positive cup, and made keys on the two pieces of the mould for it to remain intact when casting (Figure 10.6b). Fundamental knowledge of mould making for ceramics, which I was not aware that I still embodied, immediately became useful in this process, and I was able to apply it in the virtual environment that was still relatively new to me.

After being printed and taken from the 3D printer, the two pieces of the mould were de-powdered with compressed air and sprayed with water to set the mould material and to increase its plasticity when dry (Figure 10.6c). Relying on previous experience of slip casting clay, I filled the dry mould with clay slip and waited for a desired wall thickness to form in the mould. When this stage was not reached within the normal timeframe of 20–30 minutes, I realized that this 3D-printed mould was not absorbing water at the usual speed and that the duration for clay slip to set mould would be longer. I kept waiting for the clay to form the desired thickness in the mould. My prior slip casting knowledge also led me to perform another common step in the process – that of securing the two-piece mould with a rubber band before casting to enable the turning of the mould upside down to drain excess slip. As I followed this step in the very first use of the mould, I broke the top piece and needed to reprint it. Having experienced the brittleness of this mould material, I knew that I could neither put normal pressure on the mould nor turn it upside down to remove extra slip completely. Instead, after the desired thickness was achieved, I held the mould with my hands, tilted it enough to pour out the excess slip, and returned it to its upright position to dry (Figure 10.6d). This caused a thicker bottom and slightly uneven surface inside the cast cup. The cast cup was left in the mould until it became "leather hard" and could be taken out from the mould safely and eventually bisque fired. The feeling *of* clay being leather hard and retaining its shape when handling it can be considered an example of embodied knowledge that a craft practitioner develops through their senses after hours of observation and practice.

While the overall process of slip casting clay in this mould was similar to that in a traditional plaster mould, the actual casting revealed that my recalled experience could not be fully applied to the present process. This was because the new, unconventional material had properties that differed greatly from traditional plaster. First, its higher density required significantly longer time for the clay material to set in the mould. Second, its brittleness made the tying of the two-piece mould using a rubber band unfeasible. With these differences in material properties, I adjusted particular details of the slip casting process to ensure my success of working with the material that was not only new to me, but also unconventional for both slip casting and mould making.

Finally, the traces visible on the cast cup (Figure 10.7) gives evidence of the whole process, from my original hand knotting and my virtual drawing of a section of knots (Figure 10.5b) to the printhead of the Zcorp 310 printer layering material, layer-by-layer. Then, at last the uneven thickness of the cast cup is also a trace that reveals not only the unsuitability of the mould material but also the slip casting process that I adjusted in order to handle this material and continue the process. Some of these traces may be read by other practitioners, especially when I explain the process.

Figure 10.7 A cast cup revealing the trace of my freehand drawing, that of the digital fabrication of the mould making process, and that of the slip casting process. Photograph by the author.

Discussion: artefacts embodying traces of the craft practitioner's experiential knowledge

The two examples of my material practice unpack my craft experience in light of concepts in EC theory and attentive material engagement (Malafouris & Koukouti, 2022) that brings about my understanding of the practical effects and affordances of the materials at hand. They evidence a typical thinking through making that gives rise to both form- and meaning-making. In the first example, the way I organized the workflow consisting of a sequence of actions can be considered "thinking-in-acting", and in the second example, the process affords "withness-thinking" as I acted with the clay and the mould material so that they became my partner, not just means (see Brinck's chapter in this anthology). As the maker of these artefacts, I express my thoughts through them so that the viewers can associate the artefacts with their own experience, such as *The Laptop* in the first example that may be relatable to people having experienced the COVID-19 lockdown/ working from home in 2020. In reviewing my own making processes and the outcomes, I recognize how these artefacts carry not only my experiential knowledge of materials but also record the process that took place in space and time and the marks of the tools used to create them. By following the traces left on the artefacts, not only I but also other craft practitioners in the same or related fields can grasp my experiences of performing particular actions and/or using certain materials and tools. By observing these traces, they can learn about the properties and behaviour of the materials and the capacity of the tools as well as the ways in which I handled them, and thus make sense of my actions.

The analogue and digital processes, materials, and artefacts in the two examples are constitutive of my mind extending into the environment through the artefacts that I created and the tools that I used. As Malafouris (2013) asserted, "[the] spreading of the mind transforms material culture [e.g., artefacts and technologies created by humans] into an important cognitive extension, not in some symbolic or secondary representational sense, but in a more immediate and direct way" (p. 228). In the first example, my mind extends to the paper string and to my hands during the act of making and transforms the material into a tangible artefact that resembles my actual laptop. It shows that my mind extends to the emerging laptop shape in front of me, to the paper string in my hands, and to the artefact itself in its gradual progression towards completion.

In the second example, the slip cast ceramic cup evidences my mind's extension not only to the physical materials but also to the virtual space through the digital tools and virtual software. It shows how I perceive a new opportunity presented by 3D-printing technologies and act upon it by combining new learning experience with my previously acquired knowledge. This demonstrates how affordances as opportunities for action are offered by the environment and are perceived by me, based on my past craft experiences, in the current context (Baber, 2021, p. 170). My experiential knowledge involved in the making of this cup is evinced by the traces of tools and marks on its surface.

Material practice, like in these examples, inevitably involves perception-action coupling, i.e., we perceive our surroundings in order to act upon them and then perceive what happens because of our actions. As a capacity to discriminate between situations grows, the practitioner becomes increasingly sensitive to feedback from their own performance (Rietveld & Kiverstein, 2014, p. 341). Being a skilled practitioner, I am able to perceive what action each specific situation demands even when I am acquiring a new skill. This is evident in the second example when the slip casting process needs adjustments. Observation and learning by doing (Dewey, 1986) become key for understanding a new material's properties and finding ways to handle it. In this hybrid material practice, I constantly experience challenging situations which call for my reflection and sensory evaluation in order to continue the making process. The use of new materials and fabrication technologies requires my attentive material engagement in learning a new "craft" in conjunction with my experiential knowledge of what I already know. Human cognition is shaped by the environment and material culture that surround us (Malafouris, 2013). We use tools, artefacts, and other resources to support our cognitive processes and these external elements can be considered part of the extended mind.

In both examples, my negotiation with materials at times leads to improvisations of the process. In such negotiation, *bodily memory*, which implies "capacities, dispositions, skills, and habits developed in the course of one's life that implicitly influence one's present experience and action" (Malafouris & Koukouti, 2018, p. 158), plays a role. I am able to recall my embodied memory and apply it to the present situated practice through an attentive engagement, even when using new tools. This corresponds to Ingold's view (2000) that the making of an artefact is not to be viewed as a preformed activity on the available material, but rather as a mutual process of adjustment between this particular material's properties and the situated application of the maker's embodied skill and skilled movement (p. 242). As both examples show, every change I make in order to work with the materials at hand drives me to modify my subsequent actions. The dynamic process of attentive creative material engagement, according to Malafouris (2014), is the feeling *of* and *for* the material; in this process, material and human agency are coupled (p. 151). Skilful actions that leave visible traces over the artefact reflect the craft practitioner's skill and time and give the artefact meaning. Not only do they serve as a reminder for the practitioner, but they also embed specific processes undertaken by the craft practitioner that others who are practising similar crafts may be able to perceive while contemplating the artefact. Traces seen on an artefact can therefore support experiential knowledge transfer that may not be possible otherwise.

Conclusion

An artefact as a result of attentive creative material engagement can evidence what takes place in the actual creation, making visible some aspects of the making process that may even be implicit to the craft practitioner themselves. Traces of the hand and tools can be seen over an artefact's surface or form. These traces are traces of human thoughts – my thoughts – that evidence the intertwined process of my making and thinking and the characteristics of my creative work.

Through the examples of analogue and digital material practice examined from an embodied perspective, the concept of materialness is extended to encompass the craft practitioner's haptic engagement in the transition of the material into an artefact. In crafting an artefact, the practitioner constantly evaluates possibilities of actions on the material and the in-progress artefact in relation to the environment and time of the making process. Informed by the qualities of the material and the environment, the crafting of the artefact becomes a situated activity. This situated activity brings forward both form and meaning of the artefact, which, in turn, evidences the intertwining of cognition and the material world. In other words, the artefact is extended from the mind. By engaging with a material, a craft practitioner discovers the feel and functions of their senses and through them the capacities and limitations of their body in relation to the material. Through material engagement, affordances are uncovered, and possibilities of action are discovered – we come to know and apprehend the material world.

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11 Scaffolding visualization and mental rotation in designing and crafting

Marte S. Gulliksen and Camilla Groth

Introduction

Visual mental imaging has been studied largely in the field of cognitive science (cf. Kosslyn, 2005) and relatively less from a design or craft perspective. As opposed to visual perception – which is what we see when we look at an object – mental imaging is the visualization of an object when we do not look at it. We can imagine the visual appearance of something that we have not seen yet and what it would look like when rotated in different angles. Mental imaging is one of the most important aspects when designing and crafting 3D forms, and in this chapter, we open some of the issues that researchers talk about in relation to imaging, while also sharing some insider perspectives from a craft case.

Much attention is currently being devoted to the concept of imagination in relation to general embodied cognition (EC) and issues in action knowledge or skilled work (Ingold, 2021; Koukouti & Malafouris, 2020; Rucińska & Gallagher, 2021; van Dijk & Rietveld, 2020). The idea of mental representations and mental models is contested in EC theories (Baber, 2021; Newen et al., 2018, p. 8; van Dijk & Rietveld, 2020). However, researchers have lately discussed imaging as other than visual representations and generated insights into how such visual mental images are, to a large degree, grounded in a person's previous kinaesthetic and cultural experiences that also enable the imagining of future scenarios (Gallese & Lakoff, 2005; Iachini, 2011; Ingold, 2021; Schilhab, 2011, p. 319; van Dijk & Rietveld, 2020). Schilhab (2011), for example, proposed that "understanding is obtained by borrowing and transferring embodiment in the form of re-enactment from previous first-person experiences" (p. 311).

In our approach, we acknowledge that the issue of mental images is too complicated to be discussed from only one theoretical perspective. Rather, it is helpful to take on several perspectives to make a more comprehensive image. As Chemero (2013, p. 149) held, it seems "prudent to adopt a pluralistic stance" towards theorizing, and doing so might give a fuller image of complex issues, welcoming the fact that an extreme view of cognition might not give all answers. Thus, we have here related to research on a broad spectrum while giving a background for the discussion of the case example.

The idea that visualizations are grounded in previous experiences is not new as several researchers have pointed to this connection earlier (Ahsen, 1984; Keller & Keller, 1999). Even researchers writing within a representational theory of mind agree that visual mental imagery is based on stored memory of previous visual perception (Kosslyn, 2005; cf. Koukouti & Malafouris, 2020, p. 39). Also, cognitive linguistic researchers have argued that some of the same parts of the brain used in seeing are also used in visual imagination

DOI: 10.4324/9781003328018-18

(Gallese & Lakoff, 2005). Mental images are according to Keller and Keller (1999) building on previous experiences of joint activities and cultural connotations. Even aspects that have not been experienced personally may be imagined based on previous encounters of visual images or stories told by others. This is not to claim that there would not *also* exist imaginative creative assemblages and views that are entirely made up, such as dreams. However, when it comes to crafting in a material, imagination is often related to the restrictions of the material reality, that is, the material properties and their limitations in terms of affordances, something that especially the experienced craft practitioner is aware of (Koukouti & Malafouris, 2020). Enacting and simulating possible material and real-life constellations help imagine future actions; for example, a chess player might better imagine the consequences of a move by lifting the chess piece and moving it in the air to the planned place (Kirsh & Maglio, 1994).

Mental images are not necessarily just visual but can also be multimodal and somatosensory, for example, haptic or kinaesthetic, auditive or olfactory (Kosslyn, 2005). We can imagine what something might feel like or what kind of movements we could do with our bodies. By enacting possible bodily actions, it is easier to foresee future actions such as dancing steps or routes for climbing a wall. Rucińska (2021) discussed the manner in which climbers preview their routes for climbing a rock wall and showed how they engage in what she called "enactive planning" as they make their "corporeal imaginings" by visualizing their bodily positions on the route before and during their climb. Rucińska further proposed that such visualization is a form of "doing" even if the body is not in motion at the time. Similarly, when designing a coffee cup, it is important for designers to imagine what the cup should feel like in the hand, how heavy or light it should be, how it is balanced when lifting, and the best size for it.

We will not get deeper into the *general* discussion on creative and freely unfolding imagination here. Rather, we will in this chapter particularly discuss the imaging and visualizing of shapes for making 3D objects. We broadly define our topic of visualizing images as the ability to generate, recall, maintain, and manipulate visual or multimodal shapes in an imagined space (Hawes & Ansari, 2020, p. 466). We claim that when foreseeing future material engagements, it is equally important to draw on previous experiential knowledge of material properties, affordances, and construction to make realistic mental visualizations. The reason for such a visualization and imaging activity is closely connected to the ideation stage in the very beginning of a design or making process and the inspirational sources that give a spark to the ideation.

The image takes shape

When inspired to make something, the idea does not pop up in the head of the designer or craft practitioner out of the blue; rather, the process starts much earlier than that, in previous personal experiences and an inspirational source (Laamanen, 2016, pp. 12–13). Whether the inspiration is drawn from an interesting material, a concept, a poem, or someone else's creative work, the practitioner develops ideas for how to realize this in a material form. Mental images, or visualizations of ideas for shapes or functions, feels or atmospheres, colours, and tastes, are thus fundamental for craft and design practices. The imagined visualization is something that the practitioner keeps in their mind during the process, even if the realized artefact seldom turns out as the first imagined visualization due to the situated and reflective process that unfolds in the material interaction when making it (Ingold, 2013, 2021; van Dijk & Rietveld, 2020).

The image may be fuzzy and inexact to begin with, and further influenced and changed along the way (Baber, 2021, pp. 155–157). Ingold (2013, p. 71) likened this chasing of the imaginary idea to a composer whose musical imagining flies faster than his ability to pin it down in his notes. Mental images rely on working memory, but this memory is short lived and cannot keep up with the evolving pace of what is imagined – the image, feel, or notion is easily lost. This is not to say that it is necessarily unrealistic. Koukouti and Malafouris (2020, p. 40) reminded us of the materiality of imagining and that imagination happens in a dynamic relationship with the world, rather than just inside the head, always in relation to the ways in which we actually relate to aspects of our material environment. When meeting the material constraints in the actual making of an artefact, the imagined image again needs to be refined and better aligned with the material reality (Zeisel, 1981/2006, p. 26). New affordances that are "unlocked" along the process of making may inspire new directions for the image to reshape (Kimmel & Groth, 2023). Not only is the imagined shape invisible to others, but it may also be lost even to the practitioner. Therefore, making a drawing of the imagined shape is common for externalizing the mental image.

However, the process of externalizing an image is not exact either. Novice practitioners, especially, may experience difficulties in drawing the envisioned image before their eyes, possibly due to the fluctuating, temporality of the visualized image that they are unable to keep constant until it is drawn, their untrained hand-eye coordination or drawing skills, or their inability to imagine the materiality of the idea (cf. Frisch, 2010). It is also well-documented that drawing is a form of thinking in itself, during which shapes that are drawn also start influencing the drawing in a new direction, and thus the engagement with the drawing is not following a predetermined plan even if the practitioner would aim for a certain shape that they have in their mind (Ingold, 2013, p. 128; van Dijk & Rietveld, 2020).

Within design research, there has been extensive work put into communicating design thinking processes, from broadly describing the entire process to specifically examining the embodied dimension of designers' or architects' professional practice (Groth, 2017; Höök, 2010; Hummels & van Dijk, 2015; Rietveld & Brouwers, 2016) and how thinking, imaging, and making are not consecutive actions, but combined (Gedenryd, 1998; Poulsen & Thøgersen, 2011). Rietveld and Brouwers (2016) especially described the skilled intentionality of an architectural team searching for an *optimal grip* on the imagined designs the team is visualizing, i.e., forming a clearer understanding of the best possible solution to the design problem.

This search for a *grip* as in a better understanding of the optimal design is familiar; especially, design students know the importance of material exploration, both in the ideation and formation of embodied knowledge of materials and related affordances (Laamanen, 2016). Novice practitioners may feel discontentment when their mental image of a design is not working out in practice, meaning that their expectations are not met (Groth & Mäkelä, 2016; Zeisel, 1981/2006, p. 23). In renegotiating one's expectations through material manipulation and experimentation, the visualized image becomes better aligned with the material reality (Zeisel, 1981/2006, p. 26). Laamanen (2016) found that bodily experiences were part of creating mental images in design ideation. Also, Ahsen (1984, as cited in Laamanen, 2016) rejected purely representational theory in his triple code model that he called the *ISM* (Image-Somatic-Meaning) as without the bodily response in the experience of the image, the world would appear as a mere surface impression (p. 22).

As noted already, imaging is developed through physical interaction with and through activities and materials, such as drawing, prototyping, or material explorations

(Hengeveld & Frens, 2013; Koukouti & Malafouris, 2020; van Dijk & Rietveld, 2021). But what happens if your ability to imagine a 3D shape is fading away?

Several studies have explored the role of the body in interaction with the material environment as support of mental imaging. For example, Kirsh and Maglio (1994) studied participants doing mental rotations in an interactive video game called *Tetris*. They found that the participants started rotating before they anticipated the best fit for the falling shapes into the relief of the game, thus actively exploiting the environment to make the most of their limited cognitive resources, rather than relying on a "planning first" strategy. By "changing the world" through "epistemic actions", the participants were able to simplify the problem-solving task (Kirsh & Maglio, 1994, p. 515).

Similarly, acting in materials by making material mock-ups or prototypes helps externalize and thus supports mental imaging and visualization (especially mental rotating) by offloading cognitive capacities in the environment – a proposition that is aligned with the extended mind thesis and distributed cognition (Baber, 2021, p. 38; Clark & Chalmers, 1998). Craft and design practitioners use a wide variety of techniques to support mental imaging and especially rotation throughout the entire process of making, such as drawing and prototyping, or through using 3D computer-aided design (CAD) software. In this chapter, we focus on *human* abilities of mental rotation in manual craft practice and examine mental imaging and visualization in direct material manipulation by hand and hand tools. We further discuss how the visualization and mental rotation ability in humans differs among persons and how it can be trained, or even lost.

Visualization, mental imaging, and mental rotation

Before we present the case example and describe its activities and experiences, the following concepts need a short introduction: spatial visualization; mental rotation; sense of space; spatial modelling; and visuospatial working memory.

Spatial visualization becomes important because mental imaging is linked to our *sense of space* (Groh, 2014), as what we visualize often has three dimensions or are imaged in a virtual space. While spatial visualization describes the ability to imagine moving ourselves and objects in a three-dimensional space, sense of space is used as a broad term to incorporate both mental imaging of a space and our physical being in a physical space here-and-now. In the case example, the practitioner's ability to envision both her arm and the piece she was carving on was compromised, and thus she reported having issues with these aspects of spatial visualization.

Spatial visualization skills include *visuospatial working memory* – the ability to recall spatial information, i.e., drawing upon knowledge of and experience with an existing object in the world, or manipulating knowledge of a viewed object or illustration to imagine how the object will look when turned upside down or seen from behind (Hawes & Ansari, 2020). They also include *spatial modelling* – the ability to generate spatial information, i.e., imagining shapes not yet there or generating novel constructional solutions.

Mental rotation is a task-specific type of mental imaging where the imagined object is rotated or turned around some axis in an imagined three-dimensional space. It can also refer to processes where tangible objects we physically interact with are imagined as seen from the other side. Mental rotation skill is highly dependent on working memory, because, in order to mentally rotate, we need to keep in mind one position of the imagined object while also thinking of how it would look in another position (Zacks, 2008).

Next, we present a concrete example of a fluctuating ability to visualize and rotate 3D shapes, through an autoethnographic case of an experienced wood carver and the first author of this chapter, Marte S. Gulliksen, who temporarily lost parts of her ability to do mental imaging and mental rotation.

Case presentation

The events took place from December 31, 2017, to September 1, 2022. The most crucial part of the case happened in January and February 2018. A full-length description of this phase in a narrative inquiry style has been published in Gulliksen (2021). As this case is based on autoethnographic data, we switch to tell the story from Marte's first-person perspective.

In my artistic work, I have for a long time been inspired by the shapes of neural structures in the brain. Also, this time, I began my carving process with the ambition to develop two sculptural objects with interlocking forms inspired by the Purkinje cells in the cerebellum. These are neurons that are characterized by a highly complex dendritic arbour shape. In my imagined design, each object would have small golden bowls in the centre, hinting towards a cell nucleus. A thin form, like an axon, would stretch out from the centre-bowl in one end and from the other end, interlocking forms would meander out like the Purkinje cells' dendritic arbours (Figure 11.1). My aim in this project was to

Figure 11.1 Purkinje #2 and Purkinje #3, the two carved objects in *Purkinje Serie* that I was working on during this period. Photographs by Marte S. Gulliksen.

explore how I could create this complex dendritic shape in the chosen material – aspen wood. These objects would be part of a planned *Purkinje Series*.

I had always mastered mental imaging, in particular spatial visualization, to a high degree. So, when embarking upon this process, I was used to ideating in a three-dimensional space and visualizing what my ideas could look like in a material, and I had always relied on that skill throughout to successfully carve intricate forms.

During the first weeks in the wood shop, after splitting a 25-cm-diameter aspen log in two halves, I was carving on the first half based on my initial idea, negotiating with the wood's hidden branches and fibres. I then drew a tentative design on the top of this piece of wood with a pencil and started carving according to the lines. Within only a few days of carving, I realized that something was wrong with my mental imaging skills and my sense of space. I especially struggled to follow one form around the log when turning it around, i.e., my mental rotation was much more challenging than usual. By the second week, I got "lost" when I turned the sculpture upside down and could no longer recognize the form at all. Usually, this is how I check if I am on the right path in my carving – I turn the piece around, and as I remember what I just saw on the front side, I can make plans for how the shapes would continue and look like on the back side. Now, finding the guiding directions of the grain in the wood was gradually more challenging, leading to making rookie mistakes while cutting in the material with the gauge tools. Later, in analysing successive video and audio documentation of my other carving sessions, it is possible to understand that there was something fundamentally wrong with my mental rotation and my visuospatial working memory at this time (see also Gulliksen, 2021).

At the time I did not know why this was happening, I was confused but still insisted on continuing carving. The pragmatic solution I chose for overcoming the problem was to copy the form as seen from above the object onto a paper and mirroring it by holding the drawing up to a window. This drawing aided me in my visualization of how the shape would look from below – something that I was unable to imagine unaided at the time. As this was still not enough for making decisions on the cuts with my tools, I cut out the drawn shape from the paper, making a template that could be attached to the underside of the half-log and drawn onto the wood by following the edges of the paper template. This action "scaffolded" my process in the sense that the template functioned as a form of distributed cognition, helping me through cognitive offloading. Figure 11.2 shows one of the paper templates used as well as part of the work in progress. Despite this scaffolding, I got tired much more easily than normally from the effort of doing these spatial visualization tasks. I decided to stop working on this first object and instead begin carving on another, using the second half of the log. I purposely made this second piece less complicated, so that I would need less effort when imaging it.

At the same time as I experienced these visualization problems in the wood shop, I also started to experience spells of dizziness in other situations too. These intense spells, occurring about once a week and lasting only five to 15 minutes in the beginning, were accompanied by disturbances in my right visual field and I had the perception of my right hand being dislodged 15 centimetres to the left from its actual physical location. Within the next month, I was diagnosed with a brain tumour. As I was to find out later, an oedema covered my sensorimotor and visual cortices as the tumour grew in the left parietal lobe of the brain, all of which are central parts of the neural correlates of visual imagery vividness (Fulford et al., 2018) and mental rotation (Zacks, 2008). Shortly after

Figure 11.2 Purkinje #2 in-progress and a paper template used as a scaffold to aid in mental rotation, January 2018. Photograph by Marte S. Gulliksen.

the surgical removal of this tumour, both the dizziness spells and the error in sense perception were gone and my mental rotation skill was restored. The experience was naturally shocking; however, my method for recovering from this experience was to do what I love the most and so I returned to finishing both sculptures that I had left unfinished (cf. Gulliksen, 2023).

In the video and audio data of woodcarving that I, as a craft researcher, collected from this post-surgery period, one main topic for me was about explaining how "natural" it felt to do mental imaging, to do spatial visualization, and to mentally rotate objects. If these abilities had not been temporarily gone, I would never have realized that they were skills I normally mastered well. They were elusive and only became apparent to my conscious self when they were absent.

In the years after these first two intense months, I continued to study my own spatial visualization ability and to train my mental imaging skills. To date, I have finished six single and three interlocking sculptures in *Purkinje Series*. As seen in Figure 11.3, the forms in the series have become increasingly more complex – from the fourth sculpture, the dendritic branches have begun moving freely over and under one another. Purkinje #7 and Purkinje #8 have two interlocking parts, a "bottom" and a "lid" for the centre "nucleus" bowl, each made from one singular log. Purkinje #9 is also an interlocking form but has three parts and two hollowed out bowls or "nuclei". All three parts are made from one single log.

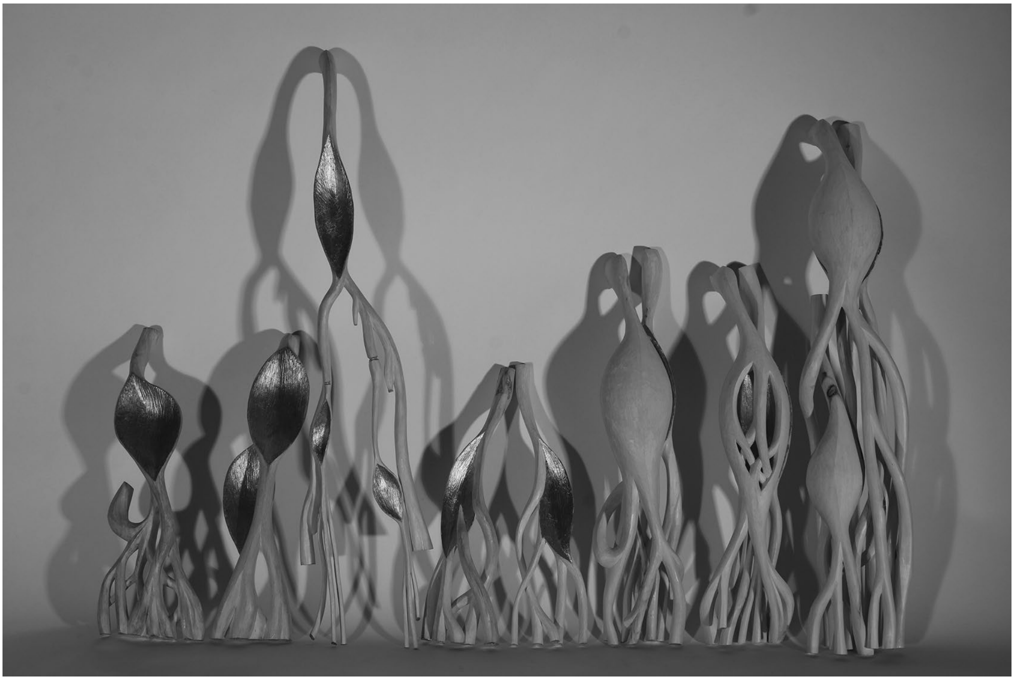

Figure 11.3 Purkinje Series, from left: Purkinje #2, #3, #4, #5, #6, #7, #8, and #9, carved in 2017–2021. Photograph by Marte S. Gulliksen.

In the last period of this case example from February to September 2022, I carved sculptures inspired by the star-shaped astrocyte cells that live adjacent to the Purkinje neurons in the brain. In this series, I took three-dimensional mental imaging to its extreme, carving out star forms across the grain of the wood. These objects are also carved from one log and are split into two parts: a "bottom" part with a "lid" part on top (Figures 11.4 and 11.5). The cancer has not yet come back despite the gloomy outlook, and I have managed to carve these complex forms without any major problems.

Discussion

In our woodcarving case, Marte reported losing her ability to visualize what she was doing in three dimensions and said that she "got lost". This incorporated *both* her ability of carving in the physical world *and* that of forming and maintaining the mental image of what the form should look like and how it would look when turned, in her "mind's eye".

More specifically, she experienced problems when attempting to mentally rotate the piece she was working on. She could not act on this lack of "grip" on the situation as it was a physiological condition she could not change. Her most acute problems occurred when she turned the wood to see it from the yet uncarved backside and needed to visualize how to carve it in order to correspond to the shapes on the front and how they would move and turn around on the backside.

Marte usually experienced quite vivid imagery and was confident in her ability to mentally imagine shapes when working with wood. That was also her inspiration and the reason why she began such a complex task – she liked to challenge her skills in this

Figure 11.4 Astrocyte #1 and Astrocyte #2, both carved in 2022. Photograph by Marte S. Gulliksen.

regard. However, when this ability suddenly disappeared, she was surprised. The fact that she was surprised is a relevant point, as even though she knew she was competent in mental imagery, she was not consciously aware of the ability as such – this was just a part of who she was. When the skill returned, she felt it natural to be able to do mental imaging as before. She could realize that she had such an ability only because it had temporarily been missing.

There is now research documenting that the cognitive process of mental imaging plays out differently for different people. For some, such mental imaging is vivid and almost like viewing an internal video where you can move around and zoom in to see details. Others have aphantasia, meaning that they do not experience internal images at all (Fulford et al., 2018; Zeman et al., 2010). In-between these types, humans live with their varying degree of abilities to visualize or imagine something that is not there right now or yet (Kind, 2017).

Doing mental visualization is generally a complicated and exhausting task; however, much mental imaging skills can also be *trained* (Moreau et al., 2012). The trainability of such skills is relevant to understanding mental imaging as an embodied process in design practice. For example, when spatial modelling can be trained through neuroplastic processes, it is likely to assume that the experienced wood carver or ceramicist would be skilled in their mental imaging of carving or throwing, similarly to what is found in Maguire et al.'s (2000) well-known example of taxi drivers in London who had an enlarged part of the hippocampus related to spatial navigation, or Elbert et al.'s (1995)

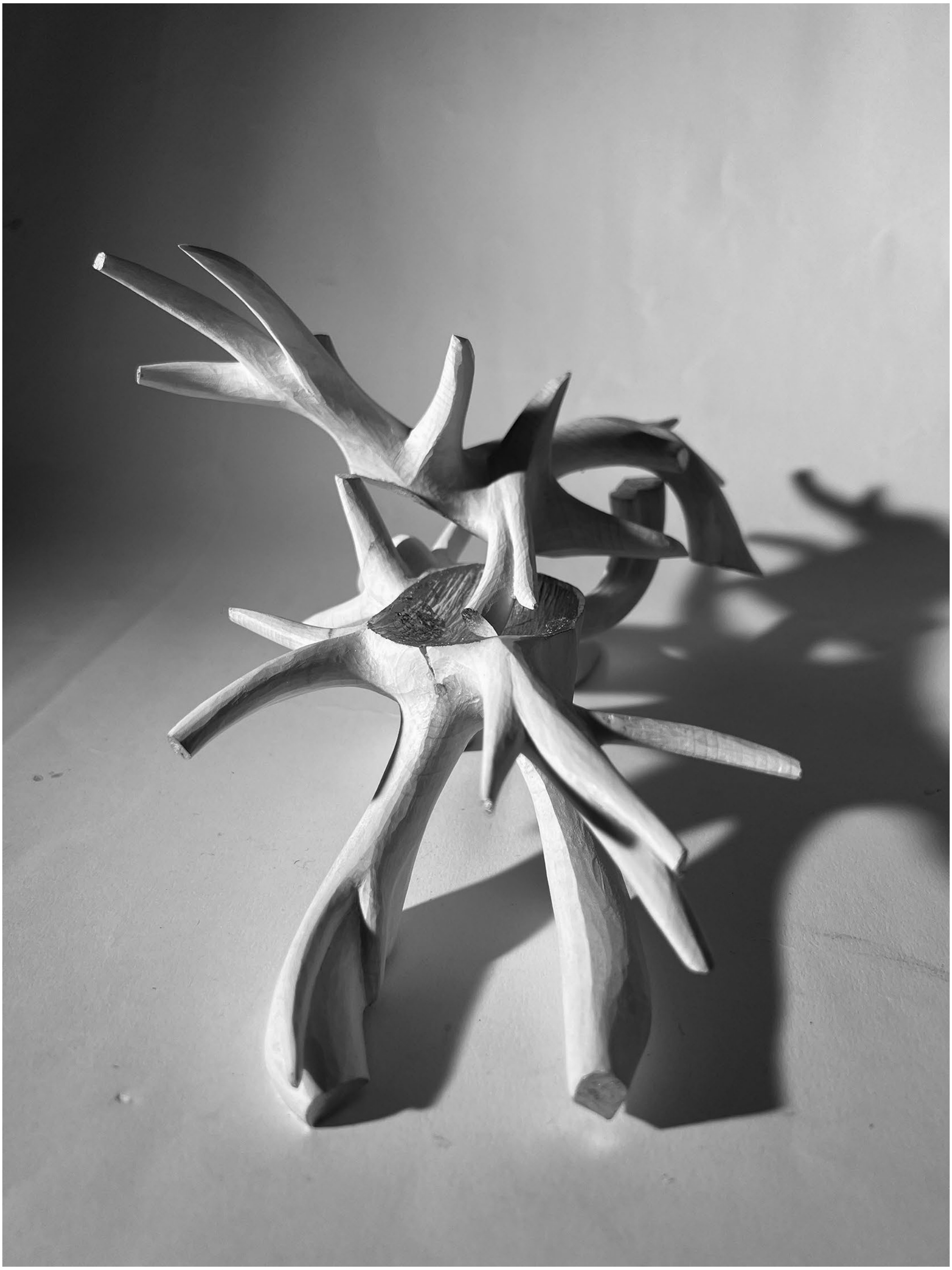

Figure 11.5 The side view of Astrocyte #1 showing an open "lid". Photograph by Marte S. Gulliksen.

study of string musicians who had increased cortical representation in the areas tasked with sensorimotor activity in the left hand. Pietsch and Jansen's (2011) study even finds that people who often do physical training or play a musical instrument are better at mental rotations too, just because they activate similar skills in their other hobbies. Based on these studies on neuroplasticity, we would expect differences in individual practitioners, as every maker has unique life and making experiences that consequently change their plastic brains.

In our extreme case, Marte employed deliberate, external techniques to "keep in mind" and remember what is on the other side of the object since her working memory could not support her mental rotation. She drew lines on the physical object to hold her ideas, and when that failed, she created a template on paper. The physicality of the template provided a kind of mental crutch or scaffold, grounding her mental rotation in a physical world and making the rotation of the mental image tangible. Although this paper template only held information in two dimensions, it sufficed, at least to the point that she could continue the process of carving, thus offloading her strained mental capacities and offering a way forward through epistemic action (Kirsch & Maglio, 1994). By doing so, she explored the environment for opportunities to distribute her cognition to a physical object which could facilitate her process (Clark & Chalmers, 1998; Kirsch & Maglio, 1994). Things like paper templates are used to scaffold cognitive tasks both individually and in groups (for a discussion of the use of physical objects to scaffold sense-making in groups, see van Dijk's Chapter 13 in this book).

Experiential knowledge is needed in the imagination and ideation processes of new designs

As mentioned earlier, experiential knowledge of material properties and affordances are important for a successful ideation process that yields realistic outcomes. This includes recalling not only a mental image but also physical properties and social connotations of materials and their feel in the selection of materials for a design. For example, Groth and Mäkelä (2016) documented a student reporting, "I was imagining mostly in my mind what the different materials would look and feel like" (p. 16). The student in question had prior experiences with other materials, due to a previous artisanal degree, and could bring the experiences to the forefront of her mental imaging and use them to choose materials. However, another student in the same group was unable to imagine how the materials he planned to use would work and as such failed to make a concrete artefact based on his idea. This second student admitted he had very little prior experience with making anything in material (p. 18). This thought about the importance of experiential knowledge in imagination and ideation processes is supported by Koukouti and Malafouris' (2020) understanding of material imagination and the relation between the craftsperson's knowledge of material affordances and the real world that is present even in the craftsperson's imaginative wanderings.

Knowing that some of our mental imaging abilities are malleable and thus possible to train and develop, there is no surprise that some people are better than others in different practical skills. Another issue related to how we access this prior experiential knowledge when doing mental imaging is that, even though it is always available, it might not always be accessible to our conscious selves. What steps could we do to support access to such types of elusive knowledge? Studies in other fields, such as gestures, have found that if subjects had their hands restrained from doing physical movement, like making gestures or manipulating objects, they score lower in mathematical thinking and verbal accuracy (Novack et al., 2014). Similar studies have been done within design and craft; for example, if we give students materials to think with, they get more concrete in their discussions, both when working alone and in groups (Härkki et al., 2016). This suggests that priming with material would help enacting and accessing experiential material knowledge in the process of imagining possible constructive solutions or ideation and gaining an "optimal grip" on the situation. The need for scaffold-thinking through external physical aids is especially clear in research into children's craft and design processes (Kangas, 2014, p. 61), as they have generally less experiences with material interaction. However, this is equally important for design students (Lawson, 2004).

What does this mean for design education?

Understanding the embodied nature of the phenomenon of mental imaging is critical in today's digital era. The materiality of our environment is changing rapidly, and virtual 3D designing and making processes are becoming the norm. Now, any designer can use 3D artificial intelligence (AI) that allows for the creation of unimaginable images and 3D shapes. However, when it comes to designing utensils for use in our daily life that we handle physically, tangible aspects, such as tactile feel of material surfaces, weight, balance of the piece, and thickness or thinness of it, make a difference for the quality and feel of the product. While digital tools such as 3D programs aid mental rotation, they do not help novice design students anticipate the "right" feel, weight, or size of their designs. If the experiential knowledge of materials is not gained before starting to design in a virtual space, it poses challenges for the mental imagination of the experiential aspects of the design, as the reality of materiality can come as a surprise. Digital tools are also only as accurate as their designers, meaning that the programmes also build on the designer's ability to mimic the real-life experience (Hengeveld & Frens, 2013).

Ramduny-Ellis et al. (2010) worried already more than a decade ago about their students' material knowledge and real-life material interaction skills in relation to the new virtual reality that their design students face. They said, "as hybrid physical/digital products are developed, designers have to understand what is lost or confused by this added digitality and so need to understand physicality more clearly than before" (p. 51). This perspective reveals the necessity of experiential knowledge that is gained through the making of physical prototypes in an iterative manner, even when using CAD tools (Kempton et al., 2017).

Strand and Lutnæs (2022) described five strategies that a teacher can use to support students' development of mental imaging in architecture, or what they call "spatial literacy", including (a) "facilitating embodied experience", (b) "activating memories and dialogue on spatial relationship", (c) "encouraging three-dimensional visualizations", (d) "introducing points of reference", and (e) "connecting floor plans to standards and measurements" (pp. 43–49). Although Strand and Lutnæs did not address EC as such, these strategies incorporate embodied experiences and material interactions, helping novices to cope with the complexities of their designs. Also, Lawson (2004) specified how novice designers differ from experts, in the way that experts can utilize their matured "schemata" and "gambits", which novices have not yet developed, to solve problems.

Such stored repertoires of experiential knowledge and well-tested ways of doing things that experts have built up over time underlie their ability to imagine design situations realistically (See also Baber, 2021, pp. 168–169; Rietveld & Brouwers, 2016).

Consequently, sufficient experiences of material explorations leading to experiential knowledge of material properties and affordances help novice designers and craft practitioners visualize their design or craft ideas better and more realistically before and during their making, even when using CAD or other 3D modelling programmes. The current trend of replacing physical workshops with computer-aided tools and software might be cost efficient but does not help students get the correct training and exposure to materials and their resistances, affordances, feels, and atmospheres.

Conclusion

In this chapter, we have presented theory and an empirical case example of how visualization, mental imaging, and mental rotation play a major role in design and craft practices. However, we have also found that individuals vary in the degree of ability or skill which depends on their prior experience and that mental imaging skills and visualization can be trained. Based on the case presented, we show that this skill can be lost because of an injury or illness – a loss that may be permanent or temporary pending the nature of the injury. There are also several situations in design and craft practice where mental imaging and mental rotation are not enough and where scaffolds or externalization of mental capacities or tasks are needed, even for healthy individuals. For example, for children who have relatively less experience of manipulating materials and visualizing shapes, such external scaffolding might be useful.

The understanding of how important this ability is for design and craft processes makes it necessary to allow students to train such abilities through sufficient material manipulation, rather than move on to using computer supported aids too soon. While 3D and CAD software can do all the mental rotations we need, this technology is also limited in its interface and affordances and does not allow for multimodal aspects of imagining materials and their feel. The immediacy and the ease with which the proposed materials and designs are produced in such programs might actually be deceiving for novice designers who do not have enough real-life experience with material resistance and construction. Further research into the topic of the influence of new technology on and the implications of making realistic mental images and visualizations is necessary.

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12 Making bumps and jumping hurdles

Understanding resistance in the processes of raising aluminium from a novice's perspective

Anniken Randers-Pehrson

Introduction

"It is hard to be a ceramicist", a girl in the eighth grade uttered with a sigh, pinpointing the sense of hard work she was experiencing while making a teacup in her arts and crafts class at school. In research, craft making is often described as a satisfying, health-promoting activity that is related to wellbeing (Gulliksen, 2023; Kirketerp, 2020; Pöllänen, 2009; Pöllänen & Weissmann-Hanski, 2020). For example, in the Norwegian government's strategic documents and in the formal curriculum, the word *skaperglede* (translated to "joy of making") is highlighted as a basic value for individuals of a society and as an integral part of the arts and crafts school subject (Kunnskapsdepartementet, 2019; Utdanningsdirektoratet, 2020). Joy of making denotes pleasurable, fulfilling, and, most of all, positive aspects related to material engagement in a craft process. This is of course all good, but a sole focus on these aspects may lead to craft making being understood superficially as an easy, non-demanding, and recreational activity. In the practices of the Norwegian school, subject of arts and crafts, making is sometimes described as taking a mental pause or break from a theoretical strain (Randers-Pehrson, 2016, p. 3), thus suppressing the fact that making is a learning process that may be quite demanding.

In the last century, Dewey (1934/2005) proposed that the element of *resistance* is an important aspect of learning. While learning involves reconstruction, it also entails suffering (p. 46). As such, learning and achievement require hard work (Manger & Wormnes, 2015, p. 13; Nottingham & Buli-Holmberg, 2012), and overcoming some sort of resistance may be understood as a prerequisite for it. At the same time, if resistance is too strong, the process can grind to a halt (Sennett, 2008, pp. 219–220). Also, within literature on wellbeing, makers' experience of hardships is recognized (Gulliksen, 2023; Huotilainen et al., 2018) and productive creativity is not just the experience of being in flow but also requires successful working through temporary obstacles and frustrations (Seitamaa-Hakkarainen et al., 2013). Learning to work well with resistance is thus important for making and learning in craft and has inspired me to explore the encountered resistance in craft making processes. Negative experiences, due to repeated mistakes, may cause disappointment and emotions of failure (Sennett, 2008). However, the exploration of problems and challenges caused by material and lack of expertise from an insider perspective may yield knowledge and further insights into how to cope with resistance. The research presented in this chapter therefore aims to gain a deeper understanding of resistance involved in a making process by asking the following question: What types of resistance does a novice experience when raising aluminium?

DOI: 10.4324/9781003328018-19

Figure 12.1 Working from metal sheet to a 3D form. Photographs by the author.

In the study, I map out my own experiences of resistance when learning to raise aluminium in the purpose of detecting possible concepts to describe these experiences in depth. Knowledge constructed within the study is applicable to the field of craft research and that of arts and crafts education. The study touches on and explores the maker's intimate experience with material in a creative material exploration.

Raising as technique: a brief description

Raising metal requires the following basic tools: hammers, anvils, and stakes. Hammers come in different sizes and with a variation of hammerheads that can be selected for use, depending on desired effects. The same goes for the anvils and stakes. Professional silversmiths often make their own tools to suit their purposes and intentions of raising metal (Longhi & Eid, 2013). In general, raising is a technique that involves hammering flat metal sheets (commonly silver or copper) into a 3D form (Figure 12.1).

Two basic raising techniques are crimp-raising and angle-raising. In crimp-raising, the metal sheet is first crimped and later smoothed. In angle-raising, the hammer moves the molecules inside the metal sheet while it is held at specific angles against the anvil. In addition to hammering, annealing is a process of heating metal to the right temperature and then cooling it off – this is vital to restructure tensions in the metal. Annealing enables working on one item for an extended period. Working the metal from a flat sheet to a 3D form requires numerous repetitive hammer strokes and annealing processes.

Making processes

In this study, I am not raising metal in order to produce traditional craft objects in the same way as craftspeople do in their studio or workshop (Adamson, 2007; Risatti, 2007; Sennett, 2008) where the maker, materials, workshop, and material culture participate in a conjoined venture reshaping and transforming material matter. Rather, I use the term *making* to signify an explorative and creative approach, in which I document my experiences of resistance as a novice.

I use aluminium sheets and engage with them using hammers and anvils, as the extensions of my body, to move molecules in the acts of pressing and pushing the metal. In the process of making, things, matter, and actions are present and intertwined and may be understood on a micro-, meso-, and macro-levels. On a micro-level, making is concerned with the material agency (Malafouris, 2019, 2020), the actions between the molecules and me, and how I respond, make sense of, and react to the resistance I get from the aluminium. On a meso-level, making is seen as holistic craft practice where the maker is responsible for the entire process from ideas to the realization of material things (Pöllänen, 2009). At this level, the process of making raises a question of the relationship between designing and making. Ingold (2013) emphasized the correspondence between maker and material as opposed to the idea that designs may be implemented in hylomorphic manner. Instead, "hopes and dreams" are guiding ideas and imagery for making processes (p. 71). This entails recognizing and embracing making as a conjoined merging of maker and material. On a macro-level, in this study, making is an act of making "a thing into something" (Alexandersson, 2007). Through material engagement, the process of shaping and making things turns the things themselves into matters of significance, something meaningful for the maker (Alexandersson, 2007; Schofield-Tomschin & Littrell, 2001). In this study, the process of making is seen not only as enactive, embodied, and extended ventures in and on these three levels but also as intertwined "thinking and feeling with things and form-generating materials" and thus a kind of "thinging" (Malafouris, 2014, p. 144, italics in original).

Resistance in making processes

Resistance in a making process may be experienced when tensions of some sort interrupt the general flow of actions. As such, resistance signifies situations often described as "problems" (Sennett, 2008), "stop-points" (Grønningsæter & Østern, 2019), or "critical incidents" (Flanagan, 1954) that may arise in different stages of a process. Resistance has been described further in craft literature, for example by Sennett (2008) as *found* and *made* resistance. Sennett contended that found resistance resides in the material properties and stands in the way of the will of the maker (p. 215). When transforming a material from one shape to another, the maker meets and works with the material's agency (Malafouris, 2013, 2020). In the proximity between the maker and the material, tensions and disruptions relate to the maker's embodied knowledge and skills. Working against the material's agency may create severe resistance. According to Eisner (2002), it is necessary to develop sufficient skill, a feel for the material, and an ability to cope with problems throughout the creative process; his notion for this is to develop an "intelligent hand" (pp. 96–97). Sennett's (2008) concept of made resistance relates to how the maker puts obstacles in the way (p. 215). This entails that the maker in fact makes things more complex and difficult in order to pursue novelty. Enhancing the level of creative exploration is the aim of made resistance, which Sennett proposed as an investigative technique and as a creative strategy (p. 225). Made resistance links to how the maker explores different solutions and searches for other or new possibilities when the work seems too easy (p. 222). In this chapter, made resistance specifically refers to how the maker adds difficulties to their creative exploration in relation to their abilities and, in many ways, willingness to challenge themselves and to pursue creativity and novelty in making.

A third way to look at resistance is from a more psychological viewpoint where resistance is connected to the maker's emotions and feelings, and thus the intimate making experience. Niedderer and Townsend (2014) described intimacy, affinity, and emotions as essential characteristics of craft. According to Huotilainen et al. (2018), craft offers a means to reach flow, which can help regulate mental states and manage emotions (see also Niedderer and Townsend's chapter in this book). Craft also plays an important role in controlling stress and enhancing relaxation. Additionally, craft provides an arena for safe failing and recovering – thus building resilience. Nevertheless, in creative practices, makers may also be learners stepping out of their comfort zone into new and unknown territories which may lead to negative emotions. Makers may experience a gap between their intentions and the result that may bring about feelings of disappointment when the two are not aligned (O'Connor, 2007). Loss of motivation is linked to the severity of the task and a sense that the results are not coming about as planned (Seitamaa-Hakkarainen et al., 2013, p. 15).

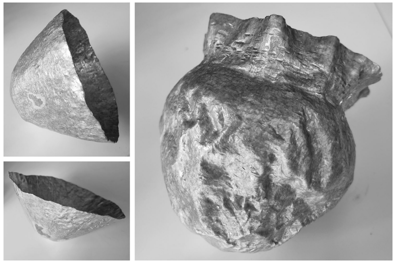
Raising aluminium as an autoethnographic and practice-led study of craft experience

The study adopts an autoethnographic approach in the framework of practice-led research. This means that knowledge is constructed through reflecting on the practice itself (Candy & Edmonds, 2018); in this case, the creative and material practice of raising aluminium. According to Karlsson et al. (2021), subjective experiences are central sources of knowledge. Autoethnography merges the researcher's position with their personal experiences as a practitioner from an insider perspective. This, in turn, helps link the personal perspective with the wider community of practices as well as the construction of knowledge in-between personal experiences and scientific knowledge (Karlsson et al., 2021). To construct knowledge about the experience of resistance in craft making, acts of making and acts of thinking are viewed as inseparable and intertwined (Malafouris, 2020, p. 108). Research through creative practice allows for experiential and embodied knowing from inside the practice to be documented, analysed, and distributed in a way that an objective or distant approach will not facilitate (Riis & Groth, 2020).

To study resistance as a phenomenon, I decided to construct a purpose-made research situation. Firstly, I chose to use aluminium as material and raising as technique. This was expected to create a situation with enhanced resistance for me as I had some basic knowledge of raising acquired several years prior to the study but no prior experience working with aluminium. This created a framework where I considered myself a novice (Dreyfus et al., 1986). Secondly, I chose to work on my own without a teacher or tutor to guide or help me in the workshop. This allowed for a learning environment rich of challenges with no one to explain or show how to perform the craft, and thus an enhanced level of experienced resistance. This was considered an advantage since it provided an opportunity to conduct a phenomenological study of what resistance feels like in a raw form.

The research process consisted of three cumulative making projects (see Table 12.1). It started with exploring if aluminium was suited for raising in the first project and was followed by two other projects. The three projects differed in their aim, but together they provided insights into the ebb and flow of resistance as a phenomenon in craft making. Project 1 aimed to test aluminium as material for the raising technique while the intention of Project 2 was to test skewedness as a concept of expression and that of Project 3 was to transform rigid metal into organic form. Data was gathered through video recordings combined with reflections and think aloud accounts (Groth, 2017, 2022). Before and

Table 12.1 Overview of the three projects and the data collected and used in the analysis

	Aim of project	*Results of raising*	*Pages of thick description in the project report*	*Hours of video*
Project 1	Testing aluminium as material for raising technique		28 pages	3 hours
Project 2	Testing skewedness as concept of expression		46 pages	15 hours
Project 3	Transforming rigid metal into something organic		11 pages	5 hours
	Total	8 objects	85 pages	23 hours

Source: Photographs by the author.

after a making session, I was recording my reflections by talking to the camera about my work, my anticipations, and my feelings. While working, I continued video recording my actions and I was thinking aloud whenever I had anything to say about the work. This resulted in a total of 23-hour video data from the making processes. The first analytical step was to write a report of each of the three projects. In the report, transcriptions of all spoken words in the think aloud accounts, written interpretations of the work observed, and screenshots from the videos were constructed into a thick description (Geertz, 1973) of the material engagement while raising aluminium (Table 12.1).

The second step of analysis was to comprise and sort the data. After the process of transcription and inductive coding in Nvivo, I sorted the data into 12 themes. Five of these stood out as relevant to understanding resistance: insecurity, bodily strains, negative emotions, technical problems, and evaluation. These themes also had most codes of all 12 themes. After a process of refining and resorting the themes, four relevant concepts emerged: not knowing, bodily strains, frustrations, and doubts. Even if the themes and findings emerged from the data, the process of research was based on abductive reasoning (Riis & Groth, 2020), a dialogical back and forth movement between the data and theory as well as much time spent lingering with the data to understand and make sense of resistance in the making process.

Making sense of resistance in making processes – presentation of findings

Resistance in making has been previously described in this chapter through Sennett's (2008) concepts of *found* and *made* resistances. This section presents the findings of my experienced resistances that I discuss from my embodied perspective. Not knowing, bodily strain, and frustrations emerge from my encounters with found resistance and its connection to material agency. Doubts are experiences of emotional character arising from the acts of made resistance.

Experiencing not knowing due to technical problems and insecurity

Technical problems and insecurity related to technique were the most recurring themes describing resistance in the data. The two themes were merged because of their connection to experiencing a lack of knowledge in the making process. The lack of knowledge manifested in a constant effort to understand the logic of the task and material properties and to seek a better next step in the process. During the three projects, it was possible to track some recurring errors in the work, e.g., the making of folds in the sheet created marks and unintended bumps in the surface of the aluminium as well as deformed the outer edge of the sheet. The data disclosed a constant negotiation and discussion of what to do and which choices to make and also revealed that I did not have a clear vision of what I wanted to make. It seemed that I was engaging with the material, trying to figure out its potential which could refer to technical aspects of how to work with the material and how I could bring about creative and expressive features in the 3D forms.

The aspect of not knowing was related to getting stuck, showing insecurity about how to proceed. The lack of prior experience contributed to understanding aluminium's response as an unexpected behaviour and created puzzled feelings, e.g., when I sensed the softness of the material and how the hammer strokes "sat deep" in the surface, or when I felt surfacing anxiousness as I tried to avoid hammering folds into the surface because this might lead to cracks and holes. Utterances like: "It is like it curls up in all directions and I have to straighten out bumps from the inside" gave insights into how my untrained hands were unable to handle the material resistance. Sometimes technical problems brought about unintended consequences, showing that the maker's actions were not based on a solid ground: "It seems as it is just maltreated. I started up here". I pointed with my finger at the edge of the bowl: "and now it is like something is popping out underneath". Several critical points were related not only to how I tried to understand what was happening but also to my insecurity about what the next step should be. Utterances like "I'm not sure if I shall continue or if I shall anneal at once" and "I am trying to make it stand … but how do I do that?" were examples of my experiences of insecurity related to how to proceed with the making process. The process entailed a lot of guesswork, and it seemed as if the making process evolved around testing and retesting to "get a grip" of what I should do next to interact and correspond with the material properties in the best way.

Experiencing bodily strains due to the physicality and hard work

Several instances in the data showed how I dried sweat off my face or took off my jumper to regulate my body temperature. Once I interpreted the hammering as being inveterate, and sometimes the video revealed my tensed body, as I was biting my jaws together and continuing working without talking. Examples of bodily strains were also present in the think aloud accounts: "This is a very uncomfortable position to work in". Working with aluminium was repetitive hard work and involved many unfamiliar body and hand positions. In the video, I could see myself stop working, shaking my wrists, and uttering: "I think it is because I get so many strokes back in my hand that makes it difficult to hold". Simply holding the sheet of metal in the right position to the anvil put my coordination skills to test. It required strength and the ability to hold still and to move the metal continuously in a controlled manner over the anvil. Several utterances were related to the experience of hard work: "It is very hard to work here", showing with my hands pointing at the metal sheet: "Super hard". The process of raising aluminium was physically hard and challenging, and it seemed that I needed to get acquainted with what was required, including how much force to use, how to regulate the force, and how to find solutions to avoid the hammering causing me physical aches and pains.

Experiencing frustrations due to time and the slowness of the process

The data provided insights into the issues of coping with the slowness of the process. When creating a sphere shape, many rounds of hammering and annealing needed to be done. Each round pushed the shape a bit upwards, but it was slow work, as I experienced when I measured the sphere after yet another round. I made a drawing of the outer edge for each round to enable me to track the progress and said: "That was not much – that was not much. That was disappointing. I thought I got it further inwards – boooh – mmmm-maybe bit more – a bit more… phew". The utterance provided insights into the sense of time and growing frustrations when the hard work was only merely visible, and progress was slower than I expected. Another utterance showed a growing restlessness about time: "I feel I start to get impatient. It takes time, indeed, to work the form up as I want to". The data captured the work-in-progress from a flat sheet to a vessel, and this was about getting past a phase of groundwork. The repetitive process of hammering round after round created frustration and impatience, as each round of hammering only slowly progressed.

Experiencing doubts due to disappointment and a continuous evaluation of the work

It was evident in the think aloud accounts that doubts were activated in Project 2 and escalated in Project 3, mostly before or after a working session. Such comments of doubt were rarely uttered while working. The reflections showed a growing concern about my abilities as a maker and the possibility of failure, as a potential outcome was surfacing. The utterance "It is nothing. It is nothing" pointed to my judgement of the work as having no value. The next utterance: "I am not sure if I will ever get there" revealed an urge to get "somewhere" or to achieve "something" but also a worry that this would not be attainable. The utterance "I sense a kind of worry, so I get to the point where I can close it … I can make a shape, but then 'so what' – that is a challenge" displayed troubling emotions that evolved as my scepticism towards the initial idea grew when transforming the idea into material existence. I evaluated the work as a failure since it failed to achieve the features of my inner vision of material expression. What surfaced were not only severe disappointment of the emerging results of my hard work but also a poor alignment between the image and vision of the desired result and what I was able to bring into physical form. The gap between the initial hopes and dreams and the emerging results questioned my making as a meaningful action. The negative emotional state was elevated throughout Project 3, as reflected in the last entry of my data

> Can something good come out of this? It's torn. It buckles. It almost looks like a paper bag being squeezed together. I laugh for myself. The worst thing is that I in fact think it became a bit cool. My voice sounds almost shameful.

Discussion: resistance in making

For this discussion, I now return to my research question of what a novice's experiences of resistance in raising aluminium might be. My study suggests that resistance is a regular and continuously recurring phenomenon that is experienced in relation to material properties. When the material is new to the maker and unexpected problems occur due to new situations not being handled correctly, the maker's insecurity over technical issues can elevate. While some problems can be easily dealt with, some others need more attention. The four types of experienced resistance – not knowing, bodily strains, frustrations, and doubts – are encountered in all the three projects in various degrees. One interesting observation is that although the experience of not knowing is present in all projects, in Project 1, even if numerous problems and stop-points evidently interfere the general flow of the work, experienced resistance is hardly mentioned. The experience of resistance of a negative emotional character surfaces first in Project 2 and develops further in Project 3. Both frustrations and doubts are experienced as severe, ultimately resulting in feelings of failure. Not knowing as an experience of resistance in the making process is present throughout all three projects and is unfolded through the complex process of raising aluminium. One emerging question is: What does resistances entail for the novice's process of learning the craft?

In my study, I find that resistance in general activates a continuous stream of embodied reflections, speculating on what is a better action that propels efforts to uncover ways to work intelligently with the material (see also Eisner, 2002; Sennett, 2008). The working process seems to be a constant exploration of the material, and the handling of tools in relation to it. It is an ongoing reflection-in-action exploration to understand and get to know the material properties and possibilities (Schön, 1992). This way of engaging may be understood as a "dance" between the material and me (Knappett & Malafouris, 2008, p. 34). The consequence of not knowing brings forth a sense of lacking control, manifested through testing and retesting, and a constant search for possibilities to solve emerging problems. Most of the time, the aluminium might be said to lead the dance. The dance in Project 3 turns sour when the relationship between the material and me resembles a fight more than a dance. Materials are not simply enabling, they are also constraining (Knappett & Malafouris, 2008), and there are limits to how far an untrained hand can push and impose ideas of form and expression on a material. Not knowing, as an experience of resistance, is nevertheless the most important aspect in the act of learning, and novices will, of course, frequently encounter situations in which they lack control and make more mistakes than competent makers. The process of raising aluminium thus evidences a growth of competence, while some aspects of raising seems to sink in as silent knowledge along the way (Polanyi, 1967). The application of higher levels of complexity, first in Project 2 and thereafter even more complex in Project 3, shows that I wanted to achieve more than what the aluminium was ready to give at that particular time.

Two other important experiences of resistance are connected to frustrations and bodily strains which are closely interwoven and will therefore be discussed together. The issue of time becomes a stressful and frustrating experience of resistance. Craft processes are time contingent and related to a goal or task. In Project 1, for example, the goal is to find out if it is possible to raise aluminium as other metals, so the timeline for this specific process lasts until this goal is obtained. This goal is achieved quite quickly by experimenting with the material that is then transformed into a resulting object (see Table 12.1). Sennett (2008) discussed the difficulty of judging time, arguing that in most work we estimate how long time it will take and then "resistance oblige[s] us to revise" (p. 221). In raising aluminium, it is difficult to observe how the shapes are evolving in each round of hammering. While the work demands executing force and the material's inherent traits are rigid, I am challenged by aches, pains, and impatience. Long phases of repetitive movements and the slow progress of the work create a form of conflict between the experience of bodily strains and the estimation, or perhaps better, the expectation of how much time and effort is needed to reach the goal. The slow progress of the shaping and the efforts that cause aches and pains seem to collide and thus hinder a temporary suspension of "the desire for closure" (p. 221).

The strongest and most profound aspect of experienced resistance in this study relates to the feelings of failure when a wanted and valued results do not seem to emerge. This is closely connected to the identity of being a maker and how the work is defined and evaluated. In this case, I am my own gatekeeper; I am the only one evaluating the results of my work. In educational or professional craft settings, there are other gatekeepers evaluating the work. Ingold (2013) described *hopes and dreams* as initial guidelines for creative work, but a gap between hopes and dreams, and negative evaluations of the results might arise when these expectations are not met. O'Connor (2007) expressed her experience of such a gap when her expected result and the actual one did not align, and this causes stress and disappointment. Making craft is about transforming material matter from one state to another, and these are not value-free actions (Niedderer & Townsend, 2014). Gatekeepers pass their judgements of the work regarding how it conforms to perceived cultural or personal expectations. This, in turn, may induce negative emotional responses in the maker. In this study, resistance clearly increases when my hopes and dreams seem to be out of reach. A significant change can be seen in the transition from Project 1 to

Project 2 when I set up a goal of raising skewed shapes and thus create an enhanced level of technical problems due to more complex intended shape and expression. A gap between my hopes and dreams and my skills therefore emerges (Ingold, 2013).

The lack of an intelligent hand (Eisner, 2002) and poor knowledge of the chosen material shift problem-solving to a series of guesswork. In this case, the expectation of a valued result activates the critical gatekeeper in me so that I keep a close eye on the work in progress and criticize the outcome. Gulliksen's (2023) study on craft as a way of coping proposes an emotional connection between the "maker" and the "made" as an important issue of craft as promoting wellbeing and joy. According to Gulliksen, such a connection provides "meaning and purpose to my situation" (p. 7). In her case, the emotional connection to what she was making took on a new meaning in a precarious situation. A positive emotional connection between the maker and the made artefact therefore seems to be an important aspect of coping with resistance. In my making process as a novice, it seems that a positive emotional connection to the emerging results becomes broken and that my sense of making "something" is lost along the way (Alexandersson, 2007). One difference between Gulliksen's and my own situation lies in the description of competence and knowledge in the craft. She emphasizes previous knowledge and ambitions in woodworking as key, as they enabled her to continue "even when it was hard" (Gulliksen, 2023, p. 8; see also Gulliksen & Groth's chapter in this book).

Ambitions and the urge to make something of value may contribute to elevating unforeseen complexity of the making process for a novice, and this, in turn, may heighten experienced resistance because ambitions are exceeding the level of expertise. As such, made resistance (Sennett, 2008) raises a question regarding ambitions and a balance between skills, effort, and the sense of meaningful action in making, especially for a novice, who strives to bridge the gap between hopes and dreams, and material results.

Summing up: a novice's experiences of resistance

This study provides insights into a novice's experiences of resistance in the processes of learning to raise aluminium and knowledge about troublesome aspects that may occur in such learning situations. Resistance is, as Dewey proposed over 100 years ago, part and parcel of any kinds of learning, and is not to be beaten down or avoided. Understandings and verbalized knowledge about the possible bumps and hurdles for novices learning a craft skill (and perhaps for more advanced craft makers as well) may help identify and develop strategies to correspond (Ingold, 2013), not only with the material, but also with the experienced resistance. For this study, resistance in the processes of raising aluminium can be summarized based on four interrelated experiences and challenges, including not knowing, bodily strains, frustrations, and doubts. On this basis, I propose that resistance resides amidst material agency, skill, ambitions, and stamina. Ambitions and stamina are workable factors while material agency simply needs to be embraced. Skill grows through overcoming these resistances.

In the aftermath

In this study, I worked in the workshop without a teacher or a tutor. This created an extreme situation for material engagement for a novice and heightened troubling feelings to a maximum. In the end, I lost motivation to engage in raising aluminium for an extended period. At the time of writing this chapter, I have seen the contours of the most forgiving element in the difficult situation and have thus got a grip on how to reformulate the project into further explorative engagement with raising aluminium.

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13 Making sense with things in participatory design

Jelle van Dijk

Introduction

How do people use things to make sense? Or, as David Kirsh (2010) put it: How do we “think with” things? How do concrete, material objects and settings *scaffold* (Mascolo, 2005) the ways in which we make sense of the world? As a cognitive scientist turned design researcher, I have explored this question for many years. I do so within the context of participatory design (PD) or co-design. PD is essentially a facilitated process of shared sensemaking, and concrete things play an important role in it (Van Dijk & Van der Lugt, 2013).

In a typical PD project, designer-facilitators invite stakeholders (in particular, end-users) to work on a design challenge, and to create a promising design in response (Sleeswijk Visser et al., 2007). In doing so, stakeholders bring their own, sometimes conflicting, perspectives and knowledge to the table (Simonsen & Robertson, 2013). Over the course of a PD project, often the original understanding of the challenge, as well as what is considered the best response to it, might both change considerably. Ideally, while working together, participants deepen their understanding of one another and, collaboratively, of the challenge and how to address it (Dorst & Cross, 2001; Van der Bijl-Brouwer, 2022).

Practically, PD often takes the shape of workshops in a dedicated space, with a facilitator guiding participants through the process. A variety of tools, props, and materials may be used to support communication and creativity (Sanders et al., 2010). As an illustration, consider a project where we developed a digital health app with patients (Austin et al., 2020). Figure 13.1 shows a moment in the project, with paper prototypes of various screens envisioned by the participants on the table. The physical order of the boxes, left to right, represented what the participants together thought would be the best information flow for the app. They reflected on the current proposal and its implications by pointing to the boxes and explored alternatives by physically re-arranging them. A scene like this suggests that participants readily use things, such as paper prototypes, to *think with*. Research in PD confirms this intuition: an established consensus within PD holds that sensemaking is facilitated by the joint creation and manipulation of things (Björgvinsson et al., 2012; Brandt & Grunnet, 2000; Buur et al., 2004; Buur et al., 2022; Ehn, 2011; Ehn et al., 2007; Frauenberger et al., 2010; Gaver et al., 1999; Robertson, 2002; Sanders et al., 2010; Vaajakallio & Mattelmäki, 2007).

Yet several interconnected questions remain. How exactly do things aid in sensemaking? What cognitive role do they play? Can anything be used to support collaborative sensemaking? Can a thing play any type of sensemaking role? Intuitively, we might suppose that there must be better or worse things to think with. But what, in the design of

DOI: 10.4324/9781003328018-20

Figure 13.1 A typical PD situation. Participants created cardboard prototypes, which now act as conversation pieces in a reflective conversation. Photograph by the author, taken with permission from Austin et al. (2020).

these things, makes for the difference? In exploring these questions, I use the word *things* as a pragmatic shorthand for concrete material objects and settings (e.g., markers and whiteboards are things; while abstract concepts like society and design method are not, pictures, diagrams, and canvasses representing those concepts are). The term *sensemaking* refers to what is traditionally called *cognition*, the practical ways by which people make sense of the situation at hand (De Jaegher & Di Paolo, 2007).

Embodied sensemaking

One interpretation, based on distributed cognition theory (Kirsh, 2010), portrays PD things as *external representations* (Norman, 2002). External representations help individual cognizers reduce cognitive load by offloading internal, mental processes to the physical world (the order of boxes in Figure 13.1 is an example). Furthermore, once content is represented in external things, other people can participate in this externalized sensemaking process as well, forming a potentially powerful distributed cognitive system (Arias et al., 2000; Hutchins, 1995). However, this is not all.

External representation is part of a broader perspective that I call *embodied sensemaking* (Hummels & Van Dijk, 2015; Van Dijk & Hummels, 2015; Van Dijk & Hummels, 2017). Drawing on phenomenology, enactivism, and embodied cognition, embodied sensemaking emphasizes how the body-in-action and the immediate socio-material environment (i.e., the lifeworld) are essential, productive elements in sensemaking. Embodied sensemaking rejects traditional cognitive theories in which sensemaking (cognition) is assumed to be a purely internal process in the brain (Clark, 1998; Hutchins, 1995). Instead, sensemaking is fundamentally situated (Clancey, 1997; Suchman, 2007); sense emerges as a self-organizing property out of the ongoing interactions between the body and its surrounding world (De Jaegher & Di Paolo, 2007; Di Paolo et al., 2018; Haselager et al., 2008; Van Dijk, 2018). This is relevant for design, given that much of this surrounding world is designed. If we have a deeper understanding of the embodiment of sensemaking, we may design things that support embodied sensemaking particularly well (Van Dijk & Hummels, 2017).

The idea that sensemaking in PD is embodied and situated can already be found in the earliest Scandinavian work (Ehn, 2008) and in various seminal publications (Frauenberger et al., 2010; Muller, 2002; Robertson, 2002; Suchman, 2007). It should therefore come as no surprise that many methods explicitly involve the use of material tools and physical contexts to support the PD process (Grufberg & Holmquist, 2011; Sanders et al., 2010; Vaajakallio & Mattelmäki, 2007). However, if we look closely at the design of PD tools, we see that the application of embodied sensemaking theory remains limited. Sometimes, the idea of materiality is used nonspecifically, as when participants are given generic, physical creative materials to work with. While these materials may help a lot, their nonspecificity remains unsatisfying from a design and research point of view. A researcher wants to know how exactly physical materials scaffold sensemaking. A PD designer ask what physical-interactive forms work best and how to better design them. Whenever tools are explicitly designed to support PD sensemaking, their design seems to hinge predominantly on the aforementioned notion of external representation. Canvasses, activity-books, card sets, game boards, posters, and so on are all designed to "transmit", "capture", "store", or "share" relevant information (Sanders et al., 2010; Simonsen & Robertson, 2013). Thus, Hassan et al. (2015) described tools as "[providing] the participant with the required background knowledge and also trigger their creative process. … [These] tools [are] a determinant of participants' creativity, and hence innovative output" (p. 479). While physical representations are very useful, I argue that their design rationale makes limited use of embodied sensemaking theory as a whole, which involves more than external representation (Fernaeus et al., 2008; Van Dijk et al., 2014).

The question is whether we can increase the import of embodied sensemaking theory into the design of PD things. Can we design powerful things that help make sense in PD? Can these things be anything beyond their traditional role as external information storage containers? In what follows, I elaborate three nonrepresentational sensemaking roles for things and give examples of designs explicating these roles, selected from projects I have personally been involved with. These three roles are: (a) sensorimotor couplings, involving tools, materials, and creative expressions; (b) participatory sensemaking with things as attunement anchors; and (c) things as part of the familiar lifeworld. I revisit the role of things as external representations in the discussion section as fourth role, functioning in interaction with, and relying on, the first three. Together, the four roles form a framework describing how things scaffold sensemaking in PD, as illustrated in Figure 13.2.

The framework presented is the product of a long iterative process of reflection-on-action (Schön, 1983), in which theory was refined in response to being "confronted with the practice" (Stappers, 2007) of doing PD and of designing PD tools. These PD projects all involved creative workshops that used physical creative materials and took place in our own lab and in my collaborations with others. These projects are described more in detail

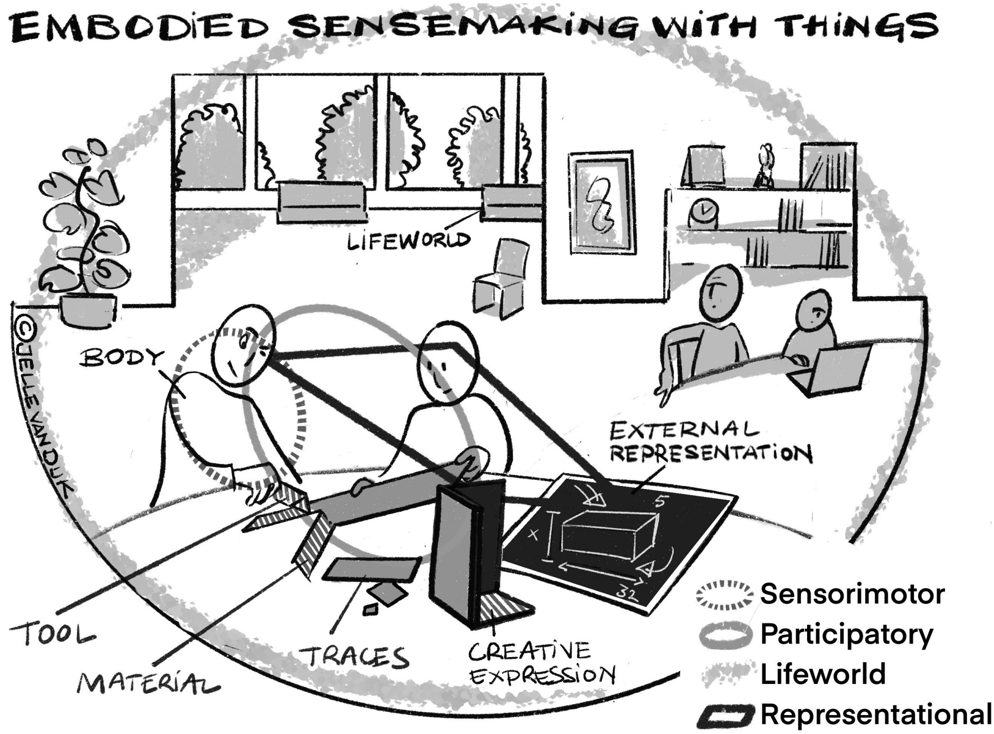

Figure 13.2 Embodied sensemaking in the PD setting: (a) sensorimotor couplings, involving tools, materials and creative expressions; (b) participatory sensemaking with things as attunement anchors; (c) things as part of the familiar lifeworld; and (d) things as external representations. Illustration by the author © Jelle van Dijk.

by Van Dijk and Vos (2011), Van Dijk & Frens (2011), Van Dijk et al. (2011), Verhoeven et al. (2016), Van Dijk & Verhoeven (2016), Jaasma et al. (2017b), Boelhouwer et al. (2019), Den Haan et al. (2019), Van Belle et al. (2019), Aslam et al. (2019), Van Dijk et al. (2019), Austin et al. (2020), Waardenburg et al. (2021), and Van Huizen et al. (2022).

Roles for things in sensemaking beyond representation

Focusing on the PD context, let us now look more closely into the three roles for things to play in embodied sensemaking that go beyond (or rather come before) the familiar function of things as representations. They are:

- Role 1. Things play a productive role in the formation and sustainment of sensorimotor couplings, i.e., things figure in our skilful ways of dealing with the world.
- Role 2. Things function as attunement anchors in participatory sensemaking, a self-organizing process taking place between people.
- Role 3. Things become part of the lifeworld, which provides a necessary contextualizing background to all sensemaking.

I will discuss each of these three roles in turn.

Role 1: things in sensorimotor couplings

The most basic way in which things facilitate sensemaking, which is not about representing at all, is in the formation and sustainment of *sensorimotor couplings*. In such couplings, things do not even present themselves as things (objects in our attention). Instead, things act as transparent aspects of unreflective, habitual "embodied coping" (Dreyfus, 2002). We act *through* things to form skilled couplings to the world, in extension to our body. Things thus become incorporated – they augment the lived, experiential body. Forming sensorimotor couplings is a way of "making sense", that is, of "getting a grip" on the situation at hand (Merleau-Ponty, 1962).

Tools

Perhaps the best-known way in which things function in sensorimotor couplings is as *tools*, for example, the hammer, discussed by Heidegger (1967), or the blind man's cane, described by Merleau-Ponty (1962). For Heidegger, tools such as hammers are first of all "zuhanden" (ready-to-hand). We are directed at the project, through the hammer, which itself is a transparent, fluid extension of our body. According to Gibson (2014):

> Tools are detached objects of a very special sort. … When in use, a tool is a sort of extension of the hand, almost … a part of the user's own body … when not in use, the tool is simply a detached object of the environment…. This … suggests that the boundary between the animal and the environment is not fixed at the surface of the skin but can shift.
>
> (pp. 40–41)

Tools are not just means to get a job done. Incorporated tools transform the body and thereby how the world presents itself to us. Action affording qualities of the tool influence how we perceive the situation. With a tool in hand, the world before us takes on a new look. Consider that many typical PD artefacts have quite similar tool-affordances: cards for writing on, whiteboards for drawing on, a table for sitting around and talking. In contrast, professional designers and artists may use many different kinds of expressive tools and actively seek out a diversity of environments in the creative process, arguably leading to a richer palette of sensorimotor couplings (Jaasma et al. 2017a).

Creative expressions

In PD, people create things (e.g., sketches, prototypes, collages). While the representational function of these *creative expressions* seems clear, they also figure in sensorimotor couplings. The artefact-in-becoming is a guiding constraint in its own production. Even when starting with an idea in mind, the properties of tools, materials, and the evolving artefact itself constrain many local decisions along the way. Donald Schön (1983) called this the "conversation with the medium" and Frens and Hengeveld (2013) captured the phenomenon by saying: "to make is to grasp". The creative expression is not *just* a *re*-presentation of an idea – its intermediate incarnations co-direct the sensorimotor coupling towards its stable form (Figure 13.3). Sensorimotor couplings contain improvisation; they respond to the local constraints and affordances of the here-and-now. In contrast to "zuhanden" tools however, the creative expression *is* in centre focus. It draws all sensemaking

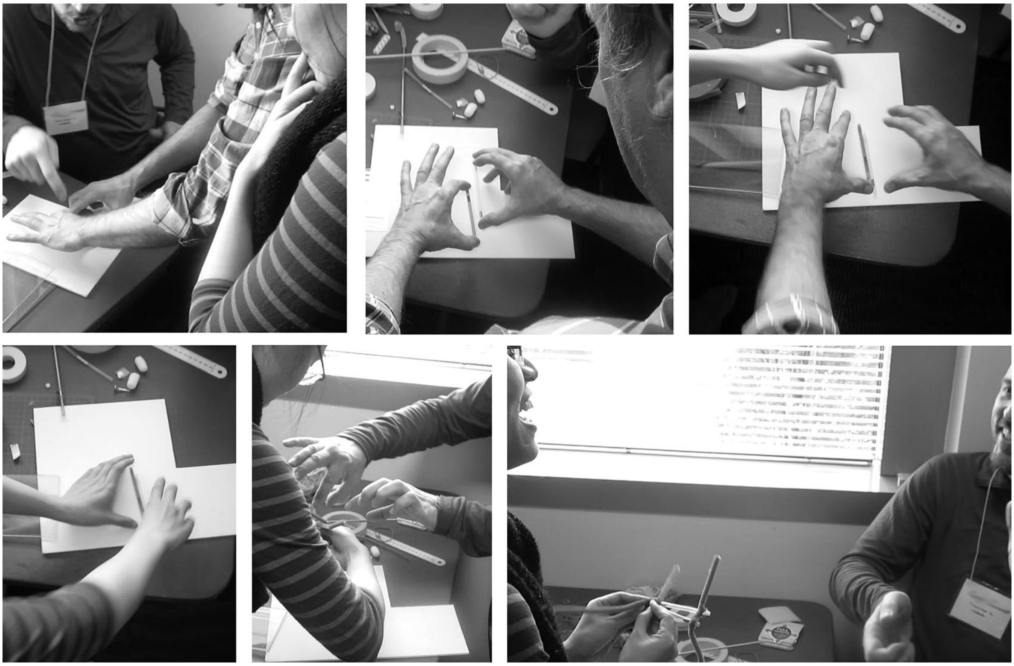

Figure 13.3 Participatory sensemaking in action, with things functioning as sensemaking anchors. Collaborative interactions with things bind individual sensemaking couplings into a shared sensemaking. Photographs by the author. Project described in Van Dijk and Frens (2011).

energy onto itself and becomes a focal point of intentionality (Dreyfus & Wrathall, 2017), just as in a concert the music performed draws together the actions of the musicians.

Materials

One peculiar category of things is *materials*. Materials are at first part of the context: the lifeworld (see Role 3, below). Once picked up for use, materials get "woven into" the unfolding sensorimotor coupling (Ingold, 2000). Materials constrain what we *can* make, which co-shapes what we *intend* to make. A vague idea crystalizes into a concrete form, partly determined by the constraints and affordances of the materials used (Frens & Hengeveld, 2013). Materials may also disturb couplings, perturbing the dynamic into a new direction. This corresponds to surprise experiences: the material refuses to behave as intended, or we unexpectedly stumble upon something we might use. Rummaging through a box of scraps or wandering through the local supply store is a common habit of designers for this reason.

Embodied sensemaking explains how unreflective creative couplings, involving tools, materials, and an evolving creative expression, make sense (that is, it produces "sense"), without serving an explicit representational function. Sensorimotor couplings (skilled action) typically alternate with moments of "reflection-on-action", which are triggered when the coupling gets disturbed (Dorst & Cross, 2001; Schön, 1983). Reflection-on-action may produce a reframing of the situation, after which the sensemaker engages in new couplings (Schön, 1983), this time starting from a different overall perspective. Stumbling on unexpected things and their behaviours can trigger such reflective moments.

PD tools designed explicitly to support sensorimotor coupling

Other than general use of creative materials, there are not many PD tools designed explicitly to support sensemaking as it happens in the process of making. Participants are asked to make things, but the focus is typically on the insight that this thing represents, not on how making a thing produces insights as such. Professional designers are often hired separately to turn insights from workshops into high fidelity prototypes, which means that participants will not experience themselves what this designer experiences as she makes sense while crafting the prototype (Ingold, 2006; Sennett, 2008).

One possible example of such a tool was created through exploratory workshops in our lab: a concept for a mobile stall with materials for creating lo-fi prototypes (De Bono Holanda & Van Dijk, 2017). The stall aims to invite non-designer participants to generate ideas through physically exploring materials and constructing prototypes (and avoid too much thinking and talking). Prototypes made by previous participants are displayed within the stall as *engagement catalysers* (Hummels & Van Dijk, 2015). Materials are deliberately open-ended scraps, rather than explicitly defined construction blocks, to promote ambiguity and improvisation. While promising as explorations, facilitating "grasping through making" (Frens & Hengeveld, 2013) in PD remains a largely unexplored terrain. Perhaps precisely because it concerns skilled, unreflective coping, it is hard to explicitly design for. The "zuhanden" way of sensemaking is, in Heidegger's words (1967): "'closest' to itself and [yet] ontologically farthest" (p. 37).

Role 2: things in participatory sensemaking

Sensorimotor couplings describe individual, skill-based sensemaking, yet PD is concerned with shared understanding in teams. Participatory sensemaking (De Jaegher & Di Paolo, 2007) explains how sensorimotor couplings become part of social couplings between people. Experientially, this feels as connecting or having rapport (or the lack of it when the coupling breaks). Explicit communication can be part of such participatory sensemaking, but the core process is an ongoing, non-verbal, pre-reflective bodily *attunement*: we continuously adjust posture, tone of voice, and use gestures to make sense of one another and, together, of the situation at hand, in a dialogical manner (Steffensen, 2012). Grounded in enactivism, participatory sensemaking theory explains how participatory couplings take on a self-organizing autonomy which draws participants further into the participatory coupling, while, at the same time, each participant also retains their autonomy as a living, sensemaking body working to sustain itself (De Jaegher & Di Paolo, 2007).

Building on participatory sensemaking theory, I propose that things act as *attunement anchors*, around which participatory couplings are formed. Again, this may involve tools, materials, and creative expressions. Prototypes may aid in shared attention (Figure 13.4). Participants may ask clarifying questions using *deictic* references to prototypes – e.g., Do you need help with *that*? What if we cut *this* part? (see Ballard et al., 1997). This supports a process of mutual attunement revolving around the prototype, resulting (hopefully) in a shared sense of what is going on.

Figure 13.4 Participants create lo-fi prototypes which function as scaffold for collaboratively making sense of possible use experiences. Projects (from left to right) described in Van Dijk (2022) and Van Dijk and Vos (2011). Photographs by the author.

PD tools designed explicitly to support participatory sensemaking

Using the Design & Sensemaking (D&S) studio, designed by Caroline Hummels, we investigated various engagement catalysers, or tangibles with various affordances, to help "physically connect strangers, and thus enhance engagement, empathy and respect" (Hummels & Van Dijk, 2015). In the study by Van Dijk and Vos (2011), participants interacted on a floor, surrounded by dynamic floor projections of "their ideas" (Figure 13.5, left). Participants interacted with the pictures using their feet to guide the conversation. Observations suggested that images were used as anchor points for (re) directing attention, taking turns, and giving others (literally) "the floor". Building on this, we investigated how tangible table-top systems would support town hall meetings (Figure 13.5, right; see Jaasma et al., 2017b). Observations reveal that people attribute a variety of meanings to the tangibles used (even though they contained icons), depending on what helped sensemaking. These studies suggest that things scaffold participatory sensemaking, and it helps if users have some freedom in attributing meaning to things on the spot. Another observation is that people will interact with things as a lever for socially *relating* to the other, which is not necessarily related to the *contents* of the thing. For example, repositioning a canvas, or ostensively removing a sticky note, could be a performative act functioning to cut off a dominant speaker, to "take the lead", or even to become acknowledged as a participant at all (Brouwer & Van Dijk, 2011; Jaasma et al., 2017b).

Figure 13.5 Left: “Floor-It”. Photograph by the author. Right: “[X]Chancing perspectives”. Photograph by Bart van Overbeeke.

Role 3: things that make up the lifeworld

Embodied sensemaking takes place against a background, or *lifeworld*. In phenomenology, the lifeworld is not the world of explicit things, but the implicit décor *against* which we may encounter anything at all. It causes us to always “already” encounter things in a way. Without a lifeworld, nothing would make sense – we would feel alienated. Things we find, create, acquire, even accidental traces of action over time become part of the lifeworld. Note that the same thing can “be many things”: it can be encountered as an explicit object, an incorporated tool, or as background element in the lifeworld.

In PD, two lifeworlds are relevant: the world of PD and the user-world or context of use, which is what the PD project is about. One of the challenges is precisely to bring these worlds together: to let the sensemaking that happens in the PD activities be informed by what makes most sense in the context of use. Typically, one researches the use-context and then represents it in artefacts such as photo collages, personae, customer-journeys, storyboards, etc., in a PD session. A more direct, non-representational approach would be to let participants perform PD *in* the actual use-context. In situated make-tools (Ylirisku & Vaajakallio, 2007), users go through their usual work routines, and then use a tinker kit to create lo-fi prototypes of new product ideas on the fly. This enables workers to make (new) sense of their own practice *through* situated prototyping. The creative expression becomes a tangible anchor between, on the one hand, the sensemaking in the design workshop and, on the other, the everyday sensemaking of a worker interacting with technology in the use context (Brereton et al., 2017; Odom et al., 2012).

PD tools to link the PD process to the user’s lifeworld

In a project involving independent living autistic young adults, we aimed to support autistic participants with everyday home routines (Van Dijk et al., 2019). We used various iterations of a technological probe (Madden et al., 2014) to connect sensemaking in PD to the participants’ own sensemaking in their home. The probe allowed programming various wireless objects. Using these, a participant might put a light on the kitchen counter, which would light up at 10 a.m. each day, to provide a subtle hint that it was time to do the dishes. The light did not explicitly inform the user about the dishes: it directed their attention to something in their lifeworld that needed attention (in this case, a kitchen, with visible actual dishes). The lights thus augmented the user's lifeworld with situated cues, triggering reflection on their routine. Trying out the amount, location, and timing of these situated reminders, participants explored their own routines and how to improve them to their own needs, using technology. Iterations of the prototype functioned to generate new design insights, gradually producing a promising, co-designed concept for a supportive device, fully integrated into the user's lifeworld.

Discussion

PD research often mentions the value of tangible tools for shared sensemaking. Most tools, however, use tangibility only to create external representations, which is a limited view on embodied sensemaking at large. I propose to open up a design space for embodied sensemaking in PD, in which representation is just one way for things to aid in sensemaking. I presented three other ways in which things figure in embodied sensemaking. Embodied, participatory couplings, situated in a lifeworld, are core ways of sensemaking, even though they can be hard to notice (as they are "pre-reflective"). This means it is also challenging to design specific tools to support such couplings. Yet we can try and enrich the PD toolset by focusing more on supporting skilled making and participatory sensemaking, and less on explicitly representing "all that matters", in objects, pictures, icons, and so on. Representing suggests control: Representational tools ensure that participants attend to the right information, perform the right activities, and focus on the right goals. An embodied sensemaking perspective asks us to dare and reduce some of this control, and to provide tools that enable an interactive, essentially improvised sensemaking process emerging between participants, there and then.

Designing for embodied sensemaking does not exclude representational media. Sensemakers use representational artefacts all the time and distributed cognition theory explains how representations help reduce cognitive load and aid in communication. The point is that the *sense* that is being made in interacting with representations is never fully captured by their *contents*. Working with external representations is one of the mechanisms that sustains embodied sensemaking, and sense is made in embodied couplings *to* things (whether representational or not), not in any specific representational content. Embodied sensemaking gives representation its proper place as just one productive constraint, in an essentially improvised sensemaking activity (Goodwin, 2000; Poulsen & Thøgersen, 2011; Suchman, 2007; Van Dijk, 2018).

One added value of representational things is that they help to ignite instances of "reflection-on-action" (Hummels and Van Dijk, 2015; Schön, 1983). To *re*-present automatically involves stepping back and taking a perspective. Creating a sketch, model, or description helps to perceive new ways to approach the situation that might otherwise have remained hidden (Schön, 1983). Using representations does not mean more basic sensemaking processes are lost. Representational things *also* still act as tools, materials, expressive outcomes, and lifeworld elements. The activity of representing is *situated* within these more basic embodied practices (Goodwin, 2003; Ingold, 1995; Stewart et al., 2010; Suchman, 2007). In PD, it is not always relevant whether a particular representation accurately represents some target phenomenon. It is often much more relevant whether representational artefacts are freely accessible to be created and used by all participants as part of their embodied sensemaking. Can all participants freely create, grab, offer, receive, reposition, order, adapt, and combine representational things? A fixed wall of photos might provide a lot of information, yet still offer limited opportunities to *make sense* if it cannot be acted on.

Finally, PD acknowledges the material aspect of stakeholder politics (Pihkala & Karasti, 2018). Stakeholder interests are, however, mostly addressed, again, through explicit representation by using representational objects, such as stakeholder avatars, personae, stakeholder-maps, and so on (Andersen & Mosleh, 2021). As we have seen, social relating may also be *enacted* through the ways people deal with concrete things, in interaction with others. This "micropolitical" function of things fits with the enactivist idea that each participant is ultimately concerned with maintaining their autonomy as a living being (De Jaegher & Di Paolo, 2017). Maintaining autonomy in social settings can be expressed even in the subtle ways in which one person hands another person a pair of scissors. An interesting avenue for future research would be to design PD things that explicitly acknowledge, and build on, the subtle, nonverbal acts of micropolitics that takes place in social interactions during the PD workshop, as a subtle approach to dealing with potential stakeholder conflicts.

Conclusion

The present framework of how things make sense in PD, grounded in embodied sensemaking theory and in reflections on PD practice, provides a first step towards overcoming a representational bias in the design of PD tools. The framework may inform and inspire the design of PD things that help participants make sense together using the full richness of their embodied engagements with the world.

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14 Interactive connected smart (ICS) materials experience

Collaborative embodied knowledge through material tinkering

Stefano Parisi, Venere Ferraro, and Valentina Rognoli

Introduction

Over the past decades, emerging materials have gained prominence in design practice, driving innovation and generating added value to products and systems; they play a crucial role in improving physical performance and enhancing product language, facilitating novel dynamic experiences and unique expressive-sensorial dimensions.

Indeed, the material domain is undergoing a transformative shift, characterized by hybridization, dynamism, and interactivity, ultimately reshaping craft practices and sensorial experiences. In this context, a new class of emerging breakthrough materials defined by the umbrella definition of *interactive connected smart (ICS) materials* (Parisi et al., 2018) appears as pivotal in redefining meaningful experiences and making practices. This category encompasses a wide range of elements, including conductive materials, stimuli-responsive smart materials, embeddable sensors, actuators, and microcontrollers. As in a kind of composite arrangement, these components can be combined with inactive material substrates to form *hybrid material systems (HMS)* enabling diverse interactive and dynamic experiences by holistically tuning their material, temporal, and form dimensions (Parisi, 2021).

In this chapter, we present and discuss the embodied experience emerging from crafting HMS resulting from the hybridization of bioplastics and embedded lighting technology. For this purpose, we unfold the knowledge at the core of ICS materials and HMS. We then outline the value of the embodied experience as a result of applying a material-centred hands-on approach. This approach involves do-it-yourself (DIY) practices, material tinkering, and experimentation in a cross-disciplinary team with eclectic backgrounds from material design and crafting to interaction design and digital fabrication. Our investigation emphasizes the central role or the expressive-sensorial qualities and materials experience. We then present our experimentation in tinkering with hybrid bio-based smart objects. Finally, we reflect on the crafting experience and discuss emerging methods and approaches for design practitioners dealing with ICS Materials and HMS. The emphasis lies in collaborative practices, experiential learning, and the unique materials experience resulting from the relations between form, behaviours, material qualities, and the researchers themselves.

Theoretical background

We live in a world permeated by advanced technologies that have reshaped human experiences and interaction with the environment and artefacts (Greenfield, 2018). Novel technologies uncover new ways to engage, entertain, and inform users, and encode new

DOI: 10.4324/9781003328018-21

communication and interaction languages. The rapid diffusion of emerging technologies, miniaturization, and digital fabrication has also impacted the material domain, catalysing the rise of HMS: material-based systems combining inactive materials; smart material components; and embedded sensing, computing, and actuating technologies.

Scholars from different disciplines such as design, material science, and human-computer interaction (HCI) have theorized different concepts relatable to HMS: (a) *expanded matter or x-matter*, materials enhanced with additional capacities such as tracking, sensing, responding, interacting, by integrating information technologies (Brownell, 2014); (b) *augmented materials*, materials with physical and computational properties, where electronics are embedded during the material's fabrication (Razzaque et al., 2013); (c) *computational composites,* composite materials in which at least one component has computational capabilities (Vallgårda & Redström, 2007); (d) *smart material composites*, smart materials combined to create complex interactions (Barati, 2019); (e) *hybrid materials*, compound of both organic and inorganic components, including micro components of a different nature, such as electronics (Saveleva et al., 2019; Torres et al., 2019); and (f) *smart composite material systems,* as a combination of smart materials providing sensor systems, actuating mechanisms, and control systems (Kelly et al., 2018).

The HMS anatomy emerges as a combination of diverse material layers or "building blocks" (Parisi & Ferraro, 2021) where the actuating, connecting, and sensing behaviours are provided by the presence of *ICS materials*. ICS materials is an overarching category of materials with interactive capabilities – including conductive materials, stimuli-responsive smart materials, embeddable sensors, actuators, and microcontrollers (Rognoli & Parisi, 2021a). ICS materials are defined as materials able to (a) establish a two-way exchange of information; (b) respond contextually and reversibly to external stimuli; (c) be linked to another entity or an external source; and (d) be programmable, not necessarily through software.

The *HMS* components are categorized into (a) *inactive components*, conventional passive materials such as paper, plastic, and textiles, whose dynamic behaviours are limited to conventional mechanical and chemical characteristics, such as ageing over time and performing flexibility; (b) *reactive components*, such as smart materials able to change some features like shape, colour, or light-emission in response to physical or chemical influences from the environment or the user's body, such as temperature, light, pressure, and mechanical stress, electric or magnetic field, chemical elements, and compounds; (c) *active components*, embedded sensing and actuating technologies, such as sound, touch, and proximity sensors, as well as LEDs, buzzers, or actuators, connected to external or embedded computing technologies; (d) *interconnection elements*, between components, through traditional wires or conductive materials, such as graphite, active carbon, and silver, and can be found in the shape of conductive fibres, threads, printed circuits, paints, and coating; (e) *sources of energy*, embeddable power supplies, like flexible batteries, or electricity-generating materials, such as piezoelectric ceramics and polymers. These components can be arranged in a variety of possible combinations to achieve systems with passive and/or active performances. Considering e-textiles, for example, designers combine traditional fabrics like cotton with ICS materials, such as conductive threads and LEDs. When worn, soft circuits within the fabric detect interactions and trigger LED responses. The interplay between traditional fabric and soft circuits forms a HMS, which transforms the piece of clothing into an informative, interactive design, and generates dynamic material qualities. As in a composite material arrangement, fabric and ICS materials unite to create a cohesive, interactive whole.

Beyond their functionality, designers can leverage the expressive-sensorial dimension of these materials (Rognoli, 2010) to enable sensorial references, emotions, meanings, and performances (Giaccardi & Karana, 2015; Karana et al., 2015), culminating in unique material experiences (Karana et al., 2015), such as dynamic ones. In the context of materials, the concept of dynamism manifests in different ways (Rognoli, 2015). Due to their constant change over time, materials are inherently dynamic. Examples of dynamism in conventional materials can be observed in the shrinkage and discolouration phenomena of organic materials, as well as naturally occurring reversible behaviours, such as bioluminescence of micro-organisms or moisture-induced shape-shifting of cellulose-based materials. Dynamism is even more pronounced in HMS. Indeed, HMS can change over time, interacting dynamically with users and yielding emotive, suggestive experiences. ICS materials dynamically change form and behaviour, generating new affordances and communication languages, creating unique material interfaces, and defining new interactions. They are "becoming materials" (Bergström et al., 2010), capable of multiple, repetitive, and temporally controlled expressions. From this viewpoint, they become informative and intuitive dialogical carriers of information, thanks to the hybridization of technology and materials. Blending technologies and materials with different properties, qualities, and affordances to create new dynamic experiences is one of the designer's tasks in this context.

The democratization of technologies and hybridization of the design space have enabled designers and makers to diverge from conventional production by crafting HMS themselves using ICS Materials (Coelho et al., 2009). This phenomenon is acknowledged as DIY materials (Rognoli et al., 2015). DIY materials emerge from individual or collective self-production experiences as a result of a process of experimenting and tinkering with materials. These materials include various technological blends and hybridization with interactive and smart elements, such as sensing, actuating, and computing technologies (Rognoli & Ayala-Garcia, 2021). Recent studies on the integration of electronics into bio-based materials using a DIY approach as a way to experiment with HMS using abundant, renewable, and biodegradable resources have emerged. For example, mycelium has been used to embed electronics to create breadboards (Lazaro Vasquez & Vega, 2019a), wearables (Lazaro Vasquez & Vega, 2019b), tangible interfaces with different actuators (Genç et al., 2022), and interactive artefacts (Gough et al., 2023; Weiler et al., 2019). Bacterial cellulose has been used to house LEDs for the creation of wearables (Bell et al., 2023; Ng, 2017) and encase different electronics, conductive, and smart materials for prototyping interactive devices (Nicolae et al., 2023). Bioplastics have been used to create interactive objects by embedding electronics such as LEDs (Kretzer & Mostafavi, 2020), conductive materials (Koelle et al., 2022; Lazaro Vasquez et al., 2022), and thermo-chromic dyes (Bell et al., 2022). Empowered by a DIY approach, digital technologies, and open-source tools, design researchers and practitioners can develop samples and prototypes, formalize models and methodologies, and ultimately catalyse innovation and change.

In this materials-making journey, practitioners unlock potentials and limits of the materials through material tinkering (Parisi et al., 2017; Rognoli & Parisi, 2021b), an approach rooted in HCI and craft practices that involves hands-on explorations of materials in a playful and creative manner (Bevan et al., 2015; Cermak-Sassenrath & Møllenbach, 2014; Sundström & Höök, 2010; Wilkinson & Petrich, 2014). Both the HCI and the craft communities have explored the implications of this approach's direct engagement with materials and experiential learning (Falin, 2022; Niedderer, 2007; Nimkulrat, 2012; Seitamaa-Hakkarainen et al., 2013; Vallgårda & Fernaeus, 2015). Experiential learning theory (Kolb & Fry, 1975) promotes acquisition and application of knowledge, skills, and feelings, by being involved in direct encounters with the studied phenomena rather than thinking about the encounters. The experiential learning cycle comprises applying, experiencing, reflecting, and generalizing, i.e., active experimentation, concrete experience, reflective observation, and abstract conceptualization.

The first phase of material tinkering is generally more explorative, goal-free, and discovery-oriented, often revealing unpredictable outcomes. It encompasses embodied explorations that foster experiential knowledge and creativity. In this phase, designers discover the performances and expressions of materials and practise their experiential sensibility and vocabulary. In contrast, the second phase is characterized by a more structured investigation to achieve an intended outcome or answer a specific research question. It encompasses practical inquiries that aid iterative material improvement and understanding of material-process-form relationships, thereby enhancing knowledge creation.

Experimenting with materials at any phase of tinkering allows for a unique embodied experience. While manipulating and crafting with materials, designers are actively engaged in a continuous embodied conversation with them (Schön & Bennett, 1996), generating new knowledge, meanings, and experiences. Indeed, tinkering enhances materials' agency, elevating the materials to a collaborator (Rosner, 2012), a co-performer (Robbins et al., 2016), and an equal partner (Barati & Karana, 2019). In this process, materials play an active role by suggesting ways of interaction and manipulation, while the designer must be open to listening and interpreting the feedback from the manipulated material.

In particular, tinkering with ICS materials for HMS crafting is a conversation among several actors: the designers, the inactive materials and their crafting techniques, the interactive elements and their programming, and the component organizations in the system forming process. In this process, the designers engage in dynamic, interactive, and hybrid types of embodied material experiences.

Material tinkering: applying and experiencing

In this section, we describe a case study of embodied knowledge and materials experience emerging from collaborative crafting experimentation of HMS with the use of ICS materials and bioplastics. It aimed at the creation of bio-based smart objects with interactive behaviours.

The experimentation involved a mixed team of four design researchers with expertise on material design, product design, digital fabrication, and HCI. It was conducted in two distinctive phases of material tinkering over four months, between January and April 2019. The experimentation was part of the first author's PhD research project under the supervision of the third author (Parisi, 2021). Centring their focus on material design, mainly dealing with bio-based materials and DIY approaches, they collaborated with two other researchers who contribute to the experimentation with their digital fabrication and HCI expertise.

Explorative and systematic material tinkering

The research team freely approached explorative material tinkering, aiming to understand the potentials and limitations in variations, processability, forming, and augmentation of different organic DIY materials. These materials include mycelium-based materials,

Figure 14.1 Samples from the first experimentation. From left: mycelium-based, animal gelatine-based and agar-agar-based bioplastics, damar gum and rosin, and fruit leather samples. Photographs by Stefano Parisi.

starch-based biopolymers, animal gelatine-based biopolymers, vegetal gelatine-based biopolymers (i.e., agar-agar based), natural resins (i.e., damar gum and rosin), pectin-based biopolymers (i.e., fruit leather), and casein-based biopolymers (Figure 14.1). Inspired by the recipes from online open publications (Pistofidou & Dunne, 2018; Ribul, 2014; Viladrich, 2014), we experimented with different ingredients and recipes by manipulating ratios, processes, and moulding shapes. We attached a label with an alpha-numerical code to each sample we generated. To keep track of the processes and practices, we documented the codes associated with the samples in a notebook. This allowed us to link the variables in the processes to the material qualities of the final samples, as experienced through sensory exploration. At this stage, tactile, visual, and olfactory exploration was a way of experiencing the materials through our senses. From the first experiments, we produced about a hundred material samples with different characteristics.

Aiming to select a single material for further experimentation in a more systematic way, we evaluated the material samples according to different criteria, such as stability, variations in visual and tactual qualities (e.g., translucency and textures), embedment of smart components (both technology and smart materials), scalability, time of preparation, economic cost, and environmental impact. The criteria were mainly related to the main objective of the following experimentation stage, i.e., to reproduce a variety of qualities and to obtain stabilized samples to integrate technologies. Finally, we identified the animal gelatine-based bioplastic as the most promising material for the following experimentation.

After we selected the material – i.e., animal gelatine-based bioplastic – we performed a systematic material tinkering to produce samples in the same shape as a fixed variable but differing in material variables. Using this approach, the shape was not the focus of the exploration and would not interfere with the perception of the material qualities in the different samples. Starting from the original recipe, we explored different variables by altering the ratio of ingredients in the recipe and some procedures in the making process, and by integrating dynamic behaviours. We have produced about 40 samples embedding different qualities. The following sections describe details of their material qualities, forming techniques and integration of interactive components.

Material qualities

The selected recipe consists of three ingredients: animal gelatine, water, and glycerine. We found that we could achieve different material qualities by modifying the ratio of these ingredients. For example, increasing the amount of glycerine would make the sample

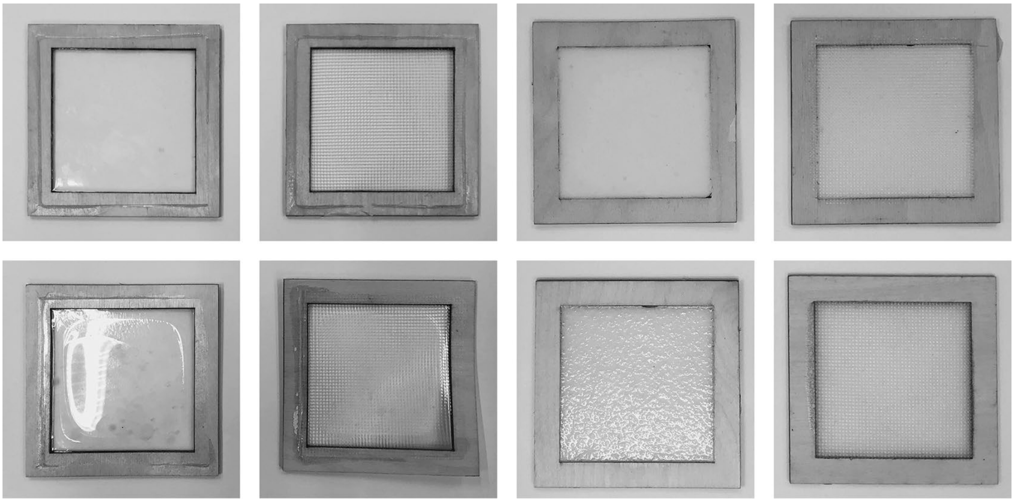

Figure 14.2 Samples combining the three contrasting qualities: flexible/stiff, transparent/opaque, and textured/smooth. Clockwise from top left: flexible, transparent, smooth; flexible, transparent, textured; flexible, opaque, smooth; flexible, opaque, textured; stiff, transparent, smooth; stiff, transparent, textured; stiff, opaque, smooth; stiff, opaque, texture. Photographs by Stefano Parisi.

more flexible, or reducing the amount of water and increasing the amount of gelatine would give the sample an opaque appearance. This recipe was also the most reliable in terms of results and reproducibility, the easiest to process, and the fastest to stabilize. Even though many qualities, e.g., scent, were identified, we chose to focus our systematic tinkering on the three most evident visual and tactile qualities, including flexible/stiff, transparent/opaque, and textured/ smooth. By matching these dimensions on a matrix, we created eight samples, each representing a specific combination of the systematically manipulated qualities (Figure 14.2).

Forming techniques

The making process corresponded to the process of cooking bioplastics: melting the ingredients together, then pouring the material and letting it dry on a surface. The material can be poured onto a flat surface to produce a thin layer of material or into three-dimensional moulds to obtain a solid with a three-dimensional volume, e.g., spheres. For our experiment, we wanted to achieve samples with homogenous thickness in all their volume, so once they were consistently dry, they could be compared with one another. For this reason, we decided to produce thin layers of bioplastic by pouring it into and letting it dry in a laser-cut wooden frame positioned on a non-sticky plastic surface. This plastic surface was laser-engraved to create a texture transferrable onto the material sample. After a few days, the material was stable and dry, allowing the plastic surface to be easily removed while the sample remained attached to the wooden frame (Figure 14.3). This rigid frame, therefore, served several purposes, including (a) shaping the sample during the moulding process, (b) preventing shrinkage and deformation of the material, (c) making the samples easy to handle and collect, (d) protecting the materials during transport and manipulation, (e) embedding electronic components, and (f) embossing the item's code.

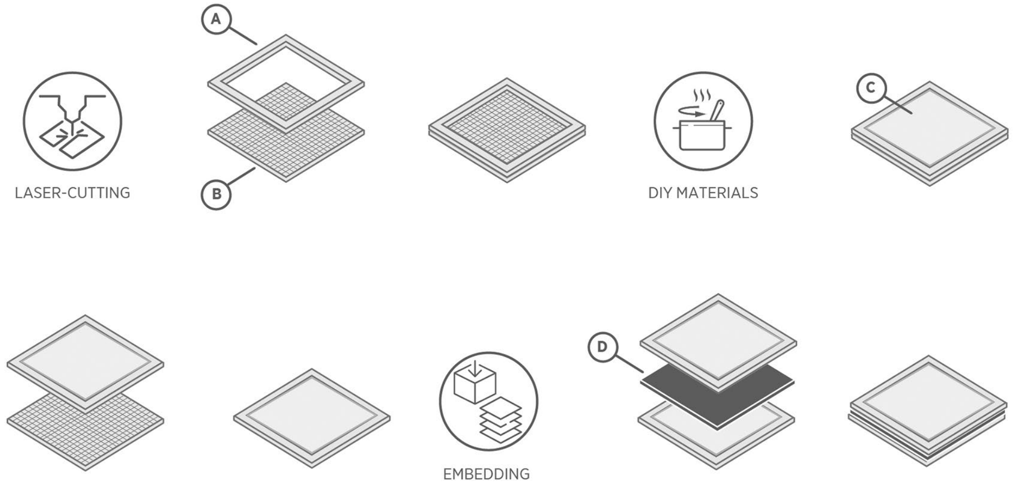

Figure 14.3 A schematic representation of the making of a sample. First, a wooden frame combined with a textured plastic surface is used to give shape and texture to the bioplastic sample. Then, the obtained sample is used to contain technologies, e.g., LEDs, batteries, and microcontroller. (A) Squared wooden frame; (B) textured or smooth plastic surface; (C) bioplastic; (D) technologies. Illustration by Stefano Parisi.

Integration of dynamic behaviours

We focused part of the experimentation on the identification of techniques to augment the material by adding dynamic behaviours through the integration of technologies into the material. In this respect, we decided to use the moulding frame as a platform for embedding the technologies. Inspired by a unique sensorial quality of the bioplastic – its nuances of translucency degrees – we chose to focus on light-emitting behaviour. To enact this behaviour, we considered two approaches: first, pouring light-emitting diodes (LED) directly into the bioplastic and using the frame to position the LEDs; and second, overlaying two samples and using the space between them to integrate the LEDs (Figure 14.4). We used the frame to hide interconnection, batteries, Arduino, and sensors on the inside. Potentially, we could activate the behaviour by a motion sensor controlling the LEDs. This would be implemented using an Arduino Mini board with a motion sensor to detect the samples being picked up and put down. This would result in an output of LED lights by switching the actuators on and off.

Observations: reflecting and generalizing

Reflecting on the ideation and making of these samples and the experience of the designer has led to a discussion about processes, functionalities, affordances, expressions, meanings, and ultimately the novel materials experiences expressed by this hybrid crafting practice. In particular, the intertwined relations between material making, forming, and technology integration into a prototype has revealed constraints and opportunities for the performativity and expression of HMS. This dialogue has grounded and cultivated collaborative embodied knowledge.

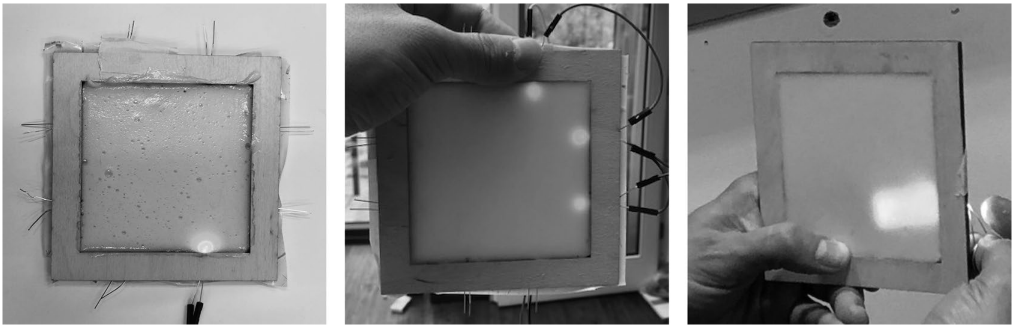

Figure 14.4 Experimentation with material augmentation to produce light-emitting samples, using two approaches. First, LEDs are placed in the back of the frame and integrated into bioplastic during the pouring and drying process (left and middle) and second, the light source is placed on the back of the sample for a more diffused lighting and covered by another sample layered on the back (right). Photographs by Stefano Parisi.

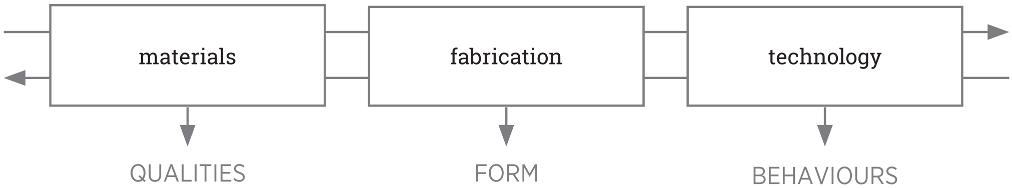

Figure 14.5 Relations between qualities, forms, and behaviours in HMS crafting. Illustration by Stefano Parisi.

Relations between material qualities, form, and behaviours in crafting ICS materials

The prototyping method includes the making of DIY bioplastics, programming and integration of smart components, and digital fabrication (e.g., laser cutting of the wooden frame and engraving of plastic surface). From the analysis of the results generated by the experimentation, we can identify three main dimensions of HMS: (a) qualities, characterized by material recipes; (b) form, characterized by fabrication techniques; and (c) behaviours, characterized by the digital technology (Figure 14.5). Therefore, the design processes required to deliver HMS are simultaneously material making, forming, and technology programming, resulting in a physical sample; these three dimensions are fundamentally intertwined, as materials and technology can inform each other. As the experiments evidence, the outcome is often dependent on the craft process, which thus becomes an essential element of material augmentation.

In the observed case study, materials are engaged in different relations with the technology. They can be elements that support or contain electronics and smart components. As sensory interfaces, materials contribute to HMS by providing their intrinsic qualities, e.g., optical and tactile, and characteristics, e.g., mechanical and environmental. This is the case of transparency/opaqueness, flexibility/rigidity, and texture/smoothness explored in the samples. The material translucency enhances the light diffusion of LEDs. The material inherently emphasizes or augments the technology actuation due to one of its qualities.

At the same time, we can transform and design the material to enable or characterize the behaviour. In the experimentations, by combining DIY bioplastics as an easily customizable material and digital fabrication as a rapid prototyping technique, we are able to obtain personalized artefacts with different qualities, affordances, and experiences.

Crafting as a hybrid practice and collaborative embodied experience

As the case study demonstrates, HMS are made of components – layers or building blocks – that have physical and interactive natures, latent and dynamic qualities, material- and technology-based elements. Due to this complexity, ICS materials and HMS are situated at the intersection of material science, interaction design, and design. This position implies specific knowledge and skills needed to design *with* and *for* these materials. For instance, to make the whole system function, programming skills are required to make the technology working, material-making skills to craft the material samples, and design skills to integrate them into a system. This has implications for defining design processes and fabrication techniques to ideate and prototype such materials.

Collaboration within a mixed research and practice group is a valuable resource for many reasons, especially for learning from one another and merging skills and knowledge to tackle multidisciplinary challenges (Groth et al., 2020). In this case, thanks to the multidisciplinary structure of the experimentation, the research team has expanded its knowledge in areas that are not usually tackled together. In particular, we find that the practice of cooking can enhance a shared experiential knowledge of materials. Indeed, the intrinsic and shared familiarity with the process of cooking facilitates a visceral creation process and an intuitive dialogue between the team members with different background, and types and levels of their expertise and knowledge. Following recipes and instructions promotes a whole bodily experience in which new knowledge and skills flourish (Sutton, 2018). In cooking, creativity is activated and embodied knowledge is revealed (Baurley et al., 2020) as designers deal with recipe instructions and personal preferences, observe results, and make extemporaneous creative decisions.

Our experimentation highlights the collaborative aspect of embodied experience. Indeed, it emphasizes the relationships between individuals and materials, and the impact of the context and the researchers involved on the creation and transmission of knowledge. Through collaborative crafting, the research team has acquired and expanded the basic knowledge, potential and limitations of bio-based materials, laser cutting and engraving, and LED integration and programming. In this space, design emerges as an experimental and interdisciplinary dialogue involving the analogue – for instance, the shared practice of cooking bioplastics – and the digital – laser cutting and engraving techniques and actuators programming.

Enabled and implied experiences

HMS and ICS materials are enablers of novel and meaningful materials experience, as a combination of the expressive-sensorial characteristics, meanings, emotions, and actions elicited by their material components and interactive behaviours. During the experimentation, we have recollected and analysed our personal experience emerging from interacting with these materials through our self-observation and discussion, following a first-person observation and self-reporting approach. To articulate, label, and link our observations, we applied in an intuitive, rather than systematic, manner the four levels of the materials experience framework (Giaccardi & Karana, 2015): (a) sensorial (i.e., how materials are sensed), (b) affective (i.e., emotions elicited by materials), (c) interpretive (i.e., meanings evoked by materials), and (d) performative (i.e., actions prompted by materials).

Among the main findings, the relationship and distinction between temporal and static expressions stands out. When the material sample does not perform a temporal behaviour, our observation reveals its considerable similarity with traditional bioplastics. This resemblance arises primarily from the sensorial experience tied to the material used to encase the technology – i.e., the one we first experience with our senses. The same implication regards the emotions and meanings elicited, which depend on our previous experience and familiarity with the material. Conversely, the sample's light-emitting behaviour exerts a significant influence across all experiential levels. For example, this temporal expression enables our emotions of surprise, fascination, awe, and contentment. As a result of the presence of static and temporal expressions, the samples generate experiential tension and contradiction; we can perceive them simultaneously as familiar, traditional, and natural – for their appearance – and strange, technological, and artificial – for their behaviours. Additionally, the occasional folding and shrinkage occurring in the samples over time introduce a slower and unpredictable temporal expression. The resulting layered and complex temporal forms contribute to our deeper emotional connection with the samples.

Expanding embodied knowledge: designing artefacts in a collaborative workshop

Applied to an educational design workshop (Parisi et al., 2021), our experimentation offers us an opportunity to share our knowledge with participants using samples, recipes, and tutorials. The developed crafting procedure and methodology based on the combination of bioplastic making, customizable digital manufacturing, and sensor and actuators embedding allow for the ideation of tangible artefacts. Access to the crafting methodology, such as laser-cut wooden frames and laser-engraved textured plastic sheets in various dimensions, enables the participants to experiment with the first bioplastic samples. After some iterations, they can start designing their own frames for form-making, surfaces for texture-making, and recipes for material expression. The participants are able to create new recipes by changing the ingredients' proportions and adding fillers (e.g., powders and pigments), exploring different properties of bioplastics, including mechanical (e.g., elasticity, stiffness), optical (e.g., transparency, translucency, opaqueness), and physical (e.g., texture) properties. They can also add interactive behaviours to bioplastics using digitally fabricated supports and embeddable electronics, e.g., touch sensors, LEDs, and an Arduino Mini board. The combination of DIY bioplastics as an easily customizable material and digital fabrication as a rapid prototyping technique support the participants in achieving personalized, tangible interfaces for unique experiences (Figure 14.6). Finally, the potential of bioplastics to embed technologies can be exploited. In most cases, the participants explore the interplay between technology, materials, and shapes using the concept of light. The light-emitting behaviour and the material qualities are intrinsically dependent and inform each other, while the texture enhances the interaction between the light and the material. We realize the value of the hands-on and extensive experimental process as being particularly informative. Thanks to the collaborative setting of the workshop, the participants master the basic knowledge, potential, and limits of bioplastics, understanding some unconventional application potential of

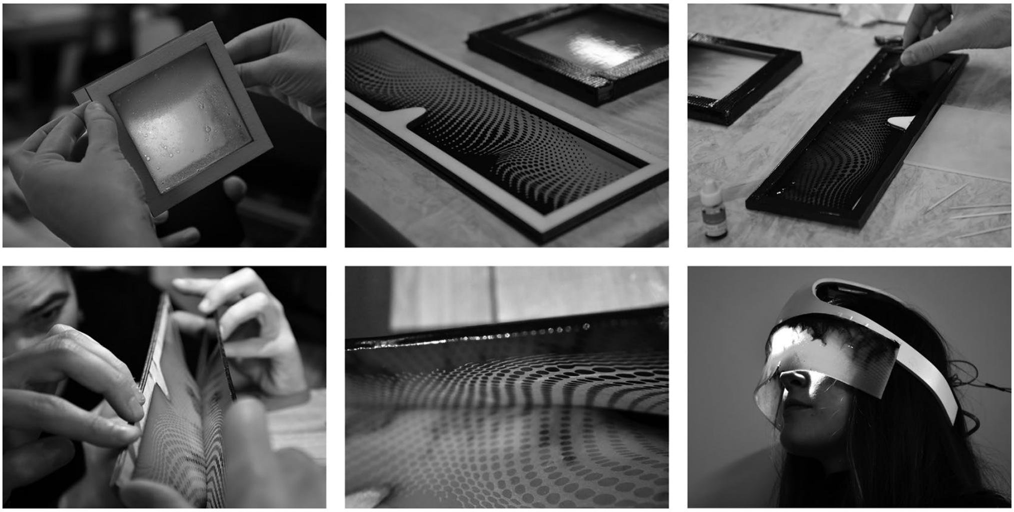

Figure 14.6 The methodology applied in a design workshop. Participants achieve personalized shapes and textures through laser-cutting and engraving on moulds, ultimately shaping a conceptual product prototype. Photographs by Laura Varisco.

digital manufacturing technologies. In doing so, they learn and first-hand experience that integrating electronic components into a prototype presents unexpected complexities. This embodied experience of the participants dealing with areas that are not usually tackled together is possible thanks to the multidisciplinary and collaborative setup of the experimentation.

Our experimentation and the organization of a design workshop have allowed us to produce physical results in the form of samples and prototypes, and ultimately to make direct observations on ICS materials and HMS. However, one of the main limitations we have encountered in the research is the difficulty of seamlessly integrating technologies into the material due to the limited available resources and the low-tech DIY techniques chosen for the experimentation. We have often opted for a "simulation" approach to overcome these obstacles. In fact, most of the samples and prototypes we have developed do not integrate technologies correctly or seamlessly. Therefore, some bulky technological components such as Arduino boards and batteries are assembled to the prototype in a removable or "quick-and-dirty" way, put close to the materials without an actual integration, or hidden in a case.

However, these prototypes should not be considered as completely functioning or feasible products ready for use but as demonstrators of possible future materials and platforms for speculative and critical thinking. From this viewpoint, the inherently underdeveloped and open-ended nature of the material forms encourages imagination. This approach facilitates envisioning potential future solutions detaching from the current stage of materialization that can be achieved today. It allows for novel ways of envisioning material-based futures and new experiential learning practices. From a technical perspective, the prototypes can easily be adapted to new configurations and technologies, becoming a platform for cultivating material thinking through bioplastic cooking and digital fabrication in collaborative and experiential learning settings.

Conclusion

This chapter has explored hybrid craft practices, their impact on designers, and the integration of technology and materials to create novel materials experiences, through a case study of augmented bioplastic. The craft method involves DIY bioplastic cooking, smart components programming, and digital fabrication, revealing intertwined relationships between material qualities, form, and technology programming. The collaborative aspect of the embodied experience has been highlighted, as crafting becomes a space for interdisciplinary and material dialogue involving analogue and digital elements. The collaborative experimentation and the workshop have demonstrated the potential of HMS and ICS materials to enable novel and meaningful materials experiences.

Acknowledgement

We thank Prof Daniela Petrelli and Nick Dulake, Sheffield Hallam University, for their collaboration in the experimentation. We thank the other members of the InDATA project at the Politecnico di Milano, Department of Design, Ilaria Mariani, Patrizia Bolzan, Mila Stepanovic, and Laura Varisco, for the co-organization of the design workshop. The project presented in this chapter was led by the first author – Dr Stefano Parisi – in the scope of his PhD research, partially funded by Fondazione Fratelli Confalonieri. The research was conducted under the supervision of the third author – Prof Valentina Rognoli – and with the collaboration of the second author – Prof Venere Ferraro – who contributed to the theoretical framing within ICS materials branch of research and to the observation and discussion of the results.

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Afterword

Tim Ingold

There is no better way to study how we think and know than by engaging directly with materials in the practice of a craft. In this volume, Nithikul Nimkulrat and Camilla Groth have assembled a formidable team of academic researchers, design professionals, and craft practitioners to address the questions such study throws up. Here, the crafting of materials and of the intellect meet on level terms, carrying equal weight as practices of discovery and scholarship. I found the masterly contributions that make up the book to be of such absorbing interest that they left me with more pages of notes than any other book I have read in a long while. Looking back through my notes, however, I realized that they were peppered not only with observations but with doubts and reservations, some marginal, others fundamental. These, indeed, are precisely what, for me, made the book so interesting. For surely, the most satisfying books are never ones that you completely agree with. It is boring to read a text, only to find your existing views confirmed in every particular. The most exciting texts are always ones that make you sit up and think, “no, that can’t be right”. Doubt creeps into my mind, “maybe they’re right and I’m wrong”. Is it not from the seeds of doubt that all knowledge grows?

In my reading, these doubts centred on recent developments in the science of cognition, which furnish this volume with the core tenets around which its discussions largely revolve. In what follows, I shall set out my reservations, in order not to disparage the book but, on the contrary, to express my appreciation for what it achieves. It is for you, dear reader, to take or leave these reservations as you think fit. I should confess at the outset that, as an anthropologist, trained to favour empirical experience over speculative theory, I have never quite seen eye to eye with cognitive scientists. They always like to see themselves as ahead of the curve. Time and again, they come bearing novel, acronym-branded and paradigm-busting products which promise to revolutionize the field. They write authoritative books explaining, once and for all, how the mind works or how people think. But they are not so good at listening to what the people whose mind-workings they claim to have explained have to say, or at attending to what they think or know. For them, that’s just data for analysis. And the result is that they are sometimes the last to cotton on to what has long been self-evident to the rest of us who, in coping with the vicissitudes of everyday life, are more prepared to trust in our own intuition.

Among these obvious, even banal truths is that we think things out as we go along, that doing so means putting bodily capacities to work, and that all our thinking-cum-doing goes on in a world of other people and things, together making up an environment, which furnishes not only the field for our activities but also the means to carry on with them. For years, cognitive science would cling to a vision of the human condition that contradicted these truths at every turn. It would continue to insist that thinking comes before doing and is entirely detached from it – as if the head could be cut from its body, the one delivering commands to be executed mechanically by the other – and that what we perceive as the world around us is nothing more than an interior mental representation of a reality "out there" of which we can have no direct knowledge whatever. Indeed, a certain kudos has always attached to the counterintuitive, as if it could give science an edge over what is patronizingly demeaned as the folk wisdom of ordinary people. Nothing suits science more than to declare that things are not as they seem, or as previously thought. That, perhaps, is why the science of cognition remained so resistant to other scholarly approaches more receptive to human experience.

These approaches would include the pragmatism of philosophers like William James and John Dewey, the semiotics of Charles Sanders Peirce and Jakob von Uexküll, the phenomenology of Maurice Merleau-Ponty and the ecological psychology of James Gibson. While differing among themselves, they share at root an acknowledgement of the bodily and environmental formation of experience – and this, long before the possibility even appeared on the radar of cognitivism. But when cognitive science did finally catch up with what exponents of pragmatism, semiotics, phenomenology, and ecological psychology had been saying all along, it did nothing to dent the confidence of its practitioners. On the contrary, audaciously appropriating the conceptual tools forged by decades of work in these latter fields, they could proudly announce the arrival of a brand-new paradigm which assimilated them all. It is the paradigm of *embodied cognition*, or EC. Having belatedly "discovered" embodiment, the science of cognition has since fallen for it head over heels, promoting it as a universal cure for all mind/body problems. Everything, it seems – be it mind, consciousness, knowledge, practice, skill, meaning, the self – is embodied. Subsequently, "embodied" has been joined by three other words beginning with the same letter, including "embedded", "extended", and "enacted", to make up what is known as *4Es cognition*.

But has anything really changed? Has the science of cognition truly undergone such a fundamental conversion as to consign much of its earlier efforts to irrelevance? Or does the substitution of the embodied, embedded, extended, and enacted mind for the allegedly bodyless and free-floating, yet skull-bound and immobile information processor – the homunculus in the head once held responsible for all cognitive operations – leave the science intact? It is fair to say that the jury remains out on this question.

Let's begin with "embodied". It seems reasonable to suppose that we are present and alive to the world only because we have, or rather *are*, our bodies. But does that make us embodied beings? The *em-* of "embodiment", after all, signifies a putting in, deposition or infolding. An embodied being, then, is one that has folded in on itself, drawing into its substance that which lay, at least initially, beyond its bounds. Thus, for cognition to be embodied, it must commence beyond the body and worm its way in – a view scarcely compatible with the idea that thinking it is manifested above all in the body's *un*folding, in its action in the world. Nine times out of ten, the contradiction can be simply ironed out by substituting "bodily" for "embodied". Cognition can be a function of bodily existence, without its being literally embodied. Every so often, however, a hint is let slip to indicate that with "embodied", rather more is at stake than grammatical nuance. It is the assumption that in the process of embodiment, knowledge once explicitly held and subject to deliberate reflection sinks down, in some imaginary column of consciousness, to ever lower levels. Here it becomes tacit, ineffable, immune to reflection, and borne forth in actions that are habitual or "second nature", if not fully automatic.

This assumption, which found its way into sociological and anthropological discussions of the bodily *habitus* long before it reached cognitive science, is to my mind deeply problematic. For one thing, it reproduces the very dualism, between a disembodied, verbally enabled intellect, and an embodied domain of wordless, automatic operations, which the perspective of embodiment pretends to dissolve. For another thing, it leaves those in possession of embodied knowledge without a voice of their own. Unable to speak for themselves, it is left to scientific researchers to do so on their behalf. No change there! And with the second e-term, "embedded", this is taken one step further. The mind, having settled down into the body, is supposed to sink even further as the body settles into the surrounding world. The contrast, here, between the emancipated mind of the scientist and the embedded mind of the practitioner could not be more pronounced. The former, searching for universal theorems, evades the constraints of context; the latter, preoccupied with practical problems, is so bound to these constraints that even words escape it. It is as though the opposition between mind and world had been transposed onto that between research and practice. There is a political dimension to this too, in the continued privileging of explicit scientific knowledge over the tacit knowledge of lay practitioners.

Arguments to the effect that the thinking mind is embedded in its environmental context often draw for support on Gibsonian ecological psychology, and most particularly on the concept of *affordance*. Gibson had introduced the concept to refer to the possibilities and hindrances that an environment offers to an inhabitant in the practice of a certain form of life. It is to these affordances, he argued, that the inhabitant primarily attends in perception and action. In his lifetime, Gibson was irascibly opposed to all forms of cognitivism. He did not however live to see the emergence of the 4Es. Had he done so, I wonder, would he have welcomed the idea of 4Es cognition as a final vindication of his approach? Or would he have dismissed it as yet another turn of the cognitivist screw? My guess is the latter. The word "embedded" figures only once in Gibson's oeuvre, to describe how small-scale environments nest within those of larger scale. When it comes to the relation between the perceiver and the world, his preferred term was not embeddedness but *attunement*. As Gibson always insisted, every affordance points both ways, towards the perceiver and towards the environment. Attunement, then, lies in the continual adjustment of the former's action to an ongoing perceptual monitoring of what the latter affords.

Afficionados of the 4Es would doubtless respond by turning to their third e-term, namely "extended". Where the prefix *em-* connotes a putting in, *ex-* connotes the opposite, a drawing out. Thus, where embeddedness is on the side of the environment as it takes in the mind, extension is on the side of the mind as it takes in the environment. While neither term may suffice on its own, taken together they give us the two sides of affordance. Yet something about the concept of extension suggests a lesser break with the assumptions of traditional cognitive science than appears at first glance. For theorists of extended cognition, notably Andy Clark, still regard the mind as a computational device, tasked with delivering solutions to problems set by the environment, based on information received, for subsequent enactment in the world. The difference is only that what Clark calls the "wideware" of the mind now includes diverse environmental objects, like pen and paper for the mathematician, or ruler and compass for the navigator, enrolled to assist it in its calculations. Here, the environment doubles up as both as an extended sphere of problem-solving, and as a domain in which solutions are implemented. How, then, can we distinguish the one from the other, solving problems from implementing solutions?

We can do so only by positing the mind not just as a cognitive agent, but as a double agent, which pretends to join with other persons and things in the environment only to recruit these others, behind their back and without their knowledge, to the exclusive benefit of its own operations. This is more infiltration than collaboration. If we think as we act and know as we go – and all experience confirms this to be so – then there can be no clear line of demarcation between solving problems and enacting their solutions. And this brings us to the final e-term, *enactment*. It may be splitting hairs to distinguish enactment from action; nevertheless, enactment literally means to put into practice a resolution already reached, rather than working things out as you go along. The latter, typical of everyday life, is an improvisation that calls for continuing attention to things and the ways they want to go. This is not to deny that in life, we confront endless problems, which we do our best to solve. It is however to insist that real-life problems never contain their own solutions. Rather, the solution always overflows the problem. Finding it amounts not to a computation in the mind – even an extended mind – but to a vital movement in the world.

For these reasons, I would take the 4Es formula with a pinch of salt. Rote repetition makes it no more compelling. What counts for me is the liveliness of bodies that breathe, speak, sing, gesture, make things, and run in and out of one another in unceasing and always passionate response to a world of materials equally bursting with vitality. But these are bodies that suffer too, as they encounter resistances and toxicities, many of which arise as by-products of their own activity. Thinking and knowing, then, are less embodied than animate, less embedded than attuned, less extended than inter-corporeal, less enacted than improvised. They are neither tacit nor explicit but atmospheric and full of feeling. Rather than connecting things up, they swirl around in the interstices between them. They can be conducted with or without words, sometimes silently, often noisily. The chapters in this volume have offered us a wealth of examples. Do the 4Es, then, get to the bottom of how people think and know, or is something vital still omitted? I have no other way to answer than by returning to my own experience, and comparing it with that of which each chapter speaks. No doubt, as you have delved into the pages of this book, you have done the same. And I am confident that in bringing your experience to the table, you have been no less richly rewarded!

Tim Ingold
Aberdeen, January 2024

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