KNOWING TOGETHER

EXPERIENTIAL KNOWLEDGE AND COLLABORATION

International Conference 2019
of the Design Research Society
Special Interest Group on
Experiential Knowledge (EKSIG)

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EKSIG 2019
Knowing Together — experiential knowledge and collaboration

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Editors: Nithikul Nimkulrat, Kristi Kuusk, Julia Valle Noronha, Camilla Groth and Oscar Tomico

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EDITORIAL

Nithikul Nimkulrat,
Kristi Kuusk,
Julia Valle Noronha,
Camilla Groth,
Oscar Tomico

EKSIG 2019: Knowing Together — experiential knowledge and collaboration, International Conference 2019 of the DRS Special Interest Group on Experiential Knowledge (EKSIG), aims to provide a forum for debate about knowledge generation in collaboration by professionals and academic researchers in the creative disciplines and beyond.

These proceedings contain the keynote speakers' abstracts and the full papers accepted through double blind review for the EKSIG 2019: Knowing Together held on 23th and 24th September 2019 at Estonian Academy of Arts.

CONFERENCE THEME

Creative practice has transformed from one based on the production of material artefacts to one that engages expertise and knowledge from multiple disciplines. Recent research in the creative disciplines has revolved around the changing territorial context of 'making' (Ingold, 2013; Sennett, 2008) and has increasingly involved professionals and academic researchers working collaboratively to explore an interdisciplinary inquiry (Plattner, Meinel & Leifer, 2018). Collaboration in such research has therefore become vital. A research team may comprise different disciplinary experts, such as scientists, technologists, artists, designers, architects, psychologists, business strategists and policy makers, working across academic, commercial and public sectors (e.g. Bowen et al., 2016; Nimkulrat & Matthews, 2017). They may work with materials and/or non-materials. Examples include research in the fields of New Materials, Smart Textiles, Virtual Materiality, Material Innovation, Embodied Ideation, and Participatory Practices in Business in which various partners are in dialogue, developing, consolidating and enhancing knowledge while generating new opportunities for interdisciplinary knowledge exchange.

This conference therefore examines collaboration within research teams of professionals/researchers and members with other diverse disciplinary expertise. Collaboration here is interpreted in the widest possible sense to include any kind of working together. This is to understand how individual experiential knowledge — or knowledge gained by practice — is shared, how collective experiential knowledge is accumulated and communicated in and through collaboration, and how it is embodied in the outputs and may be traced back to the origin of the practice. The conference also aims to illuminate 'making' as the action of change in which matter and materials are transformed through collaboration, interaction or negotiation between the collaborative team and their material and non-material environments.

Experiential knowledge generated when researchers and practitioners collaborate with experts in other fields are discussed in a rich collection of case studies presented in the papers that shed light on the relationships built within the collaboration, the approaches used and the new knowledge gained and transferred within the team. This should contribute to a more systematic approach for studying and integrating experiential knowledge into collaborative practice and research.

The call for paper encourages contributions with the following:

- What are the current understandings of collaboration and interdisciplinary research?
- How can collaboration be utilized within the framework of research?
- How can a researcher's disciplinary expertise benefit collaborative research and practice?
- How can we articulate material (and immaterial) knowledge which are tacit and embodied within the process of research?
- How can skills and embodied knowledge in different professional disciplines be shared and/or applicable to one another in a collaborative practice?
- How can we gain and communicate individual and collective experiential knowledge in and through collaboration, and how is it embodied in the outputs and may be traced back to the origin of the practice?
- What means and methods can be utilized to transfer and replicate tacit knowledge accumulated in collaborative practice?

RESPONSES

As in previous years, the conference call received a great international response with sub- missions from 17 countries including Belgium, Brazil, Chile, Denmark, Estonia, Finland, Germany, Greece, Italy, Norway, The Netherlands, New Zealand, Norway, Spain, Sweden, UK and USA.

Submissions were interdisciplinary and stem from a variety of disciplines and areas including architecture, behavioural science, ceramics, culinary art, design engineering, digital craft, education, fashion, HCI, material design, product service system design, psychology, restoration and textiles.

For the conference, contributions were selected in a one-stage process, comprising full paper selection, through a double-blind review process by the conference's international review panel of 32 reviewers. From the contributions, the following five strands emerged:

Strand 1: Handmade and Digital Crafts in Collaboration
Strand 2: Making as Action of Change
Strand 3: Collaboration towards Sustainability
Strand 4: Multi-Stakeholder Collaboration
Strand 5: Collaboration and Knowledge Transfer

Each session deals with one aspect of 'knowing together' and in total the strands cover the widest possible understanding of experiential knowledge generated in collaboration.

The conference is opened by paper presentations in **Strand 1** which focuses on hand and digital craftsmanship in collaborative practices. **Maighraed Mcewan** and **Jane Scott** discuss the transformation of the maker's experiential knowledge through collaboration with a digital tool, in this case — a lasercutter, the results of which demonstrate how collaborations between the handmade and digital can introduce craft thinking into digital workflows. **Flemming Tvede Hansen** and **Martin Tamke** present a collaborative project between an architect, a ceramicist and a programmer to develop a computational tool that embraces necessary knowledge to materialize a ceramic design that meets the architecture desired. Their case study illuminates how skills and embodied knowledge in different professional disciplines can be shared and applied in a collaborative practice. **Troy Nachtigall**, **Svetlana Mironcika**, **Loe Feijs**, and **Oscar Tomico** examine emerging forms of digital craftsmanship in shoe design that involve scaffolds of data and digital fabrication into Ultra-Personalized Product Service Systems (UPPSS). A design game for UPPSS shoemaking is designed and deployed to help designers when confronting the challenges of the complex process of UPPSS.

The first keynote by **Professor Juhani Pallasmaa** examines architecture and design from an experiential perspective. He argues that architecture and design are products of imagination which has two qualitative levels: first, the level of formal and material structures and second, the level that concerns the encounter with and experience of the imaginary physical entity. A meaningful experience always extends simultaneously our senses of the past, present and future in the act of encountering and experiencing the architectural or design work.

The keynote is followed by **Strand 2** which emphasizes making as the action of change. **Miranda Smitheram** and **Frances Joseph** addresses aspects of collaboration with the ecosystem to create artefacts that are not functional products, but rather matter flows that are formed through diverse perspectives and collaborative processes. The methodology shifts away from human-centredness to matter as collaborator and place as habitat where the relationships between things can be expressed. **Natalia Triantafylli** and **Spyros Bofylatos** present how autoethnography can be used as a critical approach in research through design to support the practitioner to contextualize her work and to open up a space for self-reflection in the documentation process in the case of designing a lighting fixture that invites users to play with its tactile operation switch. **Ian Lambert**'s paper discusses theoretical perspectives on improvisation as a powerful generator of new knowledge in practice-based research and its enhancement through the wilful naïveté approach with reference to his sandcasting experimentation.

Day 2 begins with **Strand 3** which is concerned with interdisciplinary collaboration that aims at producing sustainable materials and products. **Donna Cleveland** examines the complexities of an unsustainable manufacturing cycle and suggests an opportunity to utilize the raw material from a localized textile waste system in New Zealand to develop a value added, closed loop, innosvative and sustainable textile product. **Marie Vinter** and **Kairi Koort**'s paper offers material solutions for sensing and adapting to environment. Through interdisciplinary collaboration between textile designers and natural scientists, new morphologies of spider and silkworm silk are proposed as promising future sustainable materials. **Niki Boukouvala**, **Spyros Bofylatos** and **Nikolaos Zacharopoulos** examines a collaboration between design engineers and mycologists in the creation of mycelium-based materials using the DIY process and the Biofabrication approach, which is closely linked to the transition towards sustainability and ways of designing that incorporate different values and aesthetics. **Paula Veske** and **Barbro Scholz**'s paper presents a smart textile project that brings experts from the fields of electronics and textile engineering together to create a kit for educational purposes by following circular economy principles.

Strands 4 and 5 expand the conference theme. While **Strand 4** focuses on more complex collaboration that involves multiple disciplinary experts, **Strand 5** examines the forms of knowledge necessary in interdisciplinary collaboration and how knowledge can be shared and transferred in a collaboration.

Strand 4 starts with **Paula Dekkers-Verbon**, **Marina Toeters**, **Marije Baars**, **Emilia Barakova** and **Paula Sterkenburg**'s paper, which describes the multiple stakeholders' co-creation process of developing an interactive playmat that generates bonds between the parent and the visual-impaired or intellectually-disabled infant by stimulating sensitive mirroring behaviour of the parent. **Kristi Kuusk**, **Ana Tajadura-Jiménez** and **Aleksander Väljamäe** reflect on a collaborative project carried out by experts from the fields of e-textiles, neuroscience and human-computer interaction (HCI), the result of which is a garment that generates sensation to the wearer and the wearer in turn elicits emotional responses. The paper provides perspectives on finding a common space and language for sharing cognitive and experiential knowledge between researchers. **Pilar Fernández** and **Kristina Rovnenko** examine the restoration of Kuldīga's historic buildings that requires knowledge and expertise experientially transferred from one generation to another.

Mark Bradford begins Strand 5 by presenting a new dynamic approach of embodied practice called the "BeWeDō® framework" within the ideation process. The framework adapts one specific movement of Aikidō (a Japanese martial art) to transform the possibilities of conversation between people with physical movement that engages the body-mind-environment. **Daniel Östergren** and **Inger M. Jonsson** present their investigation into the interdisciplinary academic discipline of Culinary Arts and Meal Science (CAMS) at their university. Starting from three separate forms of knowledge — science, artistic endeavour and practical skills — Östergren and Jonsson recognize development towards three corresponding functions of knowledge — episteme, techne and phronesis — that are required by an interdisciplinary discipline like culinary arts and meal science. **Camilla Groth**, **Margherita Pevere**, **Pirjo Kääriäinen** and **Kirsi Niinimäki** discuss the ways in which the combination of scientific and artistic research in interdisciplinary projects exploring new materials provide opportunities for opening up new areas of knowledge previously hidden in-between disciplines and at the same time pose challenges in sharing knowledge between the researchers from different fields. **Joanna Rutkowska**, **Froukje Sleeswijk Visser** and **David Lamas** present the actionable palette that consists of nine qualities that act as building blocks of actionable forms of sharing and communicating design knowledge. The researchers use this palette to analyse the actionability of design research outputs, pictorials in particular.

Prof. Ron Wakkary's closing keynote explores the potential to see design from the perspective of posthuman subjectivity. Posthuman, according to Wakkary, means thinking about the world as if humans share a pivot stage with non-humans. Four assumptions that stimulate this idea consider things as interconnected, transformative, relational and vital. Design examples ranging from common objects to Wakkary's own design research to speculative design are discussed to shed light on how human designers "can co-shape the designing of things in ways that aspire to be equitable, political, and caring".

IN SUMMARY

The conference shares different views on experiential knowledge generation and communication in and through collaboration by professionals and academic researchers in the creative disciplines and beyond.

The great response to the call for papers has brought together theoretical perspectives and case studies as well as emerging models and practices in a number of disciplines, including architecture, behavioural science, ceramics, culinary art, design engineering, digital craft, education, fashion, HCI, material design, product service system design, psychology, restoration and textiles.

The accepted papers evidence the current understandings of collaboration and interdisciplinary research and various ways in which collaboration takes place within the framework of research. The issues discussed are key to understand how the researcher's disciplinary expertise may benefit collaborative research and practice and how researchers may share their skills and experiential knowledge in different professional disciplines with one another in a collaborative practice. The response to the call may be seen as an indicator that experiential knowledge is a maturing field and recognition of the inter-disciplinarity of related research.

THE EKSIG 2019 CONFERENCE

EKSIG 2019: Knowing Together — experiential knowledge and collaboration, International Conference 2019 of the DRS Special Interest Group on Experiential Knowledge (EKSIG), is hosted by Estonian Academy of Arts.

EKSIG is part of a program of Special Interest Groups set up by the Design Research Society (DRS) to facilitate international exchange and to advance knowledge in relevant areas of design. EKSIG is concerned with the understanding and management of experiential knowledge in research and professional practice in design and design related disciplines in order to clarify fundamental principles and practices of using practice within research, both with regard to research regulations and requirements, and research methodology.

The EKSIG conferences are part of a regular programme of the EKSIG group. They serve to bring together researchers and practitioners from different disciplines and to promote understanding and best practice concerning the integration of different forms of knowledge within design research and practice.

EKSIG promotes a multidisciplinary approach to engender multi-vocal debates and cross-fertilization between the creative disciplines and other practice-led disciplines, including contributions from the design disciplines (design, engineering, craft, media etc.), philosophy, education, health and knowledge management that are concerned with methods and methodology in research and in creative and professional practice; with the nature, role, and management of knowledge within research; and with the role and use of creative practice (both as process and outcome) as a means by which to develop and manage experiential/tacit knowledge within research.

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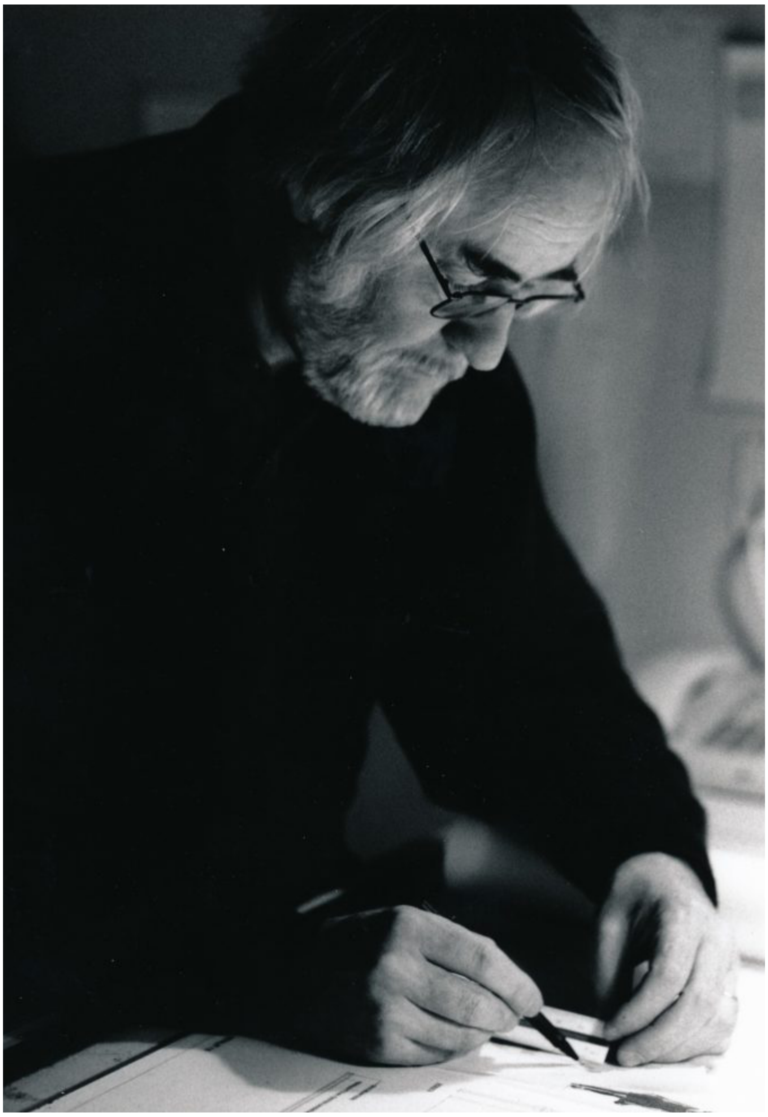
KEYNOTES



EMBODIED AND EMPATHIC KNOWLEDGE – INTUITING EXPERIENCE AND LIFE IN ARCHITECTURE
Prof. Juhani Pallasmaa

THINGS WE COULD DESIGN – A POST-HUMAN EXPLORATION
Prof. Ron Wakkary

EMBODIED AND EMPATHIC KNOWLEDGE – INTUITING EXPERIENCE AND LIFE IN ARCHITECTURE

Prof. Juhani Pallasmaa

ABSTRACT

Contemporary architecture and design are frequently accused of exclusive aesthetics and emotional coldness. Indeed, design tends to seek formal perfection and aesthetic autonomy, and this aspiration is in conflict with the spontaneity of lived life and the nature of our existential and experiential life-world. Especially the formalist Minimalism of the past decades has often distanced buildings from the realities of lived life.

Designed spaces are not just empty spaces for human activities. They guide, tune, choreograph and stimulate actions, interests and moods, while in the negative case, they stifle and prohibit this interaction. Every space, place and situation is tuned in a specific way. We live in resonance with the world, and architecture articulates and mediates this resonance. Buildings are products of imagination, and there are two qualitative levels of imagination; one is capable of projecting formal and material structures, the second is capable of imagining the encounter with and experience of the imaginary physical entity. Imagination is not a quasi-visual projection, as we are capable of imagining through all our senses and our entire embodied existence. I suggest that vision is not the most important sense in design, as the most essential qualities are encountered through our sense of existence.

I also wish to argue that true architectural qualities are not merely aesthetic, as true qualities are existential, poetic, archetypal and archaic, embodied and emotive. A meaningful artistic experience always extends simultaneously our senses of the deep past, present and future. Architectural qualities are constituted in the act of encountering and experiencing the work. The highest level of imagination is the empathic imagination, which enables the designer to imagine the experience of the other, the future user of the space. A gifted and experienced designer develops a syncretic imagination, which enables her to experience the designed entity and its complex atmospheres and resonances as a multi-sensory and existential entity. We, architects, can learn significantly from the thematic, atmospheric and emotive richness of the works of writers, filmmakers, theatre directors, dancers and visual artists. Their works fire and attune our imaginations instead of attempting to be the end results. Also, true architectural images are choreographic invitations for action and feeling, and they are also promises and gifts.

BIOGRAPHY

Juhani Pallasmaa, architect SAFA, Hon. FAIA, Int FRIBA, has been active in urban planning, architecture, and exhibition/product/graphic design since the early 1960s.

He has held many positions, including Professor and Dean, Helsinki University of Technology *(1991–97)*; Director of the Museum of Finnish Architecture *(1978–83)*; and Rector of the Institute of Design, Helsinki *(1970–71)*. He has held several visiting professorships in the US (Catholic University of America in Washington, D.C., University of Illinois, Washington University in St. Louis, University of Virginia and Yale University) and lectured widely in Europe, North and South America, Africa, and Asia.

Pallasmaa has published 50 books and more than 300 essays in 30 languages, including The Embodied Image *(2011)*, The Thinking Hand *(2009)*, Encounters: Architectural Essays *(2005)* and Encounters 2 *(2012)*, The Architecture of Image: Existential Space in Cinema *(2001 and 2007)*, and The Eyes of the Skin: Architecture and the Senses *(1996 and 2005)*.

THINGS WE COULD DESIGN — A POSTHUMAN EXPLORATION

Prof. Ron Wakkary

ABSTRACT

This talk is a posthumanist exploration of design. I investigate the potential to see design from the perspective of posthuman subjectivity. By posthuman, I mean thinking about the world as if humans share centre stage with non-humans, and that we are all bound together materially, ethically, and existentially. I'm motivated by wanting alternative approaches to the vexing challenges of how we better co-inhabit our world with species and matter that are not human. And how we design technologies that we neither fully understand nor control.

I talk about "things" as a way to describe what we would design if we were a posthuman designer. I describe four assumptions that motivate this idea: things are 1) interconnected; 2) transformative; 3) relational; and 4) vital. This helps me to see what we have already designed in a new light that is not human-centred and to think of designing differently in the future.

I start with the idea that humans are "prosthetic creatures" and so what we design shapes who we are in ways including how we run, pray, and walk through our cities. Things are also relational and dynamic, meaning they are in need of constant interpretation, whether the thing is a bowl or a public bench. Things also have a certain aliveness and direct themselves at the world in ways we don't fully understand, yet we rely on them. Finally, things are made of matter that is vibrant and agentic such that they appear to have "a life of their own" and so relate to us more like companions than tools. Lastly, in this exploration, a designer is not only human but includes technologies and matter that all act together to design things. Throughout the talk, I discuss design examples ranging from common objects to my design research to speculative design. I also lean on thinkers that philosophically engage the idea of going beyond humanism. I end the talk with some directions on how I think, we as human designers that share the stage with non-human designers and matter, can co-shape the designing of things in ways that aspire to be equitable, political, and caring.

BIOGRAPHY

Ron Wakkary is full professor in the School of Interactive Arts and Technology, Simon Fraser University in Canada where he is the founder of the Everyday Design Studio (eds.siat.sfu.ca). In addition, he is full professor in Industrial Design, Eindhoven University of Technology in the Future Everyday cluster.

Wakkary is interested in design-oriented human-computer interaction (HCI), tangible computing and the philosophies of technologies through design. Wakkary's research investigates the changing nature of interaction design and HCI in response to new understandings of human-technology relations. He aims to reflectively create new interaction design exemplars, concepts, and emergent practices of design that help to shape both design and its relations to technologies.

Wakkary considers people as integrally connected with technologies, actively shaping who they are rather than being passive users or consumers of digital artefacts. He investigates how to design computational things that are radically simple, that encourages people to determine how these things fit into and construct their everyday lives. In many ways, he sees things and systems we design as resources for inquiry rather than finished products.

Ron Wakkary holds a BFA in Visual Arts from Nova Scotia College of Art and Design, Canada, a MFA in visual Arts from the State University of New York, USA, and an PhD in Human-Computer Interaction from the University of Plymouth, UK. Ron is currently a member of the Tangible Embedded/Embodied Interaction (TEI) and Designing Interactive Systems (DIS) steering committees. He is also a member of various editorial boards including International Journal of Design (IJD). He was co-Editor-in-Chief of ACM interactions from 2010 to 2016.

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FULL PAPERS

Deciphering the Craft of the Laser Cutter

Maighraed Mcewan, The University of Leeds, UK

Dr Jane Scott, The University of Leeds, UK

Abstract

This research investigates how the experiential knowledge of a maker can be transformed through collaboration with laser technology. The research is situated within craft theory, evaluating the new tool developed through the research against the craft attributes of the hand-made, skill, risk and technology. Practice led experimental research developed a new digital drawing tool, recording the path of the lasercutter using a range of different drawing pens to yield a variety of different crafted marks. All areas of the results show a hybridisation of craft techniques and knowledge of technology, to achieve a collaborative approach to making. The significance of the research is that it demonstrates how collaborations between the handmade and digital can introduce craft thinking into digital workflows, creating a digital craft methodology which can be applied to further technologies in the future.

Keywords

Craft; Hybridity; Laser Technology.

This research is located within the context of experiential knowledge developed through craft and applied to digital technologies. Craft and its definition with association to technology has been assessed and disputed over since the Renaissance, where craft was considered subordinate to other forms of the visual arts (McCullough, 1998). Glenn Adamson (2013) and Tom Crook (2009) both argue that craft must now be analysed alongside modernity and new technologies rather than oppose them. This collaborative approach to the assimilation of technology into craft shall be explored in this research. Technology offers huge opportunities to innovate within craft practice, however in order to retain the “combination of hand, mind and eye - the technical mastery of tools, materials, aesthetic sensibility and design skills” (Fraser, 2010, no page number), therefore it is essential that craft adopt a more holistic approach to practice that encompasses technology.

This study focuses on the digital technology of lasercutting. Laser technology has developed since its advent in manufacturing purposes, and is now commonly used in craft practice. It engraves and cuts through materials (Berens Baker, 2016), and is controlled by human design on a vector based software. The craft-makers of today are not just readily adopting the laser cutter technology into their process alongside other techniques, but also re-imagining the craft of the machine itself, and the creativity it possesses.

1 Background and Theoretical Approach

The theoretical context for the research identifies four areas of craft to be examined; Handmade, Skill, Risk and technology. Technology is included as an important attribute of craft, as the increasing numbers of craft makers using digital tools cannot be ignored. These four areas are combined to use as a basis for experimentation and analysis of results. However, the literature reviewed provides a research gap to explore; whether these traditional elements of craft can be used as a methodology for makers to apply to digital technology.

1.1 Craft is Hand Made

The hand has played a vital role in making and crafting for centuries. Out of all the sensory experiences, touching and connecting with one's hands appears to play the most important role for a craftsman (Treadaway, 2009). Dormer (1997) argues this can be through direct manipulation of a material by the hand but also through tools that the hand controls. Adamson (2010) proposes that once this vital element of the hand is removed, or is not the main tool used in the creation of an artefact, it can no longer be considered craft at all.

Using our hands to touch is an innate capability; "to touch the world is to know the world" (Benjamin, 1936, p. 168). Tacit knowledge which is "experiential" can only be learnt through the hands (McCullough, 1998, p.3), and this makes craft practice instinctual, and a sensory experience (Dormer, 1997, McCullough, 1998, and Shillito, 2013). However, Sennett (2008) argues that intuition is a form of experiential knowledge which can easily be applied when using the hands to control a technology. For the purpose of this research it is important to understand whether touch can be replicated through technology or not. McCullough (1998) argues that if it is only hands that possess skill, then a technology cannot inhabit the sensorial attributes of touch.

In the context of contemporary craft, makers like Sharyn Dunn focus on the importance of the hand in their making process as they combine techniques to produce craft objects. Dunn uses a combination of processes including papermaking, lasercutting and stitch to produce each piece. She reflects on the importance of the hand as a key attribute of craft:

> "*when the personal or the hand crafting part disappears and its pure technology… it's almost like having robots produce each item"* (Dunn, 2018).

Whilst digital tools enable the production of work, ultimately the hand has been prominent throughout. The hand is not just important for ease of human access, but also promotes a personal rapport with the craft.

A different perspective is to see the hand as what it represents. Craft maker Tom Sowden argues that it is rather how the hand is used throughout the process:

> *"by hand I do not necessarily mean by actually using hands, more as a term for the human input into the making process"* (Sowden, 2018).

From this, the ambiguity into what constitutes hand-made elements in craft is still seen to vary for each craft maker. Although the traditional perception of craft is centred around the handmade, Malins et al. (2004) argue that it is rather the maker's intended idea and how he or she carry this out, not the connection to the hand that is most important.

1.2 Craft is Skill

Skill is an important attribute of craft. Sowden explains that the main attribute of craft to him is *"the learned application of skill"* (Sowden, 2018), which implies that skill is knowledge. For the purpose of this research, skill is described as a repeated and therefore learned method which produces a high level of work. It embodies knowledge, which is nurtured and practiced. The application of skill is not limited to the traditional craft sectors of pottery, textiles and ceramics, but should encompass the skill acquired in learning new technologies (Perry, 2012).

Repetition is essential in the development of practice. McCullough (1998) argues that these essential repetitions of work reinforce the process into the craftsman's knowledge, developing their skill. Sennett (2008) gives an approximate number of 10,000 hours which must be undertaken in order for a craftsman to become skilled or a master of their craft. During this lengthy period, skills are developed and fine-tuned, creating an inevitable sense of control for the craft maker. This skilled control may be found through attention to detail, and knowledge of one's tools.

Rob Ryan's practice focuses on hand cut work, but also utilises the lasercutter to reproduce designs. His application of lasercut technology exemplifies the point that the skill found in craft is now able to be replicated by technology. It is apparent that both pieces of work share the same amount of skill to the eye, suggesting that technology in this case can be used as an attribute of craft.

This connection that the maker builds with their process, embodies a “reflective dialogue with the material world” (Yair and Schwarz, 2011, p.312), which Yair and Schwarz argue is a key characteristic of craft knowledge. By taking its time to develop, skill inadvertently provides a higher level of satisfaction for the maker (Sennett, 2008). Ultimately, the more time given to any collaborative process, yields a larger engagement with the end result. Sennett believes this can be achieved through a process of “embedding” which encompasses the “conversion of information and practices into tacit knowledge” (Sennett, 2008, p.50).

When assessing this point, it is important to address Dormer’s writing on the importance of “distributed” and “personal” knowledge (Dormer, 1997, p.139). Personal knowledge is akin to tacit knowledge which is acquired through memory and experience. For as Dormer asserts, “you not only know that you know but you feel that you know” (ibid). Distributed knowledge, is acquired through the culmination of various techniques from different makers. It encompasses the idea that we also are able to use tools that require no previous personal knowledge. In addition it is the possession of this knowledge and the way it is controlled that defines craft, rather than the attention on the hand or skill.

1.3 Craft is Risk

The concept of irregularity in craft is vital, as these nuances and mistakes are what create the intended hand-crafted element. Pye calls this the “workmanship of risk” (Pye, 1995, p.20) where design or artefact can be ruined at any time. The “workmanship of risk” (ibid) can be applied to most craft outcomes. However, digital technologies strive for precision, and this can be seen to erase the “charm of mistakes” (Fraser, 2010, no page number). It is imperative to understand whether the result of risk should be classified as error, mistake, or even a form of play. For many craft makers working in the era of mass production, a fear of making a mistake led to a classification that taking risks was detrimental to craft (Dormer, 1997, p.141). However the opportunity to work with digital technologies enables mistakes to become “dynamic” (Kourteva and McMeel, 2017, p.177). In Kourteva and McMeel’s experimental architecture, the unknown and surprising results generated through what could be perceived as mistakes in lasercutting, informed the research process and led to innovation in the practice (ibid).

Many makers are now programming mistakes and imperfections into technology, and see this as a way of emitting craft attributes through a digital realm (Braddock Clarke and Harris, 2012). As the technology progresses in craft, makers shall inevitably devise innovative ways to introduce this element of unpredictability into the machines (Perry, 2012). Variable Projects (Marcus, 2016) explores the amalgamation of risk into technology. Here, drawing is presented through technology, seeking imperfection in the outcomes. Marcus’s research presents an important model for this investigation, his use of technology produces marks that are “cumulative and contingent” (Marcus, 2017, p187), and portray a feeling of craft. This project highlights that it is possible to reintroduce the element of risk through modification of technology. This exploitation of the flaws and risks in the technology, leads to a new language being developed, furthering a maker’s knowledge (Fraser, 2010). The interest in this contemporary approach to craft and technology is demonstrated in the success of the touring exhibition Drawing Codes, curated by Adam Marcus and Andrew Kudless. Here technology is used harmoniously with traditional architectural techniques to create a new relationship between maker and the digital realm. The aim of the research presented in this paper is to explore how risk can be enabled and celebrated using laser technology. It is therefore critical to consider the role of technology as a collaborative tool for craft.

1.4 Craft is Technology

Crafts history is rooted in the rejection of technology and the appraisal of hand-made techniques throughout the Industrial Revolution (Malins et al, 2004). However, the use of digital technology has transformed the skills required and the understanding of the handmade within contemporary design/craft practice. McCullough (1998) sees the value in using the computer technology as a tool for craft, which is guided by the skilled hand. This is similar to Jeremy Myerson (1997) who argues the technology of the computer is not a craft in itself rather the pre-existing knowledge of the maker.

The opportunity to explore a range of digital technologies through the lens of craft, has transformed the ability for makers to integrate skill, risk and the handmade into their work. This collaborative approach is observed in Marcus's research (2016) where the digital tools are adapted to produce a crafted process. Treadaway's research into "Hybrid Craft" explains how the fusion of digital techniques into practice is now being seen as a positive aid in one's creative process, rather than reducing the authenticity of a design (Treadaway, 2004). This process has been defined as "interdisciplinarity" (Greenlagh, 2002, p.195), suggesting that the next theme of modernity will come from the linking together of other areas in the arts, resulting in innovative and creative outcomes. These new technological techniques have been acknowledged by Ann Marie Shillito (2013) who suggests unlike Treadaway, that technologically advanced techniques cannot only inform our craft, but are the craft. Shillito values the potential of technology, whilst recognising the knowledge one can acquire from craft experience and its relationship to tactility. It could be argued that as the integration of techniques can be seen as Hybrid Craft, the fusion of craft attributes can now also be a form of hybridity. If craft is based on interdisciplinarity, then it is possible to develop this knowledge into the core attributes of craft itself, and see technology as part of this. Through experimental research, the concept of hybridity as a way to integrate technology into craft research will be evaluated, alongside the other attributes of the handmade, skill and risk critical to understanding craft theory.

2 Materials and Methods

This experimental research investigates how the experiential knowledge of a maker can be transformed through collaboration with laser technology. The research compares the marks produced during a series of design interventions using a laser cutter fitted with a series of alternative devices to replace the laser head. Each experiment records the marks made and evaluates the findings in two ways. Firstly through comparing the results across a series of experiments, and secondly by evaluating the findings against the craft attributes outlined in the theoretical context; Hand-Made, Skill, Risk and Technology.

The objective of the investigation is to provide a basis to understand what craft attributes laser technology can possess. This innovative way to approach craft, although unique, is difficult to quantify. Using the laser head as a drawing tool allows the technology to record not only the marks described through the CAD software, but also to record how the machine creates the marks. This is undertaken by recording the toolpath as it travels across the laser bed.

The laser cutter machine used is a CO2, flatbed laser cutter (CadCam technology). The laser beam moves over the flat surface, according to an x and y axis, following a toolpath unique to the design that is being cut. Every laser cutter varies in velocity and power, these controls can be adapted to produce different effects. In this investigation the speed was adapted to improve the functionality of the alternative pen devices used to replace the laser head.

The research adopts a Practice Led Research (Muratovski, 2016) approach in the form of a series of experimentations testing the craft of the laser cutter machine. This was influenced by Nimkulrat's (2012) study which aimed to understand craft as a new approach of thinking, rather than just an object. In contrast to practice based research the aim here is not to create an end set of final design solutions and artefacts, but a broad range of experimentation, testing the potential of the design intervention using laser technology. The outcome of the experimentation is a variety of contrasting marks produced using different drawing devices. These marks are analysed to determine how experiential knowledge can be developed using the technology through collaboration across craft and the digital production methods.

Initial experiments are carried out in order to understand which variables to test. A variety of pens are tested, with a thin (figure 1, Staedtler stick 430 F), medium (figure 2, STA Aquarelle Brush, no.31101 fine) and thick (figure 3, Pilot super colour marker SCA-6600) type being carried forward for variation. A variety of different speeds and velocities are tested. This ranges from 3-650, which are the minimum and maximum of the laser cutter being used. Three variables are determined from here to ensure a depth of information can be gathered that spans across 3 different velocities and powers. These remain constant throughout. A variety of materials are tested; paper, card, velvet, cotton. However, for ease of reliability the use of paper remains a constant in the experiments.

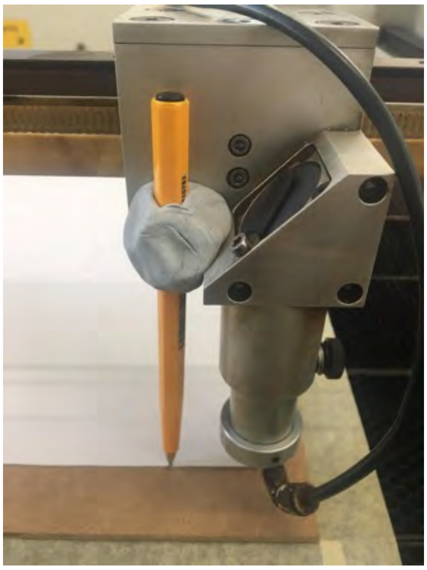

Fig 1. Attachment of Biro to Laser Machine.

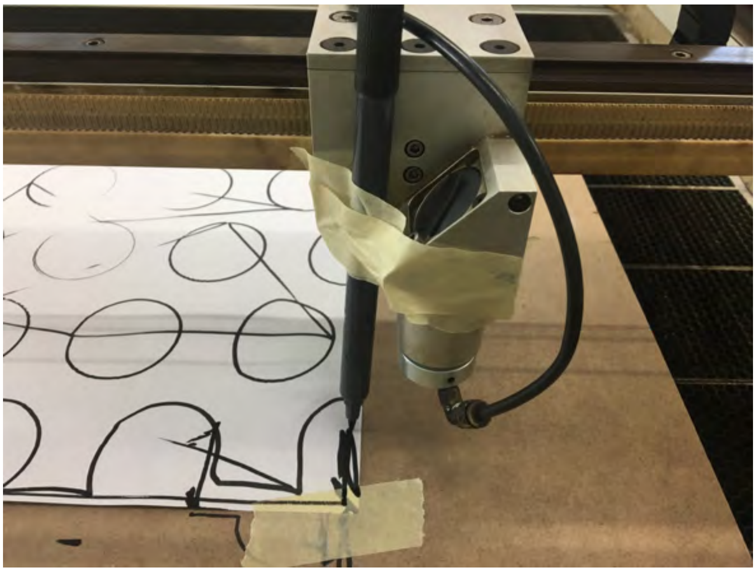

Fig 2. Attachment of Medium Pen to Laser Machine.

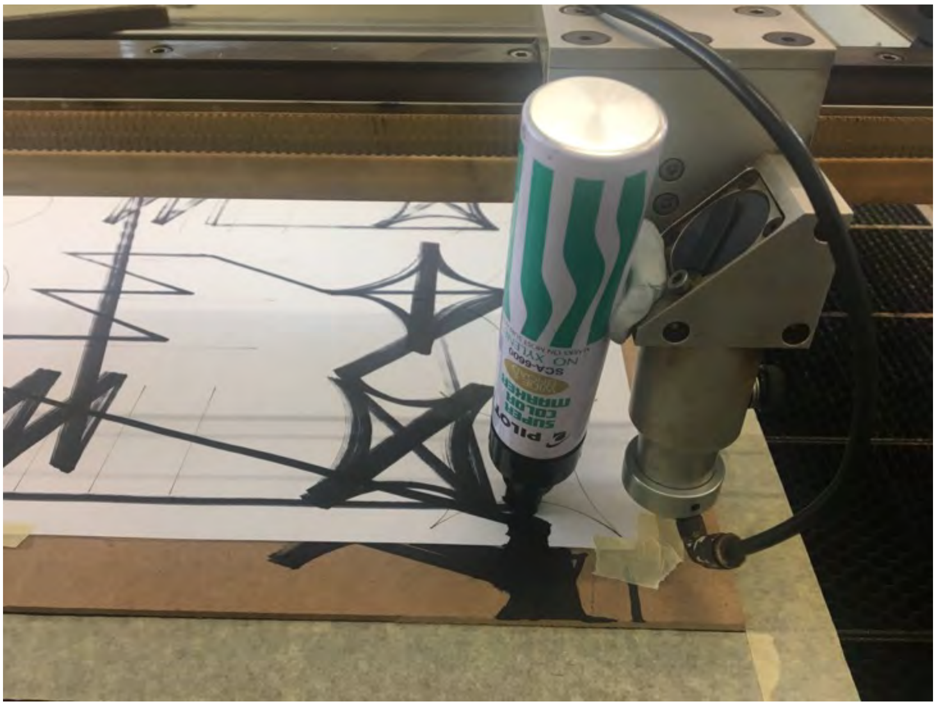

Fig 3. Attachment of Thick Pen to Laser Machine

2.1 Initial Experiments

For the purpose of ease of analysis of results, the sample experiments are given the same pattern shown in Figure 4. At first a pattern of concentric circles was used; however, this did not yield varied results. Figure 4 was subsequently created to encompass all necessary vector points of the laser. The shapes were influenced by those used by Adam Marcus (2016) in his “Variable Projects” work.

The design intervention used in the experimentation is to attach a drawing device, in the form of a pen to the laser head. The laser remains active and is set to etch. In addition, the pen records the toolpath used to create the etched design, determined by the laser technology. Three different pens are attached to the laser machine, at the same point seen in Figures 1, 2, 3. The same pens are used throughout for reliability. The paper used throughout is plain white a3 paper. The placement of paper stays the same throughout. The tests follow the same structure which is to act as a guide for the experiments. The variables explored are the role of the pen, changing the velocity, and disrupting the process by opening the lid during the cutting process. These variables reintroduce Pye’s (1995) workmanship of risk to the technological process and introduce a hands-on element applying the experiential knowledge of the laser cut technology.

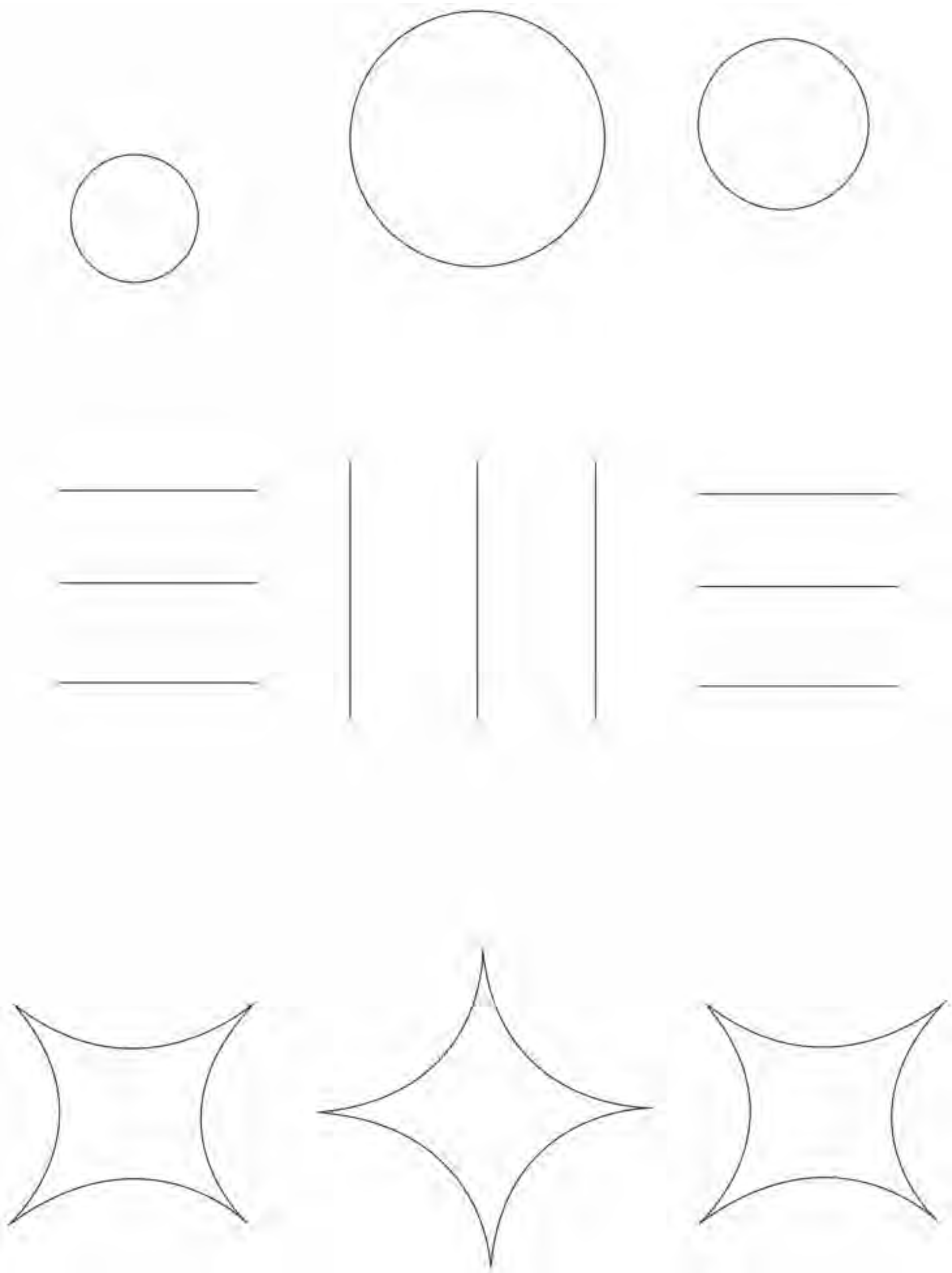

Fig 4. Shapes Used in Experiments.

Pen	Results
Biro	*Velocity 50, Power Max 5 Min 3:* Paused to push down biro at 3 vector points on right side. Overall laser marks are faint, however the pen has dragged and created a new shape at the top right of the picture. *Velocity 350 power max 20 min 3* Paused once at bottom right due to no mark appearing. Pen dragged, and did not connect with paper as well as previously. The pen dragging has created an interesting line top left. *Velocity 600 power max 20 min 3* The pen caught on the paper at the bottom right and burnt through the top area of the circles. Pen seemed to not connect with the paper very well. The laser marks are clear.
Medium	*Velocity 50 Power max 5 min 3* No intervention with the laser bed, pen seemed to connect with the paper well. Laser marks are weak, pen marks seem to dominate the picture. *Velocity 350 power max 20 min 3* Paused in the middle due to no mark appearing. Marks created are crisp, and progress from previously. Laser marks are weak again. *Velocity 600 power max 20 min 3* The laser cut through the paper and a large drag occurred at the bottom of paper. Pen marks still very clear and map the laser route. More mistakes can be seen from the pen, with burn marks apparent with the laser too.
Thick	*Velocity 50 Power max 5 min 3* Pen dragged a lot, due to slow velocity. Machine has been paused once in the middle, as pen loosened from attachment, creating interesting marks. The laser marks are faint but clear. *Velocity 350 power max 20 min 3* No intervention with machine. Pen dragged by itself creating interesting marks. Laser marks are faint and not clear. Pen marks are dominant. *Velocity 600 power max 20 min 3* The machine has cut through the paper in multiple areas, and burn marks are much clearer. Pen marks are clear and uniformed. The marks produced vary in depth and regularity.

Table 1. Analysis of Marks Created by Lasercutter

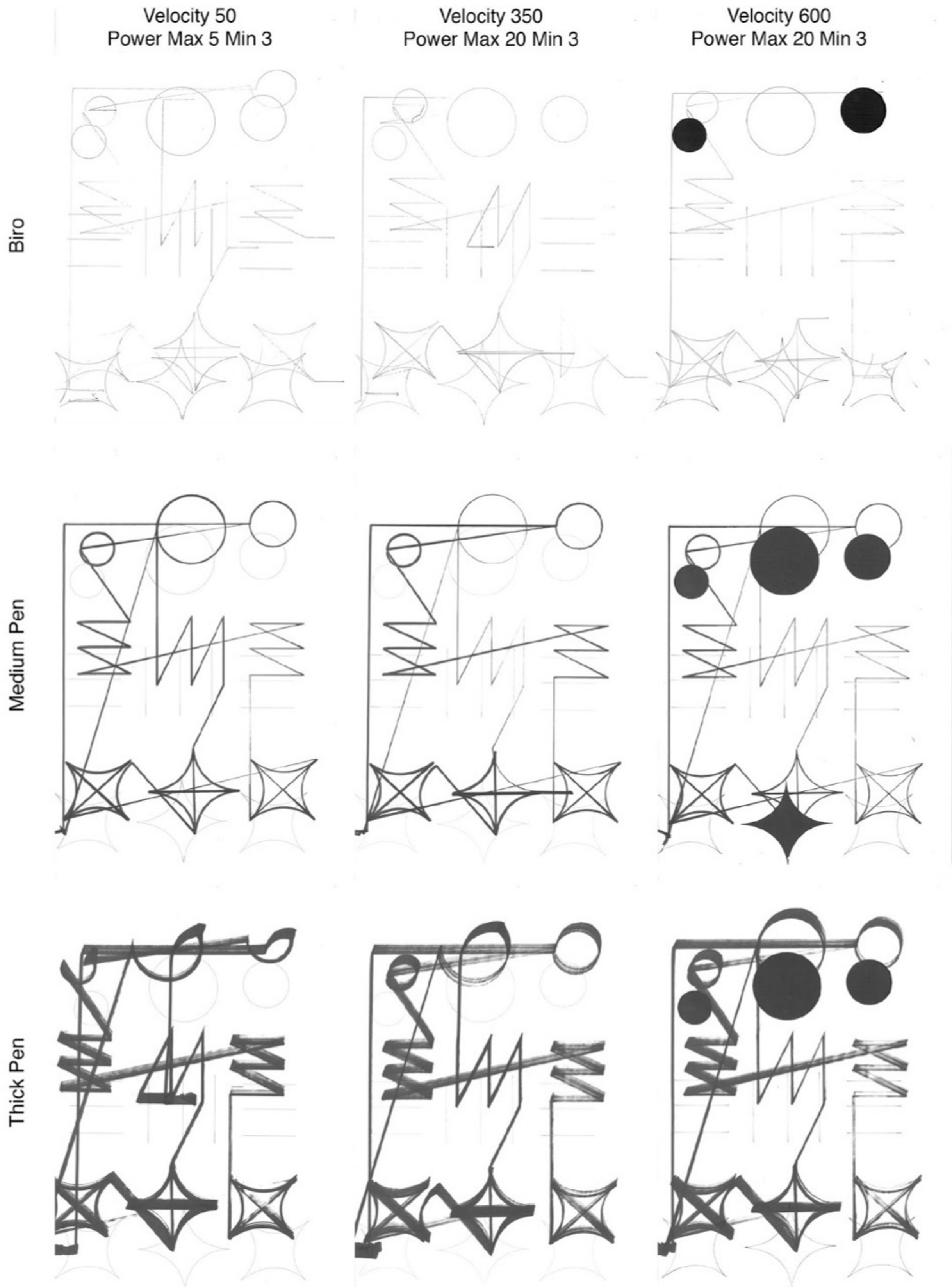

Fig 5. Experiment Results

3 Results

The experiment shows that with each pen used a different mark is produced. With reference to table 1 and figure 5 it is evident that with the medium pen; the connection with the paper has yielded the most precise marks. We are easily able to identify the laser heads path, and the added tool does not appear to veer off course. However, with both the biro and thick pen, the pen has dragged and created nuances in the designs.

It is interesting to note that at the velocity of 350, the marks produced seem to appear the most different for each pen used. The biro is seen to make jagged marks, with a varying pressure indicated in the faded appearance of the lines produced. However, the medium pen appears the most uniform. Although, the pen loses connection to the paper in certain areas of the design, which are not seen at other velocities. The thick pen, appears to produce varying depths of mark due to the colour.

At the velocity of 600 it is obvious in all 3 results with each pen that a cut through of the paper is apparent. These cut throughs, are evident in the same position in each design. The laser marks produced at this velocity also differ to the previous rounds. The marks are faint, and appear lost or integrated into the design.

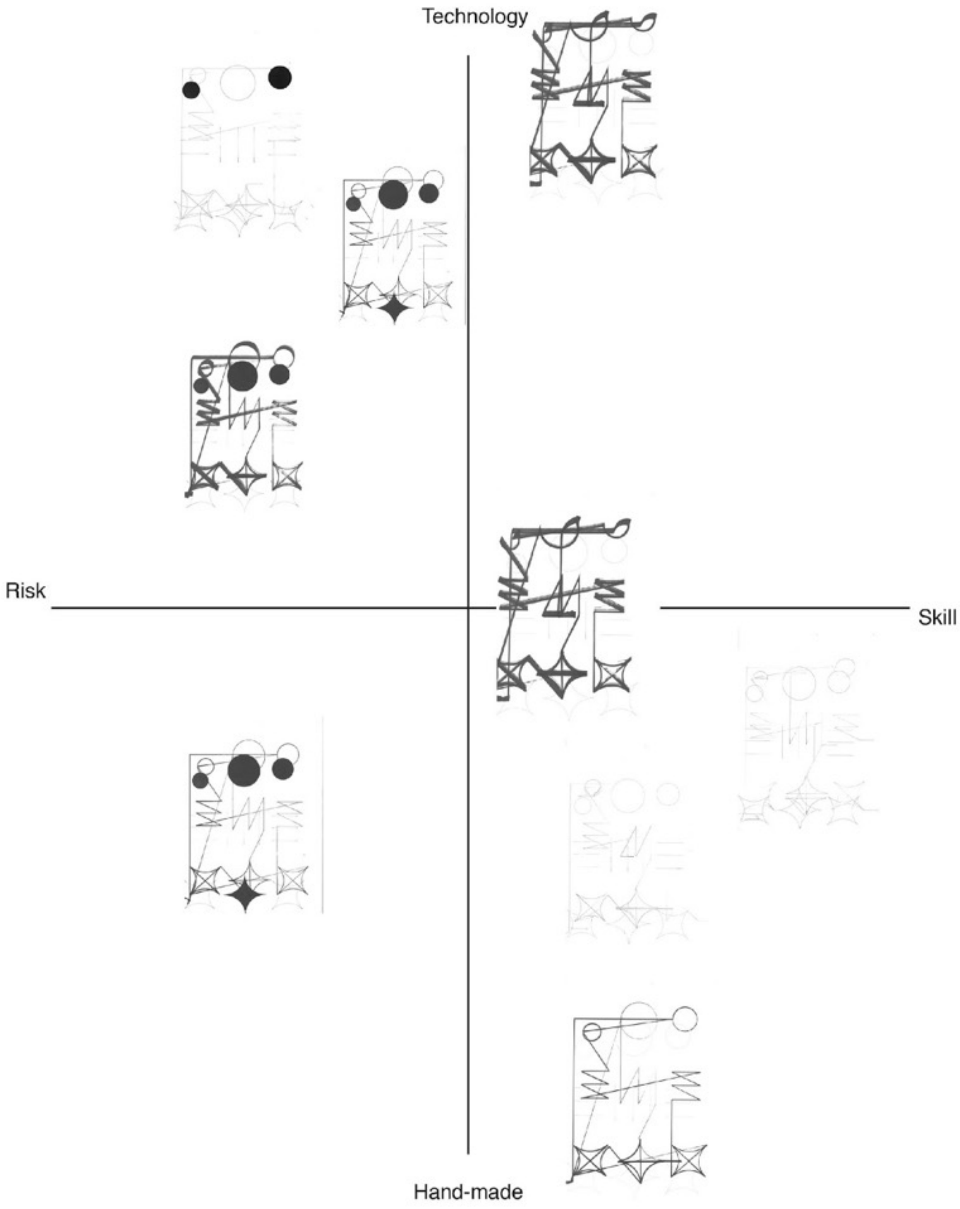

Fig 6. Graph mapping experimental results against craft attributes.

3.1 Analysis of Results

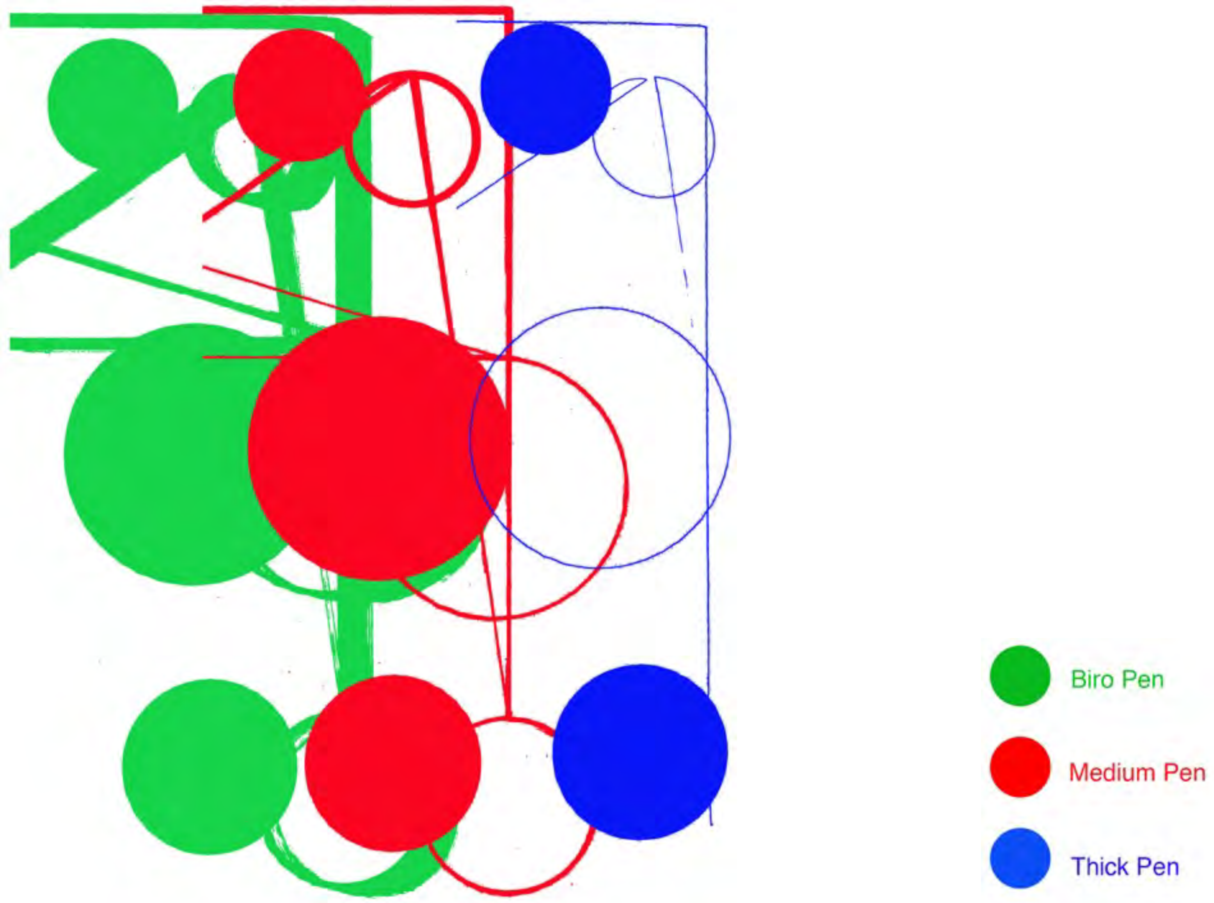

Fig 7. Experiment Results showing the laser cutting through the paper

Figure 7 illustrates the results testing the attachment of a pen to the laser head. It is apparent that for each drawing device where the velocity is raised to 600, elements of the paper have been cut through. This is shown through the large block areas of colour. All of these areas have been placed on the graph (Figure 6) as combining risk and technology. No intervention with the technology was necessary, and the pen marks appeared to make mistakes without intervention from a human hand. This rejects the conclusion by Marcus (2016) who found that risk can only be introduced by a human to a machine in order for it to be crafted. It promotes Pye's (1995) workmanship of risk, and indicates that it is now possible to find this workmanship of risk in laser technology. The areas that have been cut out were not intended to do so when carrying out the experiment, but have been produced due to serendipitous events, which Treadaway (2007) argues promotes the playfulness a maker needs in their process.

The progression of the experiment is repetitive. The marks progress in thickness due to the pens used. McCullough (1998) argues that this repetition produces further knowledge for the maker. This is evident as an awareness of knowing when to pause the machine and readjust the pen occurred. At the velocity of 50, all results show a drag of the pen, see Figure 8 for a comparison of marks made by the pen dragging. This repetitive notion that the technology has reproduced indicates skill. The slower the velocity, the easier it is for the pen to drag, thus creating different marks. It is clear that the blue mark showing the thick pen has dragged the most, indicating that the heavier pen has caused the most disruption to the technology. Through an aid of adding the pen to the machine, the technology has created a skilled process, resulting in diverse marks.

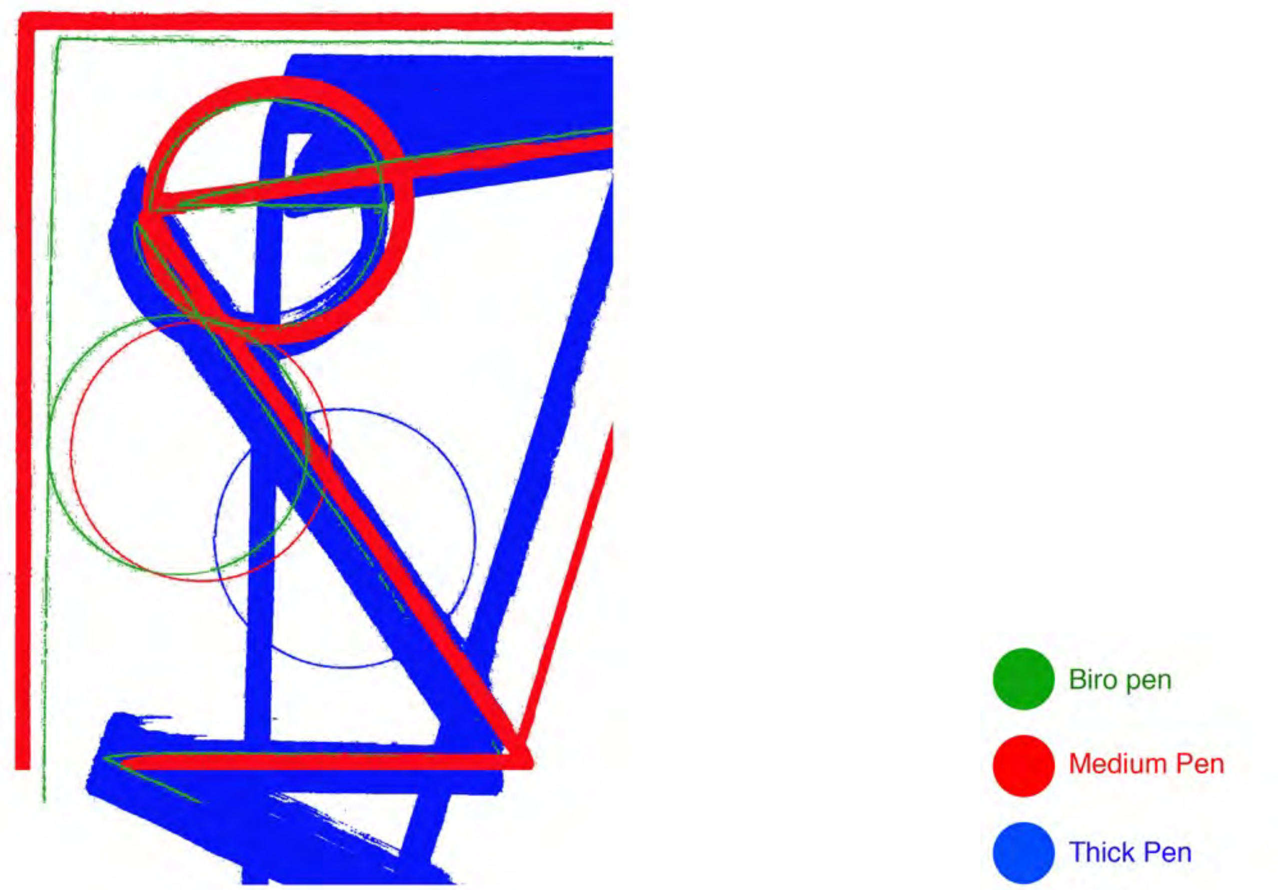

Fig 8. Experiment Results showing the pen dragging on the paper.

Human intervention with the process has been noted throughout the experiment. The hand has intervened by adding the pen to the technology, utilising the pen as a tool for the hand, which Dormer (1997) argues can be determined as hand-made. By opening the machine and adjusting the pen, the maker initiates a tactile stimulation with the process. This opposes McCullough's (1998) argument that a technology cannot possess skill due to the absence of the hand. The connection that the pen has had with the paper has not been strong enough to yield a mark, mainly occurring when the velocity of the machine is lowered. This indicates that the higher the velocity, the more scope the machine has to create the marks itself.

The marks produced using the thick pen at a velocity of 50 and the power at 5, have been placed nearest to the centre of all 4 attributes in Figure 6. Figure 9 shows these marks. The marks produced show an element of skill, as it has been discovered that the lower the velocity the more varied the marks will be due to the drag of the pen. This drag is also an element of risk, as it could be deemed as a mistake in the experiment. The machine has also been paused, as the pen caught during the experiment. This intervention with the process indicates a need for the human hand, due to a mistake in the technology. In this case, the pen loosened from the machine. The marks produced from the laser are clear, however due to a pen being attached, the machine has created crafted areas for investigation.

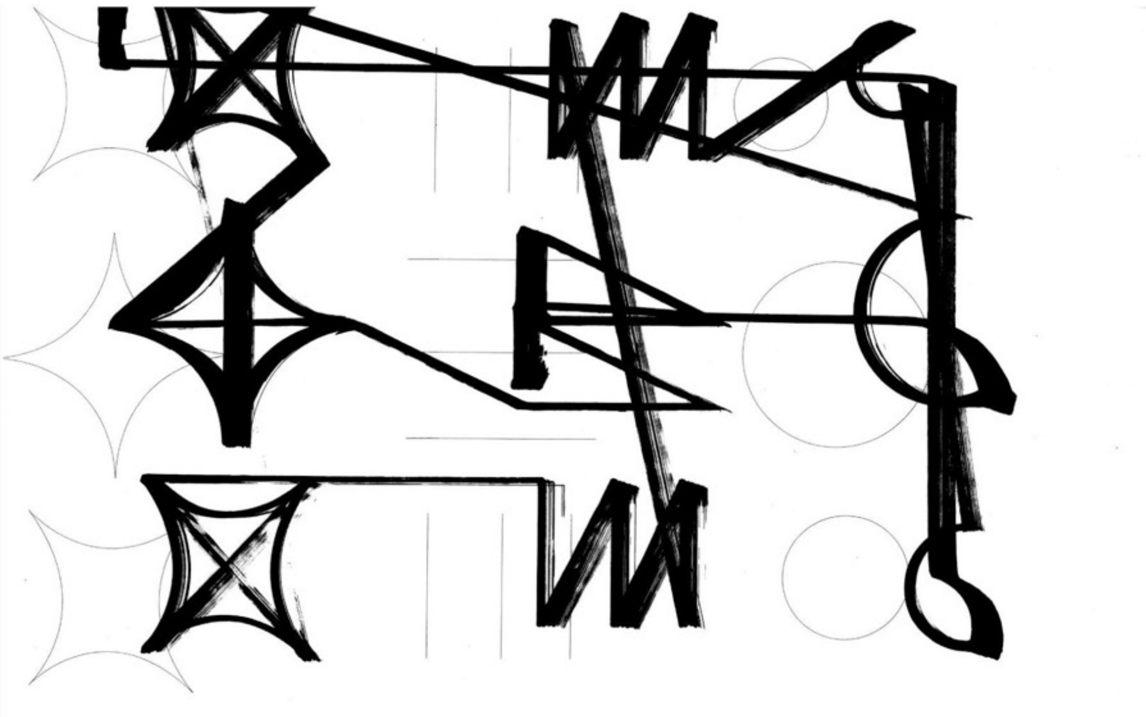

Fig 9. Experiment Results with elements of all 4 attributes

It is important to note the marks that track the lasers journey from one point to another. This would not have been evident without the addition of the pen. It invites the viewer to feel a sense of a train of thought, or an innate and experiential knowledge, one which would be felt by a craft-maker. This innate, tacit knowledge that Dormer (1997) and Yair and Schwarz (2011) highlight as being imperative to craft, is now being shown through the machine itself, through the process of collaboration with the technology.

5 Conclusions

The results from the experiments have demonstrated how technology can collaborate with other elements of craft, using the laser cutter machine to produce craft outcomes. The knowledge of the maker has not only informed the technology, but also the technology has informed the maker, resulting in an ongoing collaboration between maker and machine. The hybrid approach, where the maker and technology are not separated but rather work together, collaboratively, displayed the most craft attributes. This hybridisation has only been made possible through a greater understanding of craft knowledge, and knowledge of the technology, working together as a methodology to proceed with the study.

The analysis of results against the four attributes attained in the literature review is subjective. Although this has been taken into account due to the creative and experimental nature of the study, the marks produced may not display the craft elements to every viewer. Although a clear methodology has been put in place, ultimately, the parameters are different for every person.

When considering how this research can be carried further, the concept of hybridisation is key. From the experiments of the study, the marks produced which convey all four areas of craft, and work together harmoniously yield the most crafted results. This suggests that the laser technology can possess all areas of the hand-made, skill, risk and technology, and when these areas of craft all work together they produce the most original results. These four elements of craft, which now encompass technology as an integral feature of craft, can be carried forward as a methodology to be used in assessment of other technologies. It is important to note that the incorporation of technology has not meant the eradication of the human touch or error. Rather by introducing new innovative elements into the technology as a form of hybridisation of techniques, and creating a dynamic relationship between the hand and the machine, this study has located the inherent craft attributes of the machine.

Overall, through the hybridisation of techniques and the fusion of traditional and modern elements of craft, this research has been able to uncover the craft of the laser cutter. It is clear that through the knowledge the maker learns throughout their process, this in turn informs experimentation, whether that be via technology or not. These qualities now include technology as a pillar of craft, and one that is being shown to assimilate in craft makers practice all over the field.

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Maighraed Mcewan

Maighraed is a textile design graduate from the University of Leeds. Her work presented won the Foster Prize at the University for the highest grading dissertation in the school of design. Subsequently, she is now enrolled into the Royal College of art to study Global Innovation Design, where she will study in London, Beijing and Singapore. This course is focused on providing creative solutions to deliver positive socio/economic and environmental change.

Her practice is based on the intersection between technology and craft. Focusing heavily on the use of laser technology to create innovative interior design solutions. These examples have been displayed at New Designers in London, and Artonomy events in Leeds. Previously, she has worked in textile design studios in New York, and London Fashion week.

Jane Scott

Dr Jane Scott is an award-winning designer and educator whose interdisciplinary research challenges how emerging technologies can transform thinking in textile design. She works as a senior teaching fellow in the School of Design at The University of Leeds, and as a visiting research fellow at Central Saint Martins in London. She holds a PhD from The University of the Arts, London where she developed Programmable Knitting; an environmentally responsive biomimetic textile system.

Her work has been exhibited internationally, and she has recently presented her research at Massachusetts Institute of Technology, The Baltic, The University of Michigan, Make/Shift, the Microsoft Research Centre, Cambridge and The London Design Festival. In 2016 she received the 2016 Autodesk ACADIA Emerging Research Award (projects category) for her work Programmable Knitting.

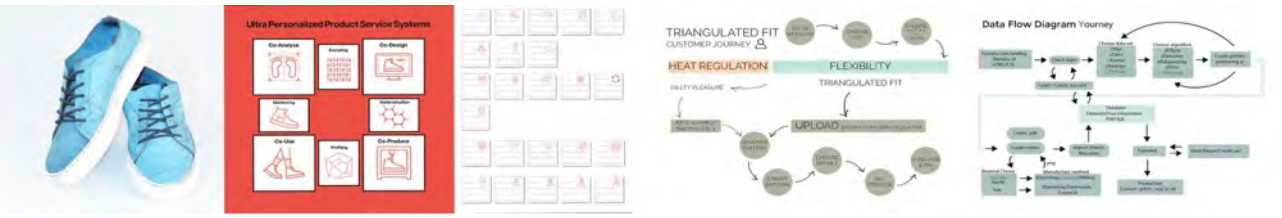
From Personal to Ultra-Personalized

Troy Nachtigall, Eindhoven University of Technology, The Netherlands

Svetlana Mironcika, Eindhoven University of Technology, The Netherlands

Loe Feijs, Eindhoven University of Technology, The Netherlands

Oscar Tomico, Eindhoven University of Technology, The Netherlands / ELISAVA Barcelona, Spain



The UPPSS design game is used to change an individual shoe making experience into a detailed product service system with customer journey and data flow.

Abstract

We envision a near future where shoe design is more than sketching shoes. Shoe design becomes the crafting of parametrically generated, data-driven, iterative forms along with multi-stakeholder Product Service Systems (PSS). Accomplishing shoes that embody this requires new forms of digital craftsmanship that build upon ever emerging hybrid crafts. New forms of digital craftsmanship are scaffolds of data and digital fabrication into Ultra-Personalized Product Service Systems (UPPSS). In the complex process of UPPSS designers are confronted with challenges; product challenges in negotiating design considerations, with service challenges in customer journeys and systemic challenges in of data flows. Design games are rarely used to design shoes but offer a lot of opportunities. In this article, we describe and deploy a design game for UPPSS shoemaking. The game was designed to help designers to confront these challenges. This included using code to program the digital fabrication of a pair of shoes. The UPPSS game was deployed with 16 industrial design students over nine weeks. Each wrote a reflection on what they learned. The reflections were analyzed to see how the design game resulted in facing the challenges of an UPPSS that is summarized in an interpretive framework. Conclusions were drawn from the challenges and opportunities confronted in the game, and what this meant to the emerging practices of digital craftsmanship and UPPSS.

Keywords

Design Game; Ultra-Personalized Product Service System; Shoe-making; Research through Design; Digital Craftsmanship

Previous research on computational composites (Vallgårda and Redström, 2007), Meta-Materials (Ion et al., 2018), and data-driven design (Bogers et al., 2016), has shown how data and materials can be crafted together to form things. The idea of digital craftsmanship, previously seen as a workshop (Jacobs et al., 2016) is emerging in the form of bespoke craft. Examples include research in academia (Wensveen et al., 2016) or in the maker movement (Papavlasopoulou et al., 2017).

At the same time, emerging technologies are enabling new possibilities in personalization (Benford et al., 2018; Zoran, 2015; Magrisso et al., 2018). Personalization means that the product and service are made to fit the style, form and behaviour of the user. While this can be done in bespoke shoemaking, the challenges of scaling up into data-driven (user data drives parametric digital fabrication) iterative (generations of objects inform their predecessors) product service systems remains in the roadmap into a future of Ultra-Personalization. Ultra-Personalized Products and Services are defined as “(1) Products in which personal data is obtained before use - such as 3D scans - and (2) products in which the data is obtained during use” (Stolwijk and Punter, 2018). In previous work we connected the two systematically (Nachtigall et al., 2019b) Shoemaking has been shown as a domain with the potential to illustrate Ultra-Personalized Product Service Systems (UPPSS) and bespoke personalization (Nachtigall et al., 2019b). Moreover, shoes have a long history of personalization (Ball, 1937; Greene, 2019).

Industry and academia are very interested in shoe mass-customization (Piller, 2012; Weerasinghe and Goonetilleke, 2011), and we find examples of bespoke personalization in small companies such as Solemaker or Feets, and in large companies like Adidas (Piller, 2012), Nike, Under Armour, Reebok, Ecco, United Nude, Desma, HP and many others. Shoes are also a good place for data, the first wearable computer was embodied in Shannons and Thorp’s shoe (Mann, 1997) with many examples of continued interest in computation in shoes as computers (Schirmer, 2015) or as the result of a computational process (Feijs et al., 2016).

Yet, training industrial designers to design an UPPSS remains a challenge. Data-driven iterative shoe personalization systems is no exception. Industrial designers have difficulties scaling up shoe design into services and systems while maintaining a high level of craftsmanship. In order to understand how to address the challenges of designing UPPSS we created a design game for scaling up bespoke shoe personalization. This was connected to helping students recognize and develop connections between the math, data and computing courses they had before (calculus, data analytics, programming) and the demands of contemporary systems design.

In this paper, we explore the value and possibilities of the UPPSS design game by analyzing the reflections from industrial design students after working with it. The game was needed to make objects like shoes that are crafted to the individual. Using an interpretive framework developed by (Nachtigall et al., 2018), we evaluate their understanding of UPPSS design. From the findings, we draw conclusions about how the game supported the creation of an UPPSS system, suggestions are made to the interpretative framework, and we reflect upon the emerging design practice of Digital Craftsmanship for Ultra-Personalization.

Related Work

“The Stuff of Bits” by Paul Dourish (Dourish, 2015) showed data to be a material that can be used to design with. Although the actual application of data as a design material to support the next level of personalization is a challenging and complex process, research on computational composites (Vallgårda and Redström 2007), Meta-Materials (Ion et al., 2018), data-driven design (Bogers et al., 2016), and the development of frameworks that suggest how to act on data (Forlizzi, 2012) in general, are at the forefront of design and HCI research. Based upon earlier explorations into product ecologies (Forlizzi, 2012) and on research done on PSS (Tukker, 2004), Ultra-Personalization grows out of the research done into embodied smart textile services (Bhömer et al., 2016). Ultra-Personalized Product Service Systems (UPPSS) are data-driven iterative personalization PSS with multiple stakeholders and enabling transitions (Nachtigall et al., 2019b).

Closing the iterative personalization loop in UPPSS requires dealing with product, service, and system challenges. The following sections describe these challenges in the emerging field of UPPSS applied to shoe design. For a summary see table 1.

Product Challenges / Learnings		Service Challenges / Learnings		System Challenges / Learnings	
Adapting Algorithms (AA)	Negotiation of design considerations	Reading the Body (RB)	A general purpose sensor is not personalized	Saving and Storing the Data Trail (SD)	Ideal vs actual
Manufacturing Misinterpretation (MM)	Limits of the current technology	Profiling Predicted Use (PU)	Potential for self - directed machine learning	Quantity and Scaling Up (QS)	Profile the thing, not the person
Standardizing Material Behavior (SB)	Ideal vs actual	Understanding Behaviour (UB)	Temporal composites	Comparing Data (CD)	Designers need data
Mechanical Sensing Material Structures (MS)	Active vs passive monitoring	Adding Sensing (AS)	Multi-purpose hybrid material geometries	Storing and Decoding Use (SD)	Understanding temporal composites as material

Table 1. An interpretive framework of the challenges and learnings faced when making a shoe based UPPSS. These are used to form the classification schema to evaluate the UPPSS game.

Product Challenges and Opportunities

Parametrically generating shoes for a specific feet requried adapting *algorithms for the negotiation of design considerations (AA)*. Researchers are applying specific geometries such as selective buckling (Paulose et al., 2015) in programmable materials (Vallgårda 2017) using algorithms to make flexible shoe soles (Feijs et al. 2016) and create dynamic behaviours (Ballagas et al., 2018). Algorithms translate these materials into dynamic forms (Frens, 2006) using of computational co-design (Malakuczi, 2017).

However, the results are not always what was expected. *Manufacturing misinterpretations (MM)* are unintended results that can appear when the limits of the technology are reached. To overcome these situations a designerly understanding is needed; i.e. human-material interactions (Giacardi and Karana, 2015) or how materials evoke a material conversation (Karana et al., 2016). Another way to look at it is as a process-led material-based research that leads to design innovation (Marr and Hoyes, 2016).

The next step is *standardizing programmed behaviour (SB)* when using data as a material. We see these opportunities already being addressed in the form of research products (Odom, 2016) where specific quality requirements (inquiry-driven, finish, fit, and independent) allow the research to be deployed for long periods over the product lifetime. Additionally, challenges include creating a consistent and uniform result having digital fabrication technologies a different precision than industrial manufacturing. Real-time feedback and feedforward can already be seen in concrete 3D Printing (Wolfs et al., 2018) which illuminates new opportunities for UPPSS digital fabrication.

Finally, UPPSS requires data to be created by the resulting products. While traditionally been done with electronics, i.e. (Hertenberger et al., 2013), *material structures for sensing (MS)* allow also mechanical (Zheng et al., 2019) biological (Steiner et al., 2018), and chemical (Kao et al., 2017) sensing to produce data.

Service Challenges

The service challenges of UPPSS revolve around the customer journey. In shoe design, it shifts towards an intimate relationship with the wearer that requires management and trust.

To start the process of UPPSS (and continue iterations) a *reading of the body (RB)* is needed. An analysis of the (physical) characteristics of the wearer provides a design DNA of the wearer. There are many methods to gather data about the body such as footscans to lasts (Zhang, 2010). Challenges include variability of body shapes and sizes (Griffin et al., 2016). Yet, new opportunities include using images to create body sizes creates (Mok and Zhu, 2018) and convert that into digital fabrication (Hong et al., 2018).

Closely related is capturing of a movement or action (or a series thereof) of the foot as *Understanding Behaviour (UB)*. The could also be the social dimensions of where a shoe is worn. In shoes, this is can be a footstep; how the user strikes the heel to the ground and progresses to the talon and big toe. Human locomotion is complex as humans evolved to be bipedal (Hagman 2005). This complexity and how it translates to materials is described in “The development of methods and procedures to determine the dynamic and functional properties of sports shoes” [Vertomenn et al., 2011].

UPPSS requires the storing of data across times at many points of the process and comparing it to how it was expected to be used. There is opportunity for *profiling predicted use (PU)* to compare that against the actual use. This can be found in predicting the needs for the shoe with i.e. machine learning (Nácher et al., 2010), or using the data to predict life events of the wearer such as puberty (Busscher et al., 2011). This becomes more complex if we adopt a model of distributed manufacturing. In building a system with data as a material, there is a challenge to make the right kinds of data described as *adding sensing (AS).* Sensing in shoes is commonly performed electronically (Shenck and Paradiso 2001) or from other places on the body (Skach et al., 2018). There is an opportunity to achieve this with materials that change in a computational system as seen in DuoSkin (Kao et al. 2016), Grow Kit (Steiner et al., 2018), and the EVA Mocassin (Nachtigall, 2017).

System Challenges

Research into system design spans decades (Norman, 1986). Software and stakeholders face challenges and opportunities as seen in the data flow of an UPPSS process. The system challenges can be observed when creating an overall picture of how the data and material interact in UPPSS (Nachtigall et al., 2018).

Saving and storing the data trail (SD) is often used in app design and social media design, not physical objects. Much like home health devices now track patient health (Habibović et al., 2018), designers of an UPPSS have an opportunity to record data at many points during the analysis, design, manufacture and use of the object. That data is shared and used with many stakeholders. This can be seen in the current way usage statistics are impacting software development (Dinner et al. 2015), in UPPSS data is created and stored for at least the product or service lifetime. Questions of data security and privacy become important as well (Wetzels et al., 2018)

Artisans make bespoke personalized shoes using implicit craftsmanship. When making shoes with data new challenges and opportunities for *quantity and scaling up (QS)* become possible**.** The form, behaviour and aesthetic can be understood as data. New opportunities emerge such as monitoring, control, optimization (Porter and Heppelmann, 2015). Challenges include the costs of digital fabrication (Baumers, 2016) and the integration of craft and technology to move from mass customization to mass personalization (Wang et al., 2017).

Self-directed machine learning has opened up the possibility of *comparing data* from predicting iterations and users. UPPSS is driven by generational (Reiss and Stricker, 2013) and multi-user comparison via pattern recognition and machine learning (Bishop, 2007) at a design system level (Yang, 2018).

As UPPSS depends upon data as a material, *storing and decoding use* is fundamental to the iterative generations of an UPPSS. We see the importance of that data in data-enabled design (Bogers et al., 2016) as well as the lifespan nature in temporal composites (Valgarda et al., 2015). Hybrid Reassemblage (Zoran and Bucheley, 2013) provides a unique window into the possibilities of generational iteration with materials.

Creating a service design game for UPPSS

Service Design games have been shown to drive innovation and knowledge creation (Hannula & Harviainen, 2016). Especially when dealing with the challenges of integrating products in service systems (Hannula & Harviainen 2016). Card games have demonstrated their capacity to deal with large amounts of complex challenges (Lucero et al., 2013). The UPPSS game we created is intended to scale up a shoe-based personal crafting experience into a full-fledged UPPSS. The game was inspired by other design games already used in service design that deal with multiple stakeholder co-design sessions (Mattemäki, 2014).

The game board was taken from the theoretical UPPSS model, representing the UPPSS phases and enabling transitions described in “Unpacking Solemaker into a model for UPPSS” (Nachtigall et al., 2019b). The game board is a circular system with phases of Co-Analyze, Co-Design, Co-Manufacture and Co-Use in the corners.

Co-Analyze is the process of understanding the needs of the person in different forms of data, including multiple expert opinions. Co-Design in UPPSS is a generative process that algorithmically negotiates the parameters of the wearer to the design considerations of the object being made. Co-Manufacture is the process of fabricating the object being made, often in a distributed location geographically close to the wearer. Co-Use is process of using the object over its lifetime, with the data feeding forward into the system for all to use that data. Between the “Co-” phases are enabling transitions of encode, materialize, profile and monitor. Encode enables Co-Analyze to become Co-Design by making the data compatible with the parameters needed to generate. Materialize enables Co-Design to become Co-Manufacturing by making the data ready for digital manufacturing processes (which may be distributed). Profiling enables Co-Manufacturing to become Co-Use by remembering the data from all previous phases for later comparison and predicting the lifecycle of the object. Monitor enables Co-Use to become Co-Analyze by taking the data from the object and the behaviour and making it available for analysis.

Working with a graphic designer known for systems illustration (Zevi, 2017), a series of icons that represented the domain of shoes were created (Figure 1). Cards representing stakeholders, objects, characteristics, phases, actions, and values were made (Figure 2). Each card had a simple icon and a word describing the icon with extra lines to fill in information from design actions and the data flow. The labels and illustrations were not set on stone, empty cards were added to encourage the addition of new icons and descriptions when needed, as suggested in Efficiently Inefficient: Service Design Games as Innovation Tools (Hannula and Harviainen, 2016).

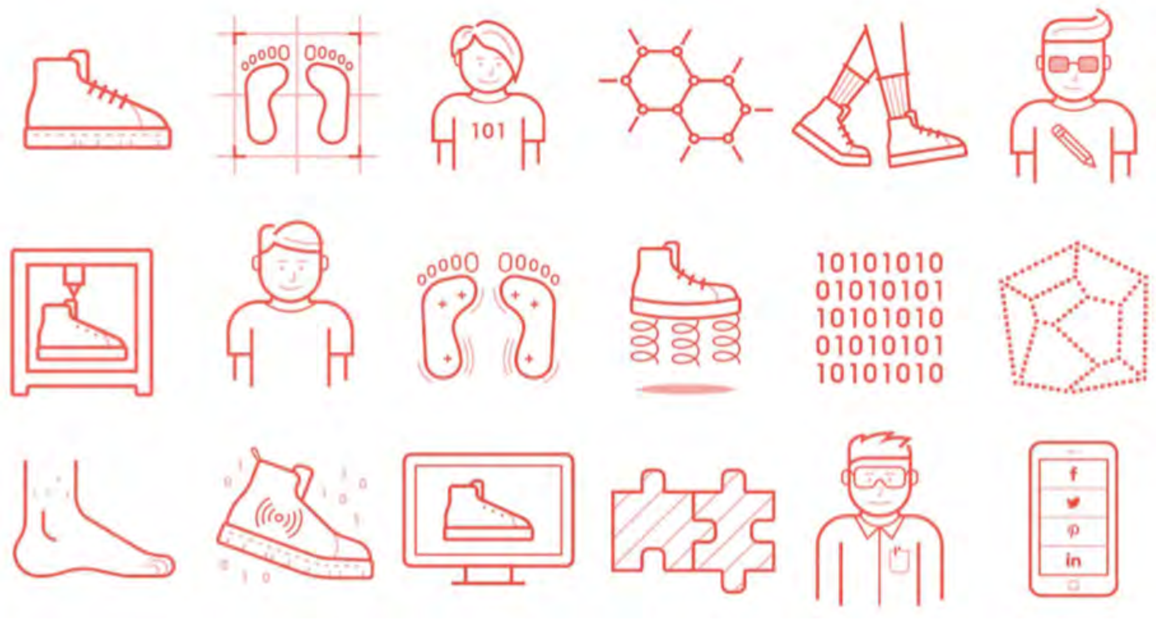


Fig 1. Icons created for the UPPSS game that describe stakeholders, objects, design considerations, phases, actions, and values in a general way that is modifiable.

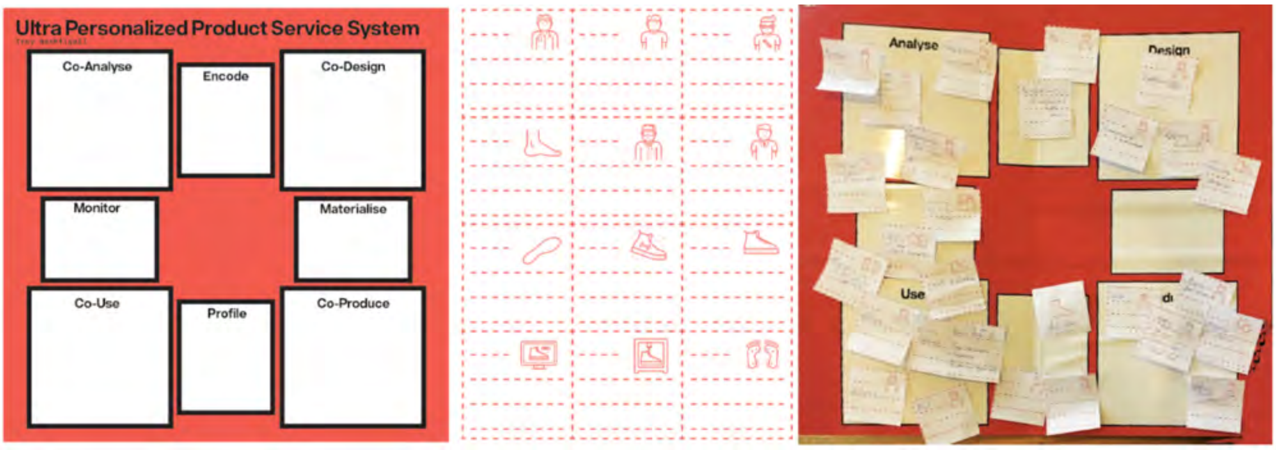


Fig 2. The UPPSS game board and cards being used to create Customer Journeys and Data Flows for an Ultra-Personalized shoe platform

Based on the following questions players selected, named, modified and described their process on cards which later were placed onto the board (see Figure 2 right):

1. Who is involved in the process?
2. What are the other objects involved in the processes areas? i.e. foot, shoe, scanner, leather, sole.
3. What happens in between each phase? Where is the data? How does the data change (i.e. formats)?
4. How and when is the “fit” (physical, social, behavioural) of the shoe controlled?
5. Are there places when changing one aspect will break another? Add a negotiation card to that moment and quickly note what happens.
6. Consider the board as a system. What is difficult and what would make the process better? Identify challenges and opportunities in the product, service and the system.
7. Walk through the system again to see what can be streamlined, modified or changed.
8. Create a customer journey and data flow from the cards on the board.

Deploying the UPPSS game

A class of second and third-year bachelor students (n=16) from a three-year industrial design program were selected to participate in this research. 8 were female, 8 were male. Their brief was to scale up bespoke shoe personalization into a UPPSS.

Fig 3. Examples of shoes personalized with digital craftsmanship and worn and by participants using code based on the ONEDAY open source shoe toolkit

Before the design game started, each participant made and wore a pair of digitally fabricated shoes. Then, the participants formed into groups and were asked to play the UPPSS game. Afterwards, with the findings from the game (see Figure 2) and a new version of the shoes (see Figure 3), they created customer journeys and data flow diagrams (see Figure 4). The final version of the shoes, customer journeys, and data flows were critiqued at the completion of an eight-week process. Participants then wrote a reflection which was coded by the researchers.

Fig 4. Examples of Data Flow and Customer Journeys created by participants after playing the UPPSS game.

A first-person embodied perspective of shoemaking was important to support a meaningful learning and valuable reflections. Participants who engage in an experience can translate material usage to memory making (Tsai and van den Hoven, 2018). Additionally, living with a prototype is key to understanding a research product (Desjardins and Wakkary, 2016; Mackey et al., 2017). We choose the ONEDAY shoe toolkit deluxe version which has been shown to be an effective tool for understanding personalization (Nachtigall, 2019a).

Inter-Coder Classification Using an Interpretative Framework

To understand if the game helped participants create an UPPSS, we used an inter-coder agreement method previously used to classify research methods and purposes (Kjeldskov et al., 2012; Tetteroo et al., 2015; Nachtigall et al., 2018). Table 1 presents an interpretative framework based on previous work (Nachtigall et al., 2019) and related work. A short abbreviation was given to facilitate the coding process as a coding schema. Two coders (PhD candidates working within UPPSS) read each reflection and coded each sentence if one of the classifications was apparent. The coders also noted when a sentence was an exceptional or interesting example of the classification. Only one classification was allowed per sentence. It was possible for a sentence to have no classification. If more than one classification was present, the coders selected the classification that seemed more important in context. After classifying, the coders reviewed their classifications together. When disagreement was found, the classification was debated until a consensus was reached with no time constraint. Each coders' classification and the final agreement classification were recorded for analysis.

Results

From the reflections all 1474 sentences were considered from the participants' reflections (n=16). The classifications, Table 2, part of the interpretative framework, were found in 753 (51%) of the sentences. Product challenges represented 384 (51% of found classifications), service challenges represented 215 (29% of found classifications), and system challenges represented 154 (20% of found classifications) The individual challenges are reported in Figure 3. The inter-coder agreement for the classifications was 0.76 using Cohen's kappa. This is found to be sufficient reliability to draw the results (Munoz and Bangdiwala, 1997). During the classification, sentences that exemplified the classification or were considered interesting were tagged for later. A representative sentence of each was selected as an exemplar (Table 3).

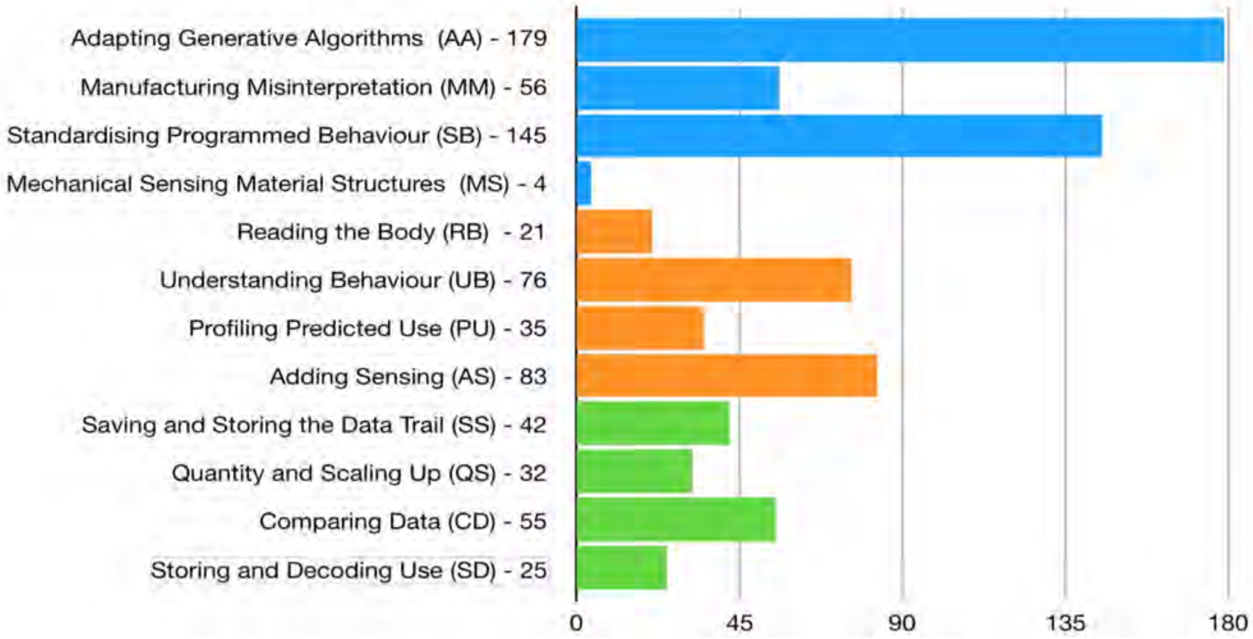


Table 2. A summary of classifications found in the reflections using inter-coder analysis.

Analysis

It is clear from the inter-coder analysis that the interpretive framework challenges were addressed by the students as reported in the results. All challenges had at least four classifications and as many as 179. We looked for the effects of the game itself in all of the challenges. The product challenges were best represented, but this could have been caused because the participants spent a significant amount of time and effort in making the shoes. The challenge of mechanical sensing material structures was the least represented. The concept that material "wear and tear" forms part of a computational system was difficult for the participants. Finding four reflections in the material sensing is still nominally sufficient. For example, P12 reflected "I also found that you can gain a lot of information about a persons' foot by looking at the shoes after wearing them for a certain amount of time." The presence of the game is also seen in other product challenges. For example, AA P4 "Now the shoe is not as flexible and it still looks nice. I had to change my initial design a little bit to fit in with our shared service design."

We found the game in the service challenges as well. AS P1 wrote, "This game gave me the idea to let customers of the service platform play with the contrast by letting them change the density of the vector markings on the top of the upper and on the back". Moreover, the game leads to personalization as PU P9 wrote: "With this design, I wanted to create an ultra-personalized shoe in which design would not be obvious for everyone but would be very important and precious for a user himself."

The system challenges had the least classifications, but there is evidence of the role of the game. QS P16 wrote: "The main objective for our service system was to keep it modular but not too complicated. We made the data flow with the website in mind; we transformed all the functionalities from the site into data objects.". Dealing with the complexity of scaling up was not taught in the classes but became apparent in the reflection. Finally, the best evidence for the game was found in comparing data CD P6 – "The provided cards helped to create a general path for all of us."

Product Challenges / Learnings	Service Challenges / Learnings	System Challenges / Learnings
AA Exemplar: "Now the shoe is not as flexible and it still looks nice. I had to change my initial design a little bit to fit in with our shared service design." -P4	RB Exemplar: "After this the feet are scanned, pressure and 3D, to gain data about the feet and make a perfect shoe." -P12	SS Exemplar: "There you can create an account that manages the customer's current and old shoe designs, number of walked steps and unlocked designs." - P6
AA Interesting: "I learned a lot of basics for using mathematical functions to generate form, but I am not yet able to create these alone from scratch." -P5	RB Interesting: "It will start measuring (the foot) with an app on your phone as soon as you wake up and start your first activity." -P14	SS Interesting: "Most of the sketches that had already been made could be implemented in the Processing.js sketch directly."- P3
MM Exemplar: "In the beginning ... and while trying to make some material explorations with some scrap leather, I faced a lot of problems with setting up the proper functions for the laser cutter and despite asking for help every time a new error was there." -P6	PU Exemplar: "When the customer is fully finished with designing, they will see a realistic render of what the design will look like." - P3	QS Exemplar: "The main objective for our service system was to keep it modular but not too complicated. We made the dataflow with the website in mind; we transformed all the functionalities from the site into data objects." -P16
MM Interesting: "For the actual realization, another material would be needed." -P3	PU Interesting: With this design, I wanted to create an ultra-personalized shoe in which design would not be obvious for everyone but would be very important and precious for a user himself. - P9	QS Interesting: "Doing this felt like a more 'professional' approach then I am used to, because in previous projects I never integrated my Processing code into a system, by allowing the code to be integrated into a system, it feels more like a 'finished' product." - P1
SB Exemplar: "With different densities, materials, placements and stitches I could see what would suit best for this project." - P4	UB Exemplar: "In order to get a good impression of the differences with my normal sneakers and to find possible design opportunities, I wore the shoes for four full days." - P13	CD Exemplar: "In the meantime sensor data from the pressure sensors on the uppers are compared to the optimal values for people with comparable features (weight, hight, shoe size, etc.)."-P5
SB Interesting: "Code can be very abstract and designers need to know what will happen to the real material if they manipulate the code." - P5	UB Interesting: "With my hands I could feel that there actually was more resistance in the heel, the place where the cells were smaller." - P8	CD Interesting: "When the customer is ready for ordering the shoe, the metadata is imported and it will check if they have walked enough steps in order to really order it." - P4
MS Exemplar: "I also found that you can gain a lot of information about a persons' foot by looking at the shoes after wearing them for a certain amount of time." - P12	AS Exemplar: "This game gave me the idea to let customers of the service platform play with the contrast by letting them change the density of the vector markings on the top of the upper and on the back." - P1	SD Exemplar: "I made sure that the output of the code is a pdf file that can be sent to a laser cutter immediately, without the need of changing the scale or removing things in Adobe Illustrator." -P1
MS Interesting: Also, the option of a printable paper model to check what size the customer needs, will be available. - P8	AS Interesting: "Even when the shoe has already been received and worn, there is an option of sending the shoe back to enhance its design" -P12	SD Interesting: "By making the service, I learned more about all the taken steps and required data." - P3

Table 3. A summary of sentences that the coders indicated were exemplary or interesting.

Discussion, Conclusions and Future Work

Working with data as a material is a complex challenge. It is especially true when we look to a future of complete product service systems that are personalized with that data. We found the UPPSS design game helped participants work together to create complete customer journeys and data flows that open up the gateway to future production systems. The cards allowed the participants to take the experience of digitally crafting a pair of shoes and scale it into a PSS platform. One of the teams was so successful that members went on to build the website P16 "To illustrate our service and learn more about implementing processing.js, Daan and I created a website." It is also interesting to note that in many of the reflections, the game influenced either the product, service or system levels or multiple of them at the same time. AA P4 – "Now the shoe is not as flexible and it still looks nice. I had to change my initial design a little bit to fit in with our shared service design.”

The results show the potential of digital craftsmanship to support the making of future production systems like UPPSS. The data and algorithms became a fluid part of the designer's toolkit. Starting from a material, moving to a product, and then to a PSS, allowed participants to have a clear mental picture of how the process would change the shoe they had made. In the future, exploring the qualities of craft (Wensveen et al., 2016) and how they specifically relate to UPPSS may reveal even a greater understanding of the game, the interpretative framework used to analyse it, and about what digital craftsmanship is.

The game captured some elements of stakeholder relationships that the interpretive framework did not encompass. Service design emerged from the relationship of people with computational things but has been shown to understand stakeholder interaction (Blomberg and Evenson 2016). Future work into the UPPSS, the game, and other future systems should look to better capture these interactions and define stakeholder roles better. This could include templates for the dataflow and customer journey that might allow for greater analysis.

The UPPSS board itself represented a static framework. It needed to be more dynamic allowing for the changing of the board (system) itself. We saw the frustration in a few of the reflections P15 - “Without having the group service platform, my customer journey probably would have been completely different.” In the future, the Co-Analyze, Encoding, Co-Design, Materialize, Co-Manufacture, Profiling, Co-Use and Monitoring phases could be in independent boxes allowing participants to manipulate the system framework. This would have helped participants like P6 who said “The design will be updated and again send back to the customer.” indicating a possible different process.

Data was challenging for the participants. The concept that materials can make data as part of the process was difficult to find in the reflections. This was tied to the fact that the circularity of bringing the data from the shoe back in the process was poorly represented. The game allowed conceptually detailed and contextually rich first-person experiences. We look forward to adding actions to the UPPSS game to address qualities such as sustainability that may help participants make the process more circular resulting in iterative shoes.

Finally, we couldn’t find any other examples that used an inter-coder analysis of personal reflections based on design action. The data to validate the game was created using this method and lead to effective research. It showed the transmission of the ideas of UPPSS and digital craftsmanship directly, although it was key to capture the exemplars and interesting quotes that informed the analysis.

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Troy Nachtigall

Troy Nachtigall is a Marie Skłodowska–Curie Research Fellow in the ArcInTexETN H2020 action which explores sustainable future ways of living. Troy is part of the Wearable Senses Lab in the Future Everyday research cluster of Industrial Design at Eindhoven University of Technology. His research looks to how computational craftsmanship and iterative product lifetimes create product service systems and future production. His PhD research investigates the programming of material, form and behaviour in flexible, wearable, textile structures, often expressed as shoes. Troy's background as a fashion designer in Italy shaped ideas of how clothing fit the user in many ways including physically and socially. He sees a future that goes beyond mass customization into data driven garments and accessories called ultra-personalization. Ultra-personalization in fashion goes beyond bespoke tailoring/shoemaking, yet has the capacity to be democratic in its application.

Svetlana Mironcika

Svetlana Mironcika is an interaction designer and researcher of interactive and smart products and services that address and appeal to the human body and bodily skills, this includes smart garment design, design for fine and gross motoric, design for kinesthetic sense. She is currently a PhD candidate in Future Everyday group, department of Industrial Design, Eindhoven University of Technology where her research focuses on co-creation processes of ultra-personalized wearables and garments. Svetlana is a part of the Next UPPS NWO and researches the design of integrated design methodology for Ultra Personalised Products and Services in collaboration with three Dutch Technical Universities (Eindhoven TU, Delft TU and Twente TU) and three industrial partners (Philips Design, Bata Industrials and HAVEP workwear). Svetlana is funded by Netherlands Organization for Scientific Research (NWO).

Loe Feijs

Loe Feijs is Full Professor of Industrial Design of Embedded Systems. His research aims to pave the way for a new type of industrial design practice based on a deeper technical understanding of the power of computation, sensing and connectivity. Feijs and his team create novel demonstrators using creative programming, creative electronics, mechanics, machine learning, connectivity and mathematics. In the future, designers should be able to design fluently with contemporary engineering concepts and use their inherent aesthetics. Industrial Design of Embedded Systems contributes technology to other chairs in the department. Working with other departments of TU/e, research hospitals and strategic partners in world-class research ecosystems on selected medical domains, Feijs and his group aim to bridge the gap between formal approaches of technology engineering and the creative needs of contemporary and future industrial design. Feijs has extensive industrial experience in telecommunication, formal design methods, software testing and embedded systems. In software architecture he created RPA (Relation Partition Algebra), which was used in organizations such as Philips, VU, Fraunhofer, NASA and FDA. His research interests include generative design, unobtrusive monitoring and bio-feedback.

Oscar Tomico

Oscar Tomico trained as an Industrial Engineer and specialized in innovation processes in design engineering. He currently heads the Industrial Design Engineering Bachelor's Degree at ELISAVA, he co-directs the Design for Emergent Futures Master’s Program in collaboration with the Institute of Advanced Architecture of Catalunya, and he is Assistant Professor in Industrial Design at Eindhoven University of Technology. His research focuses on how to design, develop, produce, and deploy Soft Wearables (clothing and textile-based accessories that incorporate smart textiles and soft electronic interfaces). He has been involved in multiple research projects like Fibrous Smart Material Topologies (3TU.Bouw, 2016), ArcInTexETN (H2020, 2015), From Design Fiction to Material Science (KIEM, 2015), Crafting Wearables (CLICKNL, 2013), and Smart Textile Services (CRISP, 2011). His communication and dissemination activities include co-organizing events like the Smart services, smart production, smart textiles debate at the Disseny Hub (Barcelona, Spain, 2016) and the Crafting Wearables breakout session at The Future of Fashion is Innovation (MoBA, Arnhem, 2013). Tomico has curated exhibitions such as the Systems Design – Eindhoven School at Design Hub Museum (Barcelona, Spain 2012) and the “Speculate, collaborate, define – textile thinking for future ways of living” exhibition at Textile Museum (Borås, Sweden, 2017).

A Visual Programming Interface as the Common Platform for Sharing Embodied Knowledge

Flemming Tvede Hansen, The Royal Danish Academy of Fine Arts School of Design

Martin Tamke, The Royal Danish Academy of Fine Arts School of Architecture

Abstract

In this paper, we introduce the project Filigree Robotics, which is a collaboration between an architect, a ceramic craftsperson, and a programmer. The focus is to examine and discuss how skills and embodied knowledge in different professional disciplines can be shared and applicable to one another in a collaborative practice.

In the project, we aim to develop a computational tool that holds all the knowledge necessary to materialise a ceramic design that meets the architecture desired. It is necessary that the individual experiential knowledge, which each member has gained through practice, is shared and communicated in and through collaboration, and embodied in the output. For that purpose, the visual programming interface Grasshopper has provided our platform and environment for the collaboration.

In the paper, we examine three phases within the collaboration. The first phase develops a common ground within the collaboration, reflected as the very genesis of shape in 3D printing with clay: the extrusion of a line of material. A second phase is characterised by several creative interdependent sub-collaborations that develop the novel use of material through new technologies and a pattern generator, which unfolds a 3D printable pattern based on a 3D-scanned hand-modelled object. Finally, the third phase points to the importance of focussed and specialised in-depth studies. This phase is characterised by efficiency that tends to involve sub-cooperation with the purpose of developing the findings and making them accessible for a wider community. Though this last phase is of great importance, we conclude it is the second phase that is the most challenging, creative, and innovative part of the collaboration. It is in the second phase that skills and embodied knowledge by Grasshopper are shared and applicable to one another in the collaborative practice. Nevertheless, the premise for the second successful creative phase is the successful initial phase.

Keywords

Ceramics; Architecture; Digital technology, Crafting; 3D printing

The focus of this paper is to examine and discuss how skills and embodied knowledge in different professional disciplines can be shared and applicable to one another in a collaborative practice. For that purpose, we introduce the project Filigree Robotics, which is a collaboration between an architect, a ceramic craftsperson, and a programmer.

In Filigree Robotics, our design ambition was to enter the architectural realm with ceramics based on our common interest in new technology and by the development of a computational tool that incorporates notions of craftsmanship.

With today's digital technology, new interfaces and processes between humans, space, and material can be created. Advances in 3D scanning and 3D printing allow a bridge from hand-modelled objects to the digital design environment and again to fabrication. At the same time, we propose that, digital technology also allows a bridge between different disciplines as it creates a common platform for sharing embodied knowledge.

We argue to see a close link between the creative process and digital manufacturing based on the view that crafting and execution in unity is intuitive and humanistic (Leach, 1940; Bunnell, 2004). Instead of thinking of craft and technology as diametric positions, we propose to see technology as an enabling force - following McCullough's (1998) idea about a close connection between digital work and craft practice. In addition, since the digital design environment is inherent for an architect, we will show, how digital technology allows a bridge between the different disciplines based on a visual programming interface as a common platform for sharing embodied knowledge.

Ceramic Craft Practice and 3D Digital Technologies

The need and the will to develop project-specific tools and processes, which are finally becoming the carrier of concept and the generator of form, is at the core of both ceramic and computational design practice within the field of architecture. These bespoke tools can provide feedback through embodied interaction. In our project, we reveal how a close link between the creative process and digital manufacturing allows both an extension and utilisation of craft knowledge based on skills and making through digital technology.

The similarity between the way custom digital design tools are developed and the way tools are developed by craftspeople in the field of ceramics is in the process of iterative experimentation within the chosen media to achieve a desired expression and behaviour of outcome.

Focusing on practices with ceramics, we question how and where traditional craft-based knowledge, rooted in the skills and experience of making 3D objects, can work with and inform novel ceramic processes in architecture that utilise digital technology. In addition, we question how skills and embodied knowledge in these different professional disciplines can be shared and applicable to one another in the collaborative practice through digital technology.

Craft Practice

Craft and artistic practice are, in this research, based on the idea that the interaction with a responding material guides the ceramicist (Leach, 1940; Dormer, 1994), and crafting and execution work in unity in a way that is intuitive and humanistic (Leach, 1940). Following Leach and Dormer, we argue that traditional craft can be understood through two parallel levels: its immediate interface to matter, which is able to provide instant feedback, and the consistency of design logic and material processing.

Bunnell (2004) defines craft as an essentially human and humanising process. "To craft something involves human interaction with technology whether it is a pen, hammer, or computer software and hardware. In the experience of a maker, it involves a high level of autonomous control over a holistic process of designing through making" (Bunnell, 2004, p 5).

Thus, the embodiment of skills and material knowledge is evident in the way we see craft practice.

New Technology

A novel set of design software brings easier ways for artists, architects, and designers to develop tools specific to their own projects. An example is the 3D modelling software Rhino (McNeel & Associates, http://www.rhino3d.com/) and its visual programming interface Grasshopper, developed by David Rutten (http://www.grasshopper3d.com/).

Grasshopper is used by artists, designers, engineers, and architects among others. The software generates geometries for shapes, objects, structures, and even highly complex buildings by finding and encoding the generative concept underlying the geometries into custom tools.

While the concept of parametric modelling of geometries in design software dates back to the earliest work in this field with the computational design software Sketchpad, developed by Sutherland (1963), it is only recently that this approach has been acknowledged across disciplines. Programming application program interface (API) and visual scripting tools are widely available as industrial software such as SolidWorks, Maya, Dynamo, and open-source tools such as Blender.

This parametric modelling approach is also, for instance, explored in depth by the Centre for Information Technology and Architecture (CITA). In their research, they develop digital models, often using Grasshopper, that are able to synthesise design intent, fabrication needs, and material behaviour to a degree. These digital models finally extend the space of design into the making of highly specified materials and behaviours (Thomsen & Tamke, 2013). We call this digital crafting (Thomsen et al., 2012). Digital design tools no longer operate in a disembodied space of representation, which take the designer away from matter; they are now a way to extend the designer's ability and senses to craft material.

State of the Art in Ceramic 3D Print

Three-dimensional printing covers a wide range of techniques, which have in common, in terms of design practice, the ability to bridge the digital design environment directly to fabrication. Our project uses an additive manufacturing process, which is based on the layering of fine threads of extruded material.

This technique has developed rapidly with ceramic materials throughout the last decade in both design and architecture. In both areas, users first explored gantry-based 3D printers. Now the focus is on using robots as the underlying technology for the movement of an extrusion head. This effort has seen a similarly rapid development from initially simple syringe-based systems to more advanced systems with complex infrastructures of pumps and containers, which pay tribute to the material complexities of clay.

In the field of design, the point of departure has been the use of desktop printers such as RepRap and Delta 3D printers. Pioneering work was done by the design duo Unfold (http://unfoldfab.blogspot.fi/) from Belgium, followed by the British ceramicist Jonathan Keep (http://www.keep-art.co.uk) and the Dutch artist Olivier van Herpt (http://oliviervanherpt.com). Working on the scale of pottery, they developed the basic technology principles of translating 3D models into ceramic pieces as well as the potential results that emerge when glitches and distortions are seen as positive drivers for design.

Within the field of architecture, ceramics are typically understood to be small parts of a larger assembly. In contrast to other large-scale investigations into the 3D printing of houses, such as the work on 3D printing with concrete, as done, for example, at Loughborough University (Lim et al., 2011) or D-Shape (Dini, 2012), projects in ceramics investigate the potential of modules, texture, and stacking. Building Bytes (http://buildingbytes.info/) did exemplary work in ceramics, a research and development project by Brian Peters. He investigates interlocking modular and stackable bricks printed on desktop 3D printers. The Institute for Advanced Architecture of Catalonia in Barcelona conducts research on the use of clay especially as a building material (https://iaac.net/research-projects/large-scale-3d-printing/pylos/) and tackles as well the challenge of scaling up. This scaling up is conducted through the use of swarm robotics, where many small robots build large structures (http://robots.iaac.net/).

What is common for these designers, architects, and artists is the ability to develop their printers, robots, and printing equipment in their own way to achieve results with individual expression. However, the complexities in terms of material processing, programming of machines, development of technology, and the ability to shape and innovate necessitate collaboration. Skills and the embodied knowledge within different professional disciplines, such as between architecture and ceramic craftsmanship, have to be shared and made applicable to one another in a collaborative practice. Our project presents a case on the collaborative development of new creative processes and products, and the supporting technology, and illustrates what type of framework and means for visualisation needs to be in place to achieve these.

Method

Design in our research project is used as a method of enquiry, a reflective practice, in which the designer engages in a dual mode of reflecting through action and on action (Schön, 1993). Design enquiries in our research project are also used as a material practice and contribution to the production of knowledge (Koskinen et al., 2008). Design is, for this purpose, a powerful form of experimentation: a means for enquiring and of producing knowing (Binder & Redström, 2006). 'It is concerned with moving away from the existing and the known, through intentional actions to arrive at an as yet unknown, but desired, outcome' (Downton, 2003). The means to enter and engage the unknown is a set of consecutive experiments.

In this paper, we illustrate how experiments in a collaborative practice can be employed strategically to drive and speculate about a design, to develop and validate technique and technology to design, and to establish and constantly renew a framework for design decisions.

The inclusion of the underlying framework and tools is, for our project, an adoption of the understanding of experiments, which Ian Hacking introduced to the scientific community during the practical turn (Hacking, 1983) to the field of design. Hacking's emphasis on process and context reveals a natural equivalent in the academic interest in process and a holistic approach towards design.

Filigree Robotics

Filigree Robotics explores the middle ground between the precision of digital tools and the adaptiveness and flexibility of craft-based material practices. In this project, we especially aim to develop a computational tool that incorporates notions of this craftsmanship. This means the tool should hold all the knowledge necessary to materialise a ceramic design that meets the architecture desired. In this project, each member of the team has a shared interest for digital technology as part of the making process. While this is the baseline of our collaboration, each member has his or her own individual skills in processing ceramic material, in digital technology, and in architecture. The project can therefore only succeed through the combination of specialist knowledge.

It is necessary that the individual experiential knowledge, which each member has gained through practice, is shared and communicated through collaboration, and embodied in the output. Key to this approach is the ability to find a common platform for exchange, ideation, and representation. This platform must balance the needs of an interdisciplinary team to be precise enough and to be understood in a similar way by all members. The platform needs to be flexible and open enough to allow for speculation, interpretation, and quick adaptation and iteration.

In Filigree Robotics, it was important to visualise the outcome of the process - the possible range of printed patterns. For that purpose, the visual programming interface Grasshopper provided our platform and environment for the collaboration. By using Grasshopper, we encode individual knowledge, not by telling, but, as stated by Ingold (2013), 'through practice and experience, precisely because telling is itself a modality of performance that abhors articulation and specification' (Ingold, 2013, p109). As Blackler states: Electronically encoded and transmitted information has been added to the traditional forms of encoded knowledge (Blackler, 1995).

Encoding knowledge into code and algorithms allows our collection of knowledge to be articulate and precise. The code is on the other side open and able to interfaces with the specific domains of the different players in the project (a threedimesnional graphical interface, simulating the design; an interface to the fabrication machinery and it´s parameters and sensors to detect the shape of the objects). This ability to interface with humans is for us of great interest, as it allows to bring in human design sense and overcome eventually what Blackler describes as drawback of electronically encoded knowledge, as "it tends to generate a unified and predictable pattern of behavior and output". Finally our code is generative, it is able to synthesize the information into a design and specify and control its fabrication.

In the following section, we present an overview of the project. We then describe the different phases of the collaboration. Finally, we evaluate the collaboration and discuss how and to what extent the visual programming interface worked as a platform for sharing skills and embodied knowledge in the collaborative practice.

An Overview of the Project

Ceramics has a tradition of being used as wall elements. The observation of the filigranity of the extruded thread in 3D printing inspired us to look at references from Gothic and Arabic windows, which have filigree patterns that fulfil functional and performative aspects. For example, the subdivision of a larger wall opening into batches of available glass sizes provides aesthetic purposes and creates local shadow figures.

However, instead of the industrial logic of the repetition of a single unit, we aimed for an individualised approach towards ceramics, an approach that is able to reflect the local needs and is open to the interventions and expression of the craftsperson. For this, we developed an interwoven design and fabrication environment with the aim of unfolding the relationship between the manual crafting of ceramics and crafting through digital technology.

Figure 1 illustrates the first step of hand-modelling a mould as input to a computational interactive system by 3D scanning. The interactive system is here a generative algorithm that is designed for the purpose and works as a pattern generator, programmed in Grasshopper/Rhino. The generated patterns are informed by the high and low points of the 3D-scanned hand- modelled mould and will change according to a change of the mould. The outcome of the pattern generator is the paths for the movement of a robot and the commands for the extrusion of a clay thread.

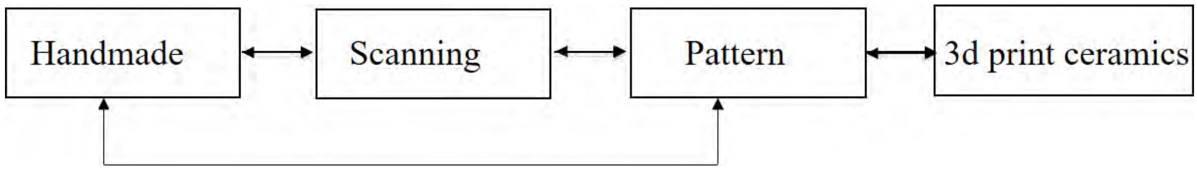

Fig 1. Overview of the design environment in Filigree Robotics.

Aim and Process in Filigree Robotics

The core of the project was the development of a robotic 3D printing system for clay. This effort included the development, evaluation, and iteration of technical, design, and material concepts. We had to be inventive in the selection of the pre- and post-processing of the clay, the control of the mechanics of the 3D printing, and the computational interactive design and fabrication system. The heart of the interactive system was a generative algorithm that worked as a pattern generator, which unfolded a 3D printable pattern based on a 3D-scanned hand-modelled object. In this way, the pattern generator provided us with a bridge from a hand-modelled object to a digital design environment and back again to fabrication. For that purpose, it was important to understand how a hand-modelled object was translated into a pattern and how this pattern was translated into paths for 3D printing by the robot.

Three Phases of Collaborative Development in Filigree Robotics

Filigree Robotics developed over a period of two years through multiple collaborative phases of varying intensities and several subprojects, which had their own deadlines, as exhibitions.

The Initial Experiments – Phase 1

To build up a common ground and to understand the need for 3D printing in porcelain, we initiated several shared experiments by using a RapMan for 3D printing in clay (see Figure 2, left). These experiments started with the exploration of the fabrication process as such. Usually, the 3D printer technique coils up a digitally sliced 3D model layer by layer. We deliberately did not use a model in 3D; we used solely a 2D graphic line to design. This approach avoided the usual way of considering the 3D printer solely as a translator of 3D form. Instead, we built upon the very genesis of shape in 3D printing: the extrusion of a line of material (see figure 2, right). It was an important strategy for us: to break apart, with the purpose of identifying the core, the bridge between digital representation and fabrication. The aim was to identify a basic common ground from where we could build up the project with an awareness about a shared understanding. In that way, we could start sharing skills and embodied knowledge to one another in the collaborative practice.

Fig 2. Left: The RapMan utilized for 3d printing with clay. Right: the very genesis of shape in 3d printing: the extrusion of a line of material.

Sub-Collaborations – Phase 2

The initial experiments created the common ground for what we will call sub-collaborations. These sub-collaborations happened in three parallel interdependent tracks. One track was concerned with the development of the pattern generator. The second track was about processing clay with a five-axis robotic print system, and the third track was concerned with performative and aesthetic aspects. The latter had as well an evaluating function for the sub-collaborations.

As mentioned, the pattern generator built on the development of the very genesis of shape in 3D printing with clay: the extrusion of a line of material along a path. At first, the drawing of a 2D line was unusual for our practice and view on craft practice. However, the observation of the filigranity of the extruded thread in 3D printing inspired us to look at filigree patterns in Gothic and Arabic architecture. Thus, the drawing of a line became interesting when explored as a pattern. Nevertheless, we explored at length the nature of the pattern and its border at the edges, as well as how the pattern was linked to the hand-modelled mould. How could we make a bridge between the 3D mould that represented the touch of the craftsperson and the concept of the 2D pattern that represented the computational interactive design system?

Finally, we devised a concept that connected low and high points in the topology of the mould with a sufficient algorithm that generated patterns. With 3D scanning, we were able to capture the mould as a digital form. As illustrated in Figure 3a (left), the basic pattern grows and meets between a low and high point in a certain number of steps and with a natural border at the edges. In the elaborated and final version, the pattern grows between one low and several high points with changes in density within the pattern (see Figure 3a, right).

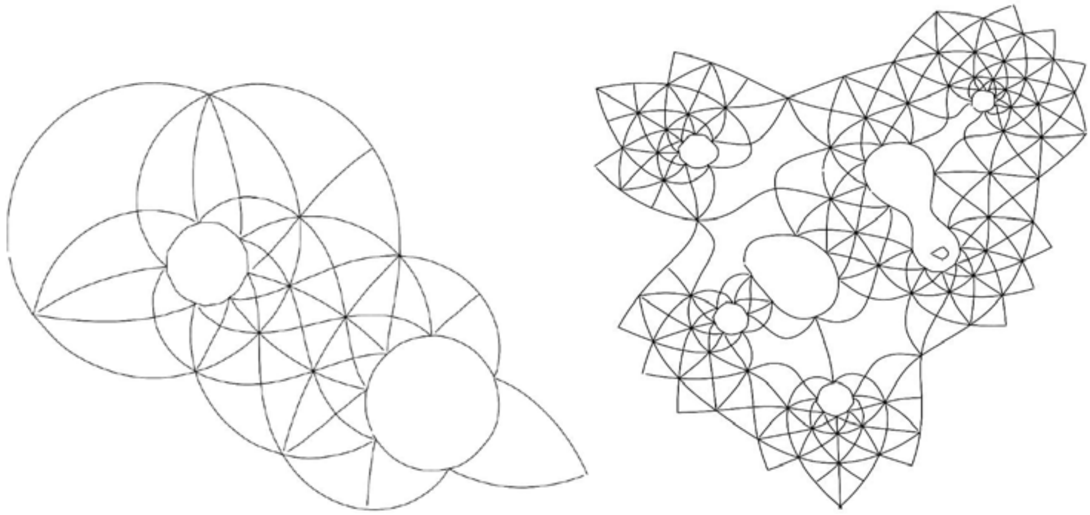

Fig 3a. Sketches of patterns generated by different generations of the pattern generator.

This development of the pattern generator was an attempt to combine our specialist knowledge. The visual programming interface Grasshopper (see Figure 3b) provided the platform and environment. All input, experiments, and tests were fulfilled through practice and with programming as our common language. We were all able to follow what was programmed by the programmer because all input was immediately translated into code and subsequently explored visually and in practise such as via 3D printing.

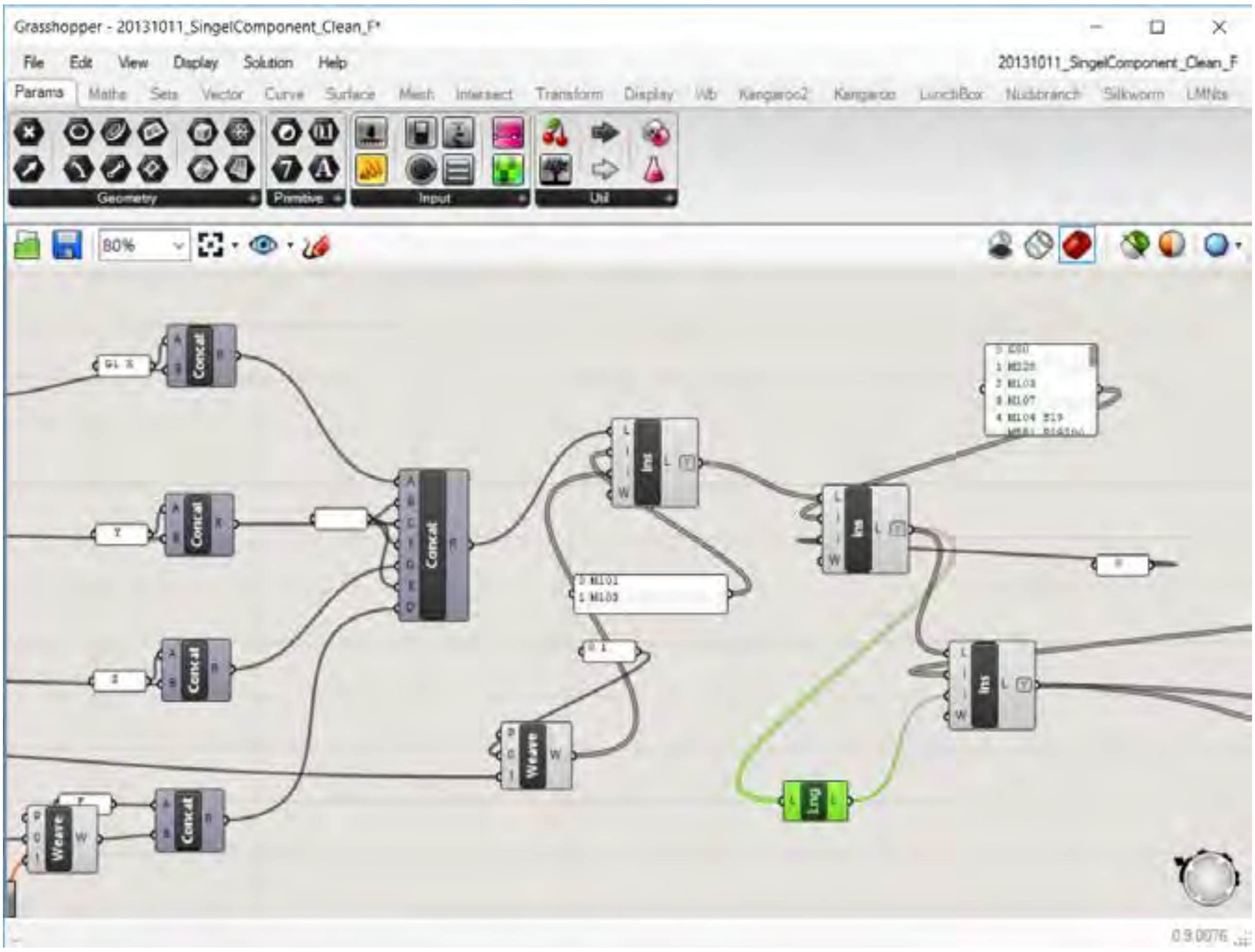

Fig 3b. The visual programming interface Grasshopper.

At the same time and as a parallel interdependent track, comprehensive development work occurred that concerned the pre- and post-processing of the clay linked to the 3D printing mechanical control and the setup of a five-axis robotic print system (see Figure 4). The pivotal point for this development work was the concept of the classic ceramic technique of 'overforming'. The overforming technique is well known in the field of ceramics and is found in a variety of versions, from simple to complex. In brief, overforming make use of a mould for making an imprint by clay. In this case, our hand-modelled object became this mould. Thus, we used overforming for the 3D printing with porcelain clay by the robot, which printed on a hand- modelled mould based on the same material, separated only by a layer of mineral coating on the mould (see Figure 5, left). The coating kept the two structures apart during the process of printing and firing. Here, it was of benefit that both the mould and the object were made of the same material with the same material behaviour during the whole process. To process clay in this way took highly specialised skills and embodied knowledge and was closely linked to the development of the pattern generator.

Printing upon the hand-modelled mould allowed for novel expressions, as the 3D print was based on a double-curved platform. In addition, the fine print was able to utilise and emphasise the nature of porcelain as a plastic material, with spikes in the layered build (see Figure 5, right).

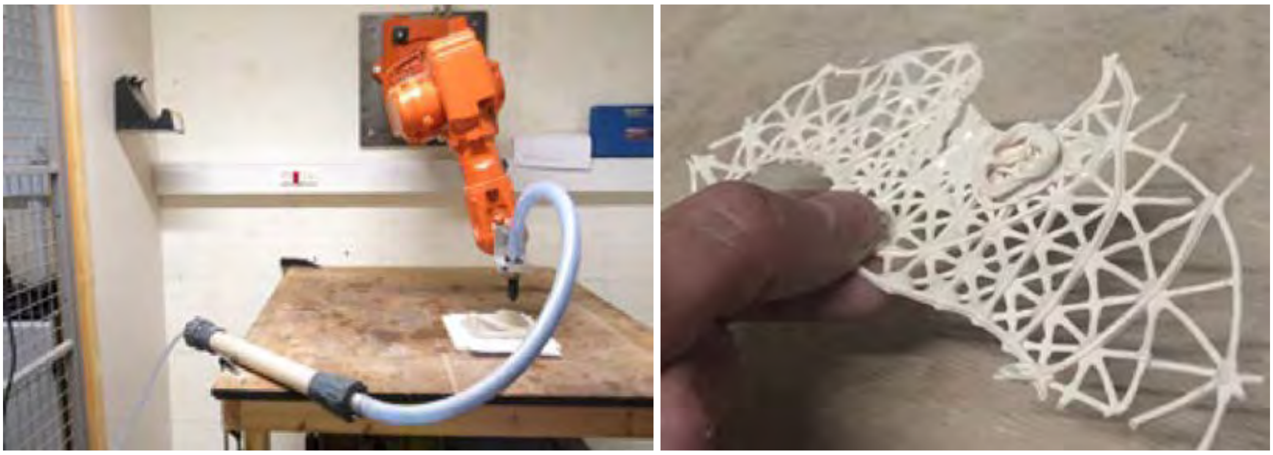

Fig 4. Test of setup for the 5-axis robotic print system.

Fig 5. Left: Test of "overforming" by robotic 3D printing with porcelain upon the hand-modelled mould. Right: Test of plasticity and "life" of clay expressed through spikes.

Finally, a third sub-collaboration occurred to ensure and explore the quality achieved from the inspiration of the Gothic and Arabic patterns. The materiality of test-printed porcelain was investigated and explored in the interplay of strong light coming through the pattern (see Figure 6). In this way, the filigranity made by the printed ceramic was evaluated with regards to performative and aesthetic qualities.

These sub-collaborations occurred as parallel interdependent tracks. The visual programming interface Grasshopper worked as the common platform for exchange, ideation, and representation based on the combination of specialist experiential knowledge. Thus, skills and embodied knowledge were shared and applicable to one another in the collaborative practice.

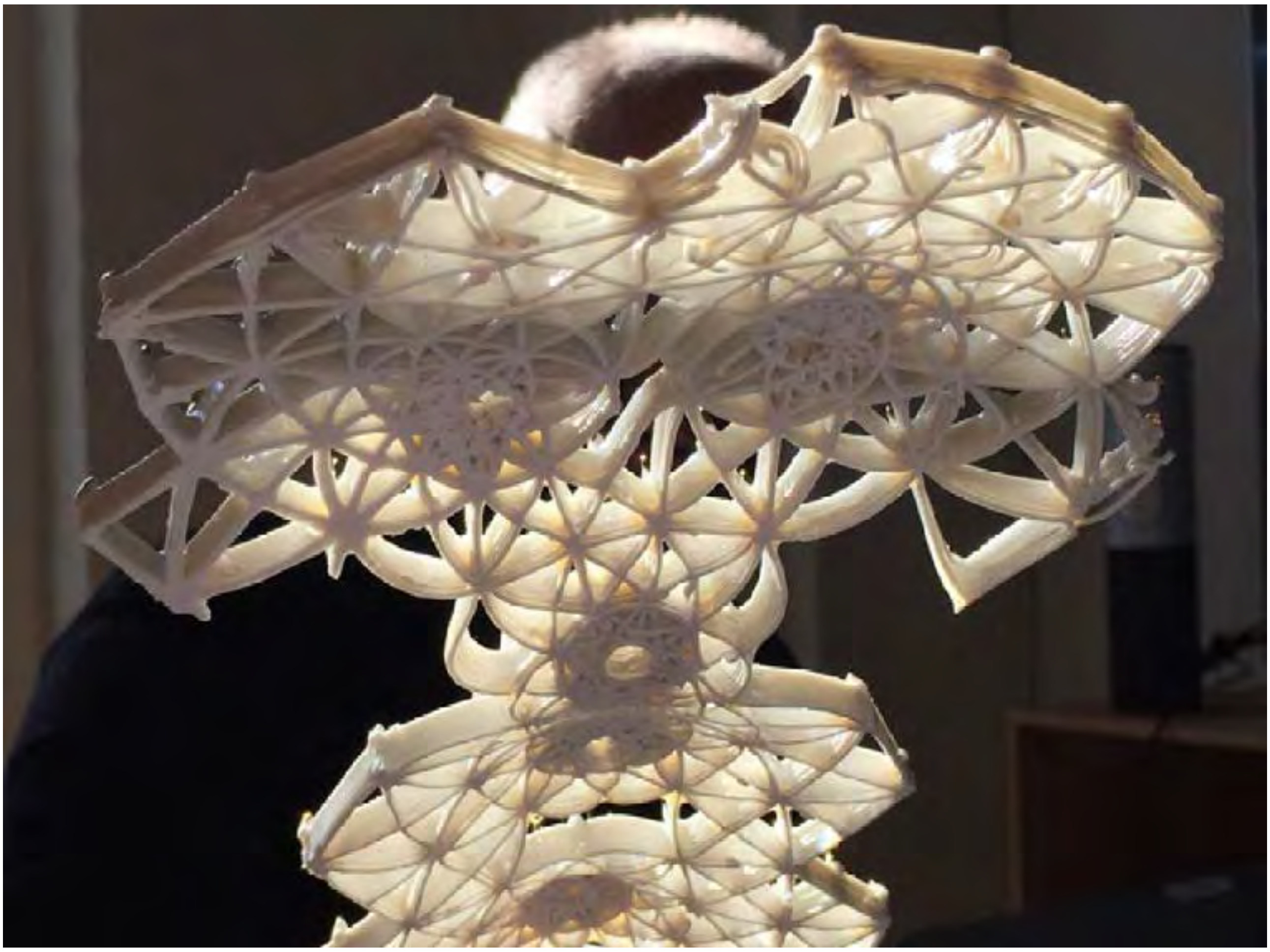

Fig 6. Artefact being explored as a light filter.

Operating from a Platform of Experience and the Final Results – Phase 3

The experimentation in the sub-collaborations led finally to the development of design and fabrication concepts, and tools and processes for the robotic additive manufacturing of filigree ceramic structures. The result can be summarised as follows: The first step is the hand-modelling of the mould (see Figure 7) as input to the computational pattern generator. The visual programming interface Grasshopper provided the environment for developing the pattern generator, which knows about the limits and constraints of the 3D printing extruder and robot and produces paths, which can be directly fed into them (see Figure 7, right). The focus is set on individual moulds that are 3D-scanned (see Figure 8) and taken as input for the pattern generator. The adapted 3D-printed paths drive the robotic movement of a clay extruder nozzle with porcelain clay that prints on the top of the hand-modelled mould (see Figure 9).

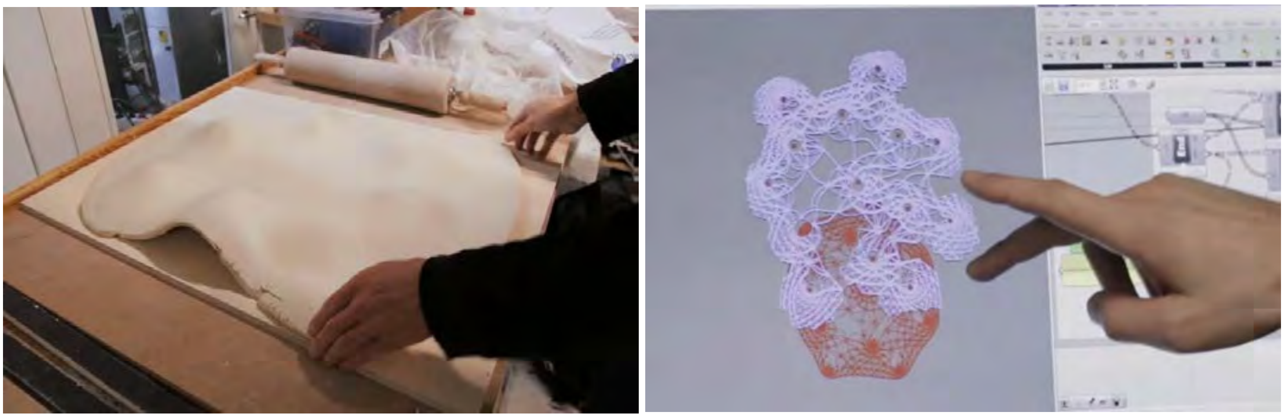

Fig 7. Left: The hand-modelled mould as input to the responding system. Right: The 3D modelling software Rhino/Grasshopper that provided the environment for the pattern generator.

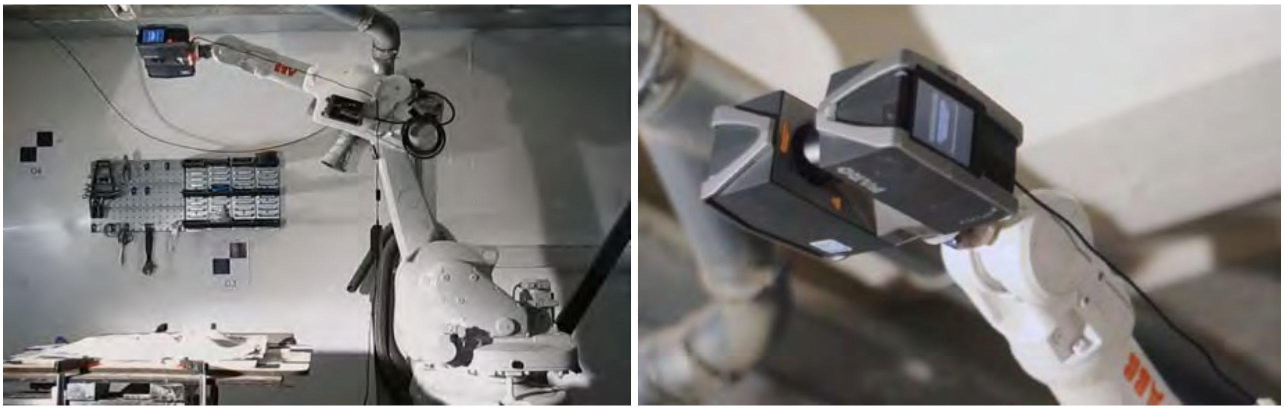

Fig 8. The topology of the mould is 3d scanned as input for the pattern generator.

Fig 9. The adapted 3d printed paths are driving the robotic movement of a clay extruder nozzle with porcelain that prints on the top of the hand modelled mould.

Becoming experienced with the use of a pattern generator based on a hand-modelled object as input is about how "personal knowledge both grows from and unfolds in the field of sentience comprising the correspondence of the practitioners' awareness and the materials with which they work" (Ingold, 2013, p. 111). The pattern generator is like a virtual material, and several experiments are needed to gain access for the user to embodiment of skills and material knowledge. Such experimentation is about human-environment interaction and crafting working in unity in a way that is intuitive and humanistic (Leach, 1940; Bunnell, 2004) and technology as an enabling force (McCullough, 1998).

Through several focussed practical experiments guided by the ceramic craftsperson, final examples were developed. This happened in close dialogue with the collaborators to fulfil the needed performative aspects and the right processing of the porcelain. The final examples were glazed with a glossy glaze and fired to 1260 degrees Celsius. The growth of the algorithm by the pattern generator between the low and several high points was emphasised by the build of spikes that subsequently were glazed with gold (see Figure 10).

Fig 10. The growth of the algorithm by the pattern generator was emphasized by the built of spikes that subsequently were glazed with gold.

At last, the materiality of the printed porcelain was investigated and evaluated in the interplay of strong light coming through the pattern, as they were light filters playing in and through the glossy glaze. This happened through practical experiments guided by the architect in a spatial setup within a gallery, as was it in a light laboratory (see Figure 11). The filigranity made by the printed ceramic fulfilled the performative and aesthetic investigation using a display setup that enabled the object to be viewed from both the top and bottom in relation with the shadows of the pattern (see Figure 12).

Fig 11. The printed porcelain was finally investigated and evaluated in interplay with strong light in a spatial setup within a gallery, as was it in a light laboratory.

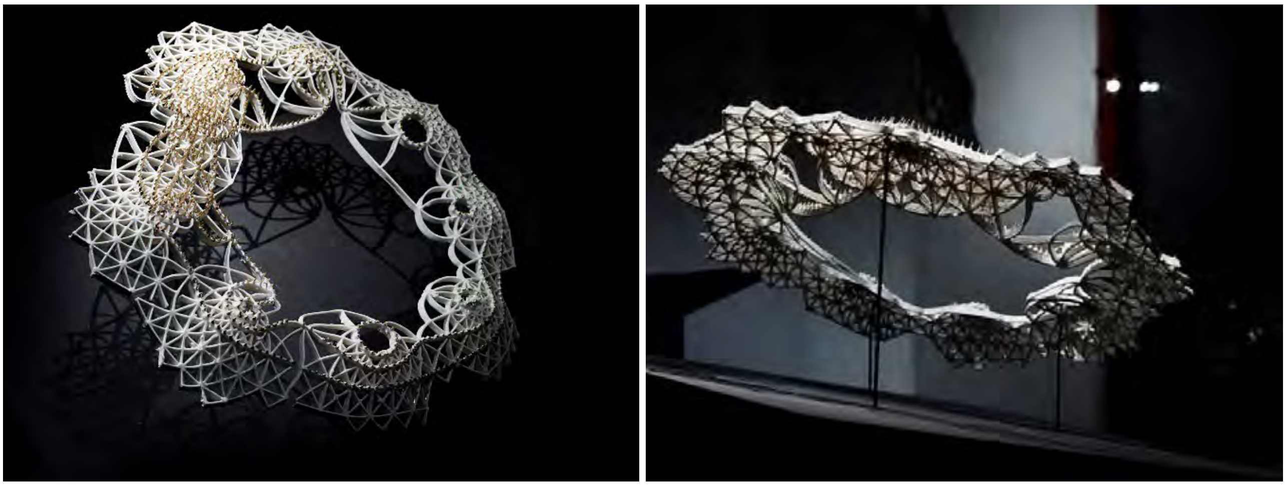

Fig 12. The filigranity made by the printed ceramic fulfilled the performative and aesthetic investigation by a display that enabled the object to be viewed from both top and bottom in relation with the shadows of the pattern.

Reflection and Discussion

We have presented Filigree Robotics with the aim of examining and discussing how skills and embodied knowledge in different professional disciplines can be shared and made applicable to one another in a collaborative practice.

In the project, we explored how and where traditional craft-based knowledge, rooted in the skills and experience of making 3D objects, can work with and inform novel ceramic processes in architecture that utilise digital technology.

At the same time, we explored how digital technology allows a bridge between different disciplines based on a visual programming interface as a common platform for sharing skills and embodied knowledge. For that purpose, we used the visual programming interface Grasshopper.

We found the digital platform provided the necessary platform to encode skills and embodied knowledge from our different professional disciplines. The strength was found in the combination of the visual programming interface and 3D representation as a common language across our disciplines. Thus, our encoded specialist knowledge could be accessed and applied by others through the platform. Furthermore, the open nature of the platform allowed a constant learning process, where encoded knowledge and skills could be updated and new ones added to develop a shared digital tool that could serve us all.

We also found that the overall collaboration was divided into three phases that consisted of several modes of collaboration. For this purpose, it is of interest to note the differentiation between collaboration and co-operation as described by Leifer and Meinel. They describe how “collaboration demands a team-of-teams organisation”, while “co-operation demands a command-control organisation” (Plattner et al., 2018, p.1).

In our collaboration, we experienced how the initial experiments and the sub-collaborations were driven by “creative collaboration and by agreeing to disagree until something worked or a breakthrough occurred” (Plattner et al., 2018, p.1). Whereas the described collaboration in the sections “Operating from a platform of experience and final results” tend to characterize cooperative work.

1. The initial experiments reflected an initial phase of great importance since they developed a common understanding and language through practice to stand and build on. We found that crucial since it went beyond what the project was about and dealt with how and if the project would succeed. Key to this was the ability to find a common platform for exchange, ideation and representation since the platform dealt with the way we shared skills and embodied knowledge.

2. We characterise the sub-collaborations as the central and creative phase within the project dominated by interdependent sub-collaborations that generated innovative ideas. The experimental development of the pattern generator, the concept of printing upon the hand-modelled mould, and the investigation of the performative and aesthetic investigation of the printed porcelain were groundbreaking artistic development work.
3. Finally, we experienced a third phase, introduced in the sections "Operating from a platform of experience and final results", that we characterise as cooperative work (Plattner et al., 2018). This phase tended to be dominated by efficient cooperative work and in-depth studies based on guidance and recommendations from the specialist. This phase was more about developing and strengthening performance and the idiom by the use of the pattern generator than being creative about developing an innovative concept for the core of the project. Nevertheless, we found this phase important since it dealt with the purpose of extracting the findings and making them accessible for a wider community through an exhibition.

An overview of the overall collaboration is illustrated in figure 13.

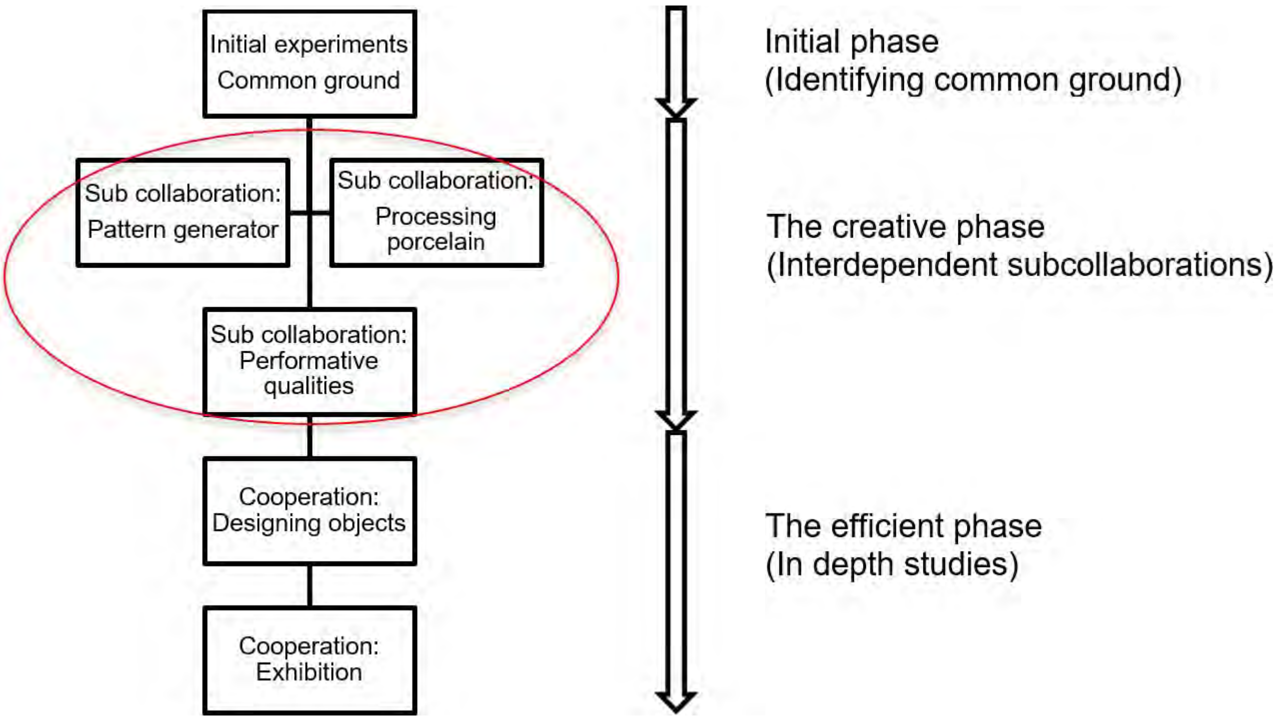

Fig 13. Overview of the two phases and the sub collaborations within the project.

Conclusion

We have introduced the project Filigree Robotics and have demonstrated how a visual programming interface can be utilised as a common platform for sharing embodied knowledge. We have also demonstrated how the overall collaboration was divided into three phases: the initial, the creative, and the efficient phase, respectively, and how these phases consisted of different modes of collaboration where some tended to be about co-operation.

The strength of the visual programming interface Grasshopper as a common platform for sharing embodied knowledge was found in the second phase of the collaboration. Here our encoded specialist knowledge could be accessed and applied by the others based on the combination of the visual programming interface and 3D representation as a common language across the disciplines.

This phase was driven by interdependent creative sub-collaborations that generated new, innovative ideas based on the idea of agreeing to disagree until something worked or a breakthrough occurred. Nevertheless, this creative phase would never have been successful without a successful initial phase that was the premise and that contributed a common understanding and language to build on.

The final and third phase was driven by a proof of concept by testing, evaluating, and realizing what was possible and how. This phase tended to be dominated by efficient co- operation and in-depth studies, driven firstly by a comprehensive exploration of the pattern generator based on hand-modelled moulds as input, and secondly by investigating and evaluating the materiality and performance of the printed porcelain.

Though we found the third phase important, it is the second phase that we found the most challenging, creative, and innovative part of the collaboration. It was in the second phase skills and embodied knowledge were shared and made applicable to one another in the collaborative practice.

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Flemming Tvede Hansen

Flemming is a graduate student from The Royal Danish Academy of Fine Arts – School of Design (KADK), Copenhagen, 1995 specialized in ceramics and glass. His Ph.D. Scholar considered integration of digital technology in the field of ceramics and defended in 2010 at KADK. Flemming is currently Associate Professor and head of the master program in Ceramics Design at KADK. His current research considers how experiential knowledge of crafts rooted in ceramics can be transformed and utilized in the use of digital technology and is mainly focussing on 3D print technology in clay.

Martin Tamke

Martin Tamke is Associate Professor at the Centre for Information Technology and Architecture (CITA) in Copenhagen. He is pursuing a design led research on the interface and implications of computational design and its materialization. He joined the newly founded research centre CITA in 2006 and shaped its design-based research practice.

Projects on new design and fabrication tools for wood and composite production led to a series of digitally fabricated demonstrators that explore an architectural practice engaged with bespoke behaviour. Currently he is involved in the Danish funded 4-year Complex Modelling research project and the EU funded interdisciplinary and intersector Marie Curie ITN Innochain.

Collaborative Ecologies through Material Entanglements

Miranda Smitheram, Auckland University of Technology, New Zealand

Frances Joseph, Auckland University of Technology, New Zealand

Abstract

This paper addresses aspects of collaboration and conceptual frameworks in practice that are central to our project, *Phenomenal Dress*. The research has been informed by material thinking, posthuman theory and New Zealand Māori perspectives, through processes of "making-with" (Haraway, 2016). Working with an ecosystem, engaging with localized non-human phenomena as well as cultural and scientific experts, mediated materials, textile surfaces as new forms of "dress-action" (Tiainen, Kontturi and Hongisto, 2015) have been developed through relational entanglement. The artefacts produced in the project are not functional or fashionable products, they are matter flows, formed through diverse perspectives and collaborative processes. They suggest a reconsideration of dress as material-aesthetic activations and pathway towards co-emergent understanding.

Through this approach, the ecosystem is recognised as the primary collaborator, repositioning human and more-than-human relationships. This approach is informed by Māori knowledge and ways of knowing (mātauranga Māori), perspectives of kaitiakitanga (stewardship) and deeper relationship with the lifeworld through acts of sensing, noticing, making and following. The methodology is grounded in an ontological shift away from human-centredness, where matter and place have been positioned as object, to focus instead on matter as vital collaborator and place as habitat where the interconnections between things can be expressed.

Keywords

Collaboration; Whakapapa; Materiality; Making-with; De-centred design

The complex environmental impacts of human actions on the world cannot be addressed within a single disciplinary framework. Collaboration is fundamental to the exploration of these pressing issues, with a growing body of research into forms and methods of interdisciplinary collaboration (Darbellay et al, 2014; Szostak, 2017). Collaborations between the arts and sciences have gained momentum, however, there are fundamental assumptions behind most cross-disciplinary research approaches that stems from our immersion in western knowledge frameworks. If research is to move beyond disciplinary boundaries and transcend the limitations of their established worldviews (Klein, 1990) attention must be paid to ontological positions outside of established western paradigms and to emergent methodological approaches that enable new conceptual frameworks in practice, supported by more interconnected forms of collaboration. Anna Lowenhaupt Tsing (2015) argues that staying alive—for every species—requires liveable collaborations, and that collaboration means working across difference.

This paper addresses the emergent frameworks, collaborative forms of engagement and processual materialities that have been central to our design project, *Phenomenal Dress*. The project was based at Karekare, an ironsand beach, forty kilometres from Auckland on the west coast of the North Island of New Zealand. The frameworks that locate and have informed this research, in particular new materialism and indigenous Māori perspectives are discussed. We do not claim consensus between these frameworks, and acknowledge the significance and specificity of Māori knowledge and agency within the bicultural context of Aotearoa/New Zealand. Situated within this environment, the imperative of working with decolonizing methodologies can be seen as acts of tino rangatiratahi - self-determination (Smith, 2012). The framings discussed in this paper have helped guide us to new areas where the interconnections between things are considered and explored through decolonized and new materialist lenses.

Working with the medium of dress, we have shifted away from traditional western notions of clothing as representation and object, to a consideration of dress as site of material aesthetic activation. The human body has long been regarded as the locus of dress. In seeking to de-centre the human, we engage diverse terrestrial bodies within an ecosystem through a process of making-with (Haraway, 2016). Working within a specific environment with localised non-human phenomena as well as cultural and scientific experts, we have co-produced mediated materials, textile surfaces and new forms of dress through collaborative processes of making. Dress becomes action and connective capacitor rather than representational object, fashioning relationships between things.

The processes and methods informed by these framings are addressed. Collaboration is reoriented within a context where the ecosystem is the primary collaborator, repositioning human and more-than-human relationships. This approach is grounded in an ontological shift away from human-centredness where matter and place were positioned as objects, to recognise a vitality of matter, as both subject and collaborator. Through this approach diverse boundaries intersect, reframing and enabling new understandings and forms of expression. This situated, participatory, practice-led approach, involves a process of being-with through sensing, noticing and following material and phenomenal intra-actions (Barad, 2007).

Finally, we discuss two completed works that involved processes of thinking through acts of making informed by new materialist and mātauranga Māori frameworks. We conclude with a short discussion of insights gained through this research. The paper highlights the urgency of developing new modes of research through practice that engage with materiality from perspectives other than human-centric and commoditized. Without collaboration and deeper understandings of our interconnection through and in the material lifeworld, there can be no future.

Focus and Framing

De-centring the Human

Human-centredness has been a key design strategy for several decades, seeking to “promote the well-being of people by helping to gratify their basic needs” (McKim, in von Thienen, Clancy and Mienel, 2018). The success of ‘usable’ systems and products has elevated the widespread adoption of human-centred design approaches within the context of a globalized economy of mass production and hyper-consumption and its repercussions as waste and environmental degradation. A repositioning where the non-human is recognized as central to being, and where human well-being is no longer the dominant concern for designers within our interdependent life world, is overdue.

In considering these complex issues, the *Phenomenal Dress* project has drawn from two distinctive frameworks: the predominantly western theories of new materialism and traditional Māori perspectives of connection between human and non-human. This approach recognises that holistic thinking based on long-held Māori knowledge (mātauranga Māori), has increasing relevance to the growing environmental and societal problems that face our world. This has some synergies with emerging western perspectives that seek to reposition the human as part of, rather than separate from the world. The Māori world view (te ao Māori) acknowledges the interconnectedness and interrelationship of all living and non-living things. Thus, the significance of Māori knowledge and agency is pivotal. We have sought areas of productive interaction and new understandings generated between these different frameworks. This is not about claiming similarity, but recognises that mātauranga Māori already embeds an expanded view of relationship between people, place and things. Language has been important within the project in developing understandings, and te reo Māori (the Māori language) has opened up new insights and pathways. This aspect is discussed through the example of whakapapa.

New materialism can be understood as an ontological turn to reprioritise matter, recognising the agency of things and assemblages of human and nonhuman, such as natureculture (Haraway, 2003). This rethinking of materiality has also focused attention on processes of making, prompting a re-evaluation of design and its potential beyond cycles of fashionability and replacement. This material turn that includes both physical processes of making and methods based in mediation, has contributed to an ontological re-orientation that decentres the human, recognising the notion of active matter and the vital materialism we are part of. Anthropologist Daniel Miller talks of 'sapient materiality', where both consciousness and cognition are "bound to the specifics of materiality rather than defined by their opposition to a material world" (2005, p.34). This material knowing challenges dualities of body and mind, material and immaterial, object and subject (Joseph et al, 2017). In this context, facture is an embodied process, even when technologies are utilized or things made by non-human agents.

Embodied practices of making create greater awareness of the interrelationships between things. Anthropologist Tim Ingold (2010a) identifies designerly approaches to making as "an imposition of form upon the material world by an agent with a design in mind" (p.91). Rather than this enforcement, he proposes that the forms of things arise within fields of force and flows of materials. Practitioners make things by intervening in these force-fields and following these lines of flow. Recognising the interwoven nature of textiles and making as a practice of weaving things together, he introduced the term 'textility'. The complexity of textiles as material systems made from interwoven or tangled fibres, becomes a metaphor for the interrelatedness of things in the material world. The concept of textility is relevant to complex material systems as well as textiles, and this notion also becomes a thread within our research.

Fig 1. Karekare Beach, Wāitakare Ranges, Auckland, New Zealand. M Smitheram, 2018.

The Project Whakapapa

Karekare Beach provides both the location and the mauri that physically and spiritually grounds the project. 'Mauri' is a Māori concept that refers to lifeforce, the elemental energy which binds and animates all things in the material world. The presence of mauri infers a whakapapa to this place. It is alive; therefore it has histories, existing relationships, ancestry and kin. Whakapapa extends from and surrounds a thing, as layers of connection and can be understood as a genealogy and a geological layering of people, places and things. Scientist Mere Roberts describes whakapapa as:

> *"most commonly understood in reference to human descent lines and relationships, where it functions as a family tree or genealogy. But it also refers to an epistemological framework in which perceived patterns and relationships in nature are located. These nonhuman whakapapa contain information concerning an organism's theorized origins from supernatural beings, inferred descent lines, and morphological and ecological relationships." (Roberts et al, 2004)*

It is impossible to work with or consider matter from Karekare in isolation without engaging with inherent socio- cultural narratives. The discovery of the whakapapa of matter from a grain of sand to volcano, informs and forms layers of response through making- with. Each new unfolding of history and narrative in turn influences the making practice.

Another perspective on whakapapa can be found by examining the word itself. An important aspect of te reo Māori is the layers of meanings contained within words, often involving combinations of other words and contexts. Cultural commentator Bidois (2006) offers a definition while cautioning that there are many understandings of words and this is just one:

> *"Whaka can mean 'to create, to cause, to bring about, to action.*
>
> *Papa can refer to firmament. Ground. Solid base. (Papatuanuku – Mother Earth).*
>
> *From one perspective and understanding, Whaka-papa can be seen to mean 'To bring about grounding' 'to provide a solid base'."*

Whakapapa can be visualised as sedimentary layers, charting the intersections of lineage between places, people and things (see Moore and McFadgen, 2006). There is a synergy between this cosmological concept in relation to the context of the Anthropocene, with human industrial production adding a new, destructive geological layer to the planet. Within the *Phenomenal Dress* project, tracing whakapapa and relationships of things has assisted design decisions and actions.

New materialism theorist Jane Bennett describes a similar kind of ontological philosophy of relationship, one in which matter has never been dead or separated from people, urging us to imagine "an ontological field without any unequivocal demarcations between human, animal, vegetable, or mineral. *All* forces and flows (materialities) are or can become lively, affective, signalling." (2010, pp 116–17). Anthropologist Dame Anne Salmond (2017) draws a parallel between Bennett's theory of vital materialism and mātauranga Māori, bringing our attention to the thoughts of nineteenth century Māori philosopher Nepia Pohuhu, who said: "All things unfold their nature [tupu], live [ora], have form [āhua], whether trees, stones, birds, reptiles, fish, quadrupeds or human beings".

The black ironsand that makes up the west coast beaches between Whanganui and Auckland originated in the rocks of the central North Island volcanic field some 2.5 million years ago. Over centuries, these rocks eroded from mountains including Taranaki, Ruapehu and Pirongia, the particles washed down waterways including the Whanganui and Waikato rivers, transported by ocean currents along the coast and deposited as sand on west coast beaches.

Thus, the geology and whakapapa of Karekare Beach can be traced through these sediments to these rivers and mountains. To situate a whakapapa of this iron sand that forms the beach and trace a line from matter back through cosmogony to origin, we propose this sketch (Figure 2). This whakapapa is by no means definitive, but is an approach to thinking through the whakapapa of a particular material within this project and ecosystem.

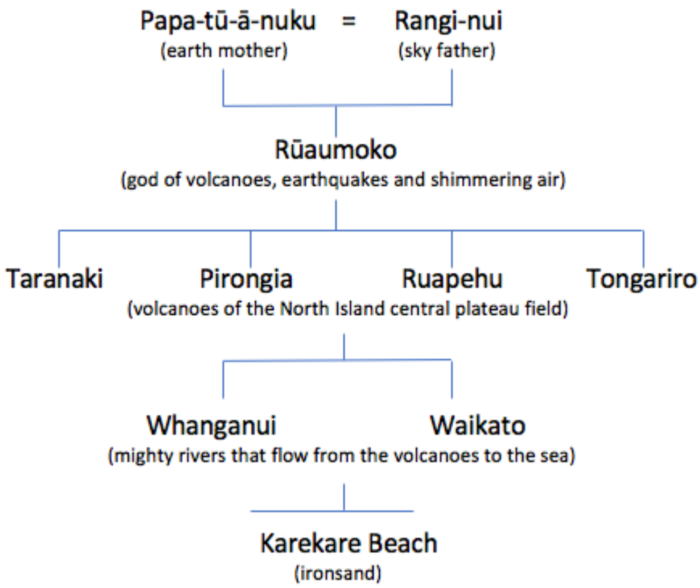

Fig 2. Ironsand Whakapapa, M Smitheram, 2019.

Figure 2 illustrates a lineage from creators to individual grain of sand. For the researchers it is significant in understanding the potential and connectedness within a particular form of matter. This whakapapa charts the descent from earth mother Papatuanuku and sky father Ranginui, the primordial couple in Māori creation traditions. Their union created many children from whom all human and non-human things in the world descend. This foundational narrative connects human, place, water, mountain and gods in te ao Māori. One child was never born, but instead stayed within his mother's womb. When he moves the earth shakes. To keep Papatuanuku warm, he holds volcanic fire. This god, Rūaumoko, is known as the god of earthquakes, volcanoes and of heated shimmering air, such as we see across the sands at Karekare on a sunny day.

Fig 3. Making-with ironsand, M Smitheram & F Joseph, 2017-19.

In charting this whakapapa the ontological and cosmogenic sense of matter in familial relationship to people is highlighted. Matter is not only ‘vital’, it is situated *within* our Māori genealogies and histories, an extended and complex addition to the capacities Bennett attributes to matter, “edibles, commodities, storms, and metals act as quasi agents, [....] with their own trajectories, potentialities and tendencies” (p. 9, 2010).

Dress, Embodiment and Making-with

Dress may seem a peculiar form to choose in attempting to engage with an ecosystem and decentre the human. Traditionally, the locus of clothing is the human body. Interpretation of dress in cultural and fashion studies has been through frameworks of constructivism and representation (Barthes, 1967; Davis, 1994). While the field of Dress Studies researches physical artefacts, focussing on materials, design and construction rather than representation (Taylor, 1998) its concerns remain human-centric. These normative perspectives on fashion and dress, based in a hierarchical separation of mind and human perspectives over matter and the non-human, are being challenged by new materialist thinking (Tiainen, Kontturi and Hongisto, 2015; Edelkoort, 2016; Ruggerone, 2017; Smelik, 2018).

Recognising this ‘material turn,’ Smelik suggests fashion is “materially embedded in a network of human and non-human actors” (2018 p. 34). Decentring the human subject, fashion expands “beyond the frame of the body and human identity to the non-human world of technology and ecology”. Tiainen, Kontturi and Hongisto (2015, p.14) ask how we might consider aesthetics “beyond the assessment of cultural expressive patterns as the initial impingement of the worlds materialities from physical locales to mediatised textures upon us?” The project *Phenomenal Dress* explores such inter-connections through collaborative practices of dress-making and performance as material-aesthetic activations.

Through this ontological shift we change focus from human subject to engagement through “active materials that compose the lifeworld.” (Ingold 2012. p.249). This position recognises that consciousness is inextricably linked to material processes; that our minds and bodies are not separate dimensions; that physicality is more than ordinary matter. In this entangled context, the artefacts produced in the *Phenomenal Dress* project are not functional or representational garments, they are expressions of sensory receptivity that trace the relational emergence of phenomena at Karekare into perceptibility. The human body and its associations with individuality and subjectivity is replaced by a notion of inter-related bodies that form the ecosystem. Dress becomes a medium for exploring this trans-corporeality (Alaimo, 2010) as ways in which bodies interface with other human and non-human bodies in reciprocity.

Methods and Research Process

These philosophical and cultural frameworks have informed research protocols and methods including: the observation of mātauranga Māori protocols; the investigation of cosmogonic, scientific and historical accounts; acts of sensing, noticing, following and being in the environment; material agency through experiment, play and collaborative processes of making-with; embodied activations through performance; mediation, documentation and ethnography. The project is practice-led, involving refractive methods in a process that is both generative and iterative. Here we consider certain aspects of the research process.

Collaboration

We have engaged through an expanded notion of collaboration as ‘working with others’ including human and more-than-human participants. This was fundamental to the project. We have collaborated with various phenomena and things that are part of the Karekare Beach ecosystem. Together we make-with sand, wind and sea, streams, dunes, rocks, hills, flora and fauna, through emergent methods of co-production. In keeping with this sense of interconnection between things, this process of making-with rather than extractive notions of making-from or functional approaches to making-for informs the design process. Agency, as the capacity to act and to make choices, is co-constituted and emerges within the complex, changing relationships of human and non-human things.

The research has been realised through our collaborators, the communities they align with and have been informed through. A fundamental collaboration is between the artists/authors who bring diverse cultural backgrounds as well as prior experience and knowledge of different forms and histories of making to the project. These include fashion and costume design, pattern and dressmaking, sculpture, installation, textile and puppetry design and digital media production. We have drawn and extended from the technical and aesthetic considerations of these fields, their particular methods, materials and orientations to the body.

Our main collaborator is Karekare Beach, its life and the forces and systems that influence or connect with it such as the sun (evaporation, heat), moon (tides), wind, rain (erosion) and volcanoes. In particular, we acknowledge the westerly wind; the conglomerate rocks of the Wāitakere Ranges; the dunes and black ironsand; the powerful waves, tides and foam of the Tasman Sea; the salt crusts forming on the hot sand; the spiders and their cottony webs; seaweeds and algae; the shy, blue penguins who burrow in the dunes; the courageous dotterels, nesting precariously on the sand too close to the powerful sea; the spinifex grass that holds the dunes; the pohutukawa trees clinging along the edge of the land; driftwood, flax, stream and all the others, without their engagement and contribution this project could not exist.

We have also worked with various apparatus, materials and devices that extend our human capabilities, heightening senses of hearing, seeing, remembering and touching, while also bringing their own mediated perspectives and histories to play. We have worked with human collaborators including dancers, mātauranga Māori advisors, scientists, engineers and artists, in the investigation of cosmogonic, scientific and historical accounts and areas of technical, aesthetic and performative experimentation.

Practice-led Research

Research through arts has been acknowledged as a way that anti-dualist materialist theories can be transformed into a methodological framework to guide practical research (Vannini, 2015; Schadler, 2019). Our research is practice-led, recognising that creative practice enables alternative forms of understanding through artistic experimentation and aesthetic production. Here we consider five strategies followed in the project.

Fig 4. Photo documentation of field trips, M Smitheram and F Joseph, 2017-19.

Field Trips

Our field trips to Karekare began with a karakia (prayer) to greet our beach collaborator. This moment signalled a formal beginning to research of that day and an active invitation to the elemental forces and ecological collaborators. The karakia acknowledges the mauri of the beach and for the human researchers was a prompt to breathe, notice what was happening around us, observe the conditions, recognise any changes since our last visit. Over numerous visits to Karekare we spent time walking, watching, smelling, touching, following, sitting, swimming, noticing how things behave and interact with us and with other things. This post-phenomenological tendency acknowledges a rethinking of intentionality as an emergent relation with the world. It emphasises exploration through the senses, considering the different scales and temporal shifts that affect the way things engage and interact. This approach, based on experience through being-with, paying attention and noticing rather than relying on formalized knowledge independent from experience, was central to the research. We followed things, considering ways of extending out from encounters and experiences. Documentation was produced through drawings, notes, photographs and video. Sample materials were collected from things washed up on the beach, windfall leaves and flowers or where there was an abundance of a particular material.

Material Agency

Through material engagement we gained awareness of the agency, contexts and interrelationships within the Karekare ecosystem. A focus on the flows of materials and their intra-actions is of critical environmental significance and has been a key principal in the realisation of the project. For example, an important socio-political issue is associated with the use of ironsand as a resource in New Zealand, with commercial seabed dredging used to harvest ironsand for steel production causing ongoing ecological and biophysical damage (KASM, 2018). Recognising the webs of interconnection between a substance such as ironsand and the cultural, geo-physical, biological and industrial dimensions that impact on it, is important to the way materials make-with us and in creating greater awareness and understanding of them.

Fig 5. Experiments and prototypes, M Smitheram and F Joseph, 2017-19.

Play and Experimentation

Strategies of play and experimentation have enhanced awareness of phenomena and behaviours. We engaged in spontaneous play- walking barefoot through mud; crunching through dried salt crusts on the exposed sand; floating in rock pools; chasing tumbleweed along the beach. Through more structured experimentation offsite, we noticed particular reactions (for example, the ways various ironsand on cloth mixtures responded to magnetic forces). With scientists and engineers, we analysed materials and processes, to understand their behaviour and transformation.

These experiments gave us a greater sensitivity to materials and how they combined with other things in the environment at Karekare Beach, sparking new ideas and areas for research. Walking on the salt-crusted sand led to experiments with salt crystals. Through trial and error, we learned what conditions aid or impede their formation. Whakapapa as an ontological understanding helped identify these symbiotic relationships. We came to understand the time frames of crystallization, the affect of the seasons, humidity and light. The salt crystal textiles are part of an ongoing series, evolving as we develop ways of working-with evaporation.

Performance

Performativity has been intrinsic to the exploration of the ecosystem and the making and activation of artefacts. Karen Barad (2003) recognised the challenge that performativity poses to the issue of representationalism. She notes that the discursive practices generated through performativity are not language based but are “specific material (re)configurings of the world through which local determination of boundaries, properties and meaning are differentially enacted.” (p.821)

Through reciprocal intra-actions between human and non-human actors at Karekare, material discursive forces emerge. Transcorporeal forms of interrelationship - for example between bodies of dancers, rock, wind, sea and cloth - reveal differential constitutions and forms of agency. Performativity enables diffractive material reconfigurings through iterative intra-activity. These diffractive flows were inherent to the ways the dresses were created: as we touched, arranged, wore and moved with the dresses and the phenomena they were activated by. This led to further adaptations and extensions of these works into the environment. We also collaborated with professional dancers from Atamira Dance Company who brought a distinctive perspective to the activation of matter and place through movement and embodiment in te ao Māori. A performative dimension has carried through to the activation of work (as physical artefacts or mediated through documentation) in galleries and presentations.

Fig 6. Activation: Volcanic rock, magnetic cloaks, salt crystal sculpture, M Smitheram, 2018.

Remediation

Two approaches to remediation have informed the project. The notion of a medium as an intervening agency or means by which something is conveyed was engaged across a range of creative and technical fields. The term mediation emphasises the heterogeneity of transformations arising from media across temporal and social spaces, rather than a single media logic. This idea challenges any futuristic sense of technological progression. Mediation acknowledges diverse disciplinary and technological histories through new combinatorial strategies. Remediation is an integral practice to both new and old media forms that continually inform and react to one another "making new media forms out of older ones" (Bolter and Gromola, 2003, p. 83).

Photography and video were used to document the project. In turn, these images have been used to generate new works. For example, a lichen cloth was developed using photographs of lichen growing at Karekare along with background imagery from an eco-print made from lichen. This digital print was then washed in rain water and lichen was cultured and grown on the printed cloth. The resulting cloth, incorporating growing lichen and different representations of lichen, was draped on rocks and dancers at Karekare and photographed. Eventually the lichen ate through the cloth adding jagged holes to the assemblage.

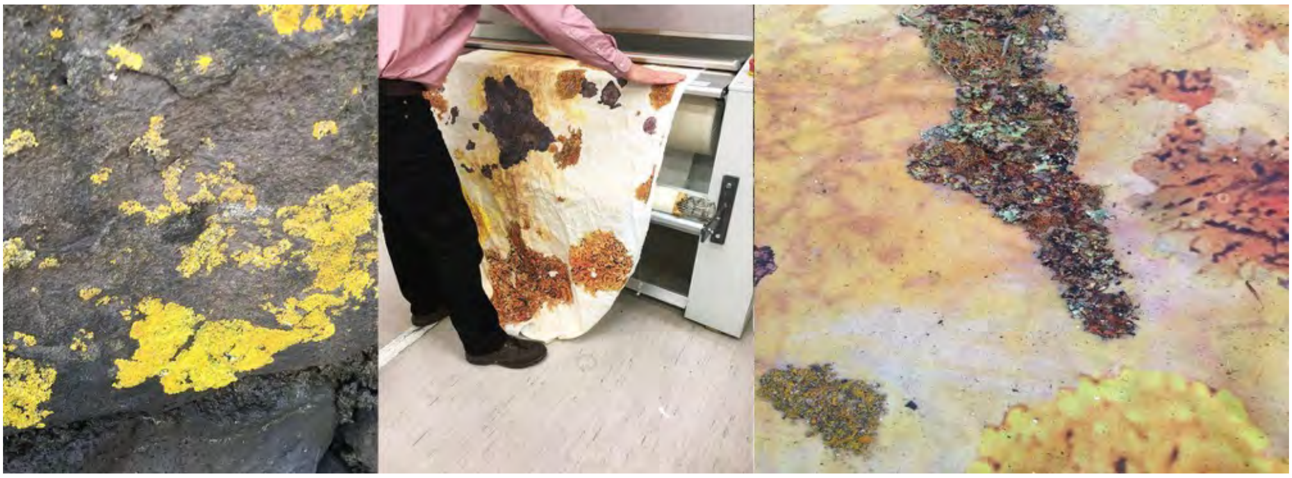

Fig 7. Lichen, digital print, and lichen cloth. M Smitheram and F Joseph, 2018.

Remediation also refers to the action of remedying, in particular of reversing environmental damage. A key protocol has been not to leave anything we brought with us behind, minimising and ameliorating impacts we have on the beach. Where possible materials gathered on site are returned back to where they were collected. The salt on the salt crystal textiles dissolves back into the sea. This phase also closes loops of active collaboration with matter, opened by the karakia, and closed by the respectful return of matter to decompose, return to nutrient and collectivity within the ecosystem.

Ethnography and Analysis

Sociologist Cornelia Schadler recognises that new materialisms are becoming "entangled with methodological tools that have been created within other theoretical frameworks." This entanglement challenges already-existing boundaries produced in these research traditions redefining them "within a new materialist ethnographic apparatus" (2019, p. 215). Research becomes a shared enactment involving the researcher and other participants, their values and drives along with the research methods, tools, apparatus and associated discourse. In recognising the histories, boundaries and tensions between these various positions, entities and processes, research is re-negotiated and re-configured.

In our project this shared enactment has been expressed through creative practices of dress-making and in material-discursive forms including exhibition (figure 8), video and writing. In documenting and articulating the project through ethnographic accounts we have worked diffractively rather than reflectively, approaching material assembled from different perspectives.

Fig 8. Documentation of practice, exhibited at Deakin University, Melbourne, Australia, M Smitheram and F Joseph, June 2019.

Case Studies

Phenomenal Dress is an ongoing project with a number of works still in progress. Here we present two works as case studies, highlighting diffractions of phenomena, collaborators, histories, processes and entanglements.

Collaboration with the Wind: The Hīnaki Dress

The west coast of New Zealand is subject to powerful, onshore winds blowing off the Tasman Sea. Some vegetation at Karekare grows bent over permanently in an easterly direction due to the force of the wind. The Hīnaki Dress is based on the form of eel nets (hīnaki) that were used to catch tuna (freshwater eels) a major food source for Māori, particularly for tribes living along the west coast rivers like the Whanganui. While some 400 weirs for eel trapping were recorded along the Whanganui River in the mid nineteenth century, within sixty years they had all but disappeared due to the impacts of colonisation. The endemic long finned eel is now endangered, being adversely affected by human activities, such as pollution, the building of dams, loss of near habitat vegetation and commercial overfishing over the twentieth century.

The Hīnaki Dress is made like a skirt from a series of concentric tucked layers of cloth, rather than woven like a traditional hīnaki. But we were not trying to catch eels, rather we sought to explore traditional hīnaki forms in relation to air flow. The dress also resembles a windsock, used to indicate the wind direction at airports. High above the skies over Karekare Beach, jet planes arriving from distant places descend for landing at Auckland Airport on the far shore of the Manukau Harbour.

The scale of the mouth of this form is related to the extended height of a human-being so it can be held (by hands and feet) and performed with. The dress is inflated and channels the flow of the wind. Positioned at the water's edge, the power of the gusting wind and the wash and pull of the waves over the sand are channelled through the dress and felt in a visceral way by the performer. The Hīnaki Dress is large and feels huge and powerful when experienced by the performer. The wind seems to delight in any chance to capture and billow the hīnaki and the performer clings on in 'shared' exhilaration as gusts direct its flow and motion. The agency here is the wind, and the performer feels its strength and rhythms through the medium of the dress. Observing the performance from along the beach, the drama seems remote and unremarkable. The white of the dress contrasts with the dark sand and rugged expanse of Karekare, blending with the foam of the waves, becoming part of the landscape.

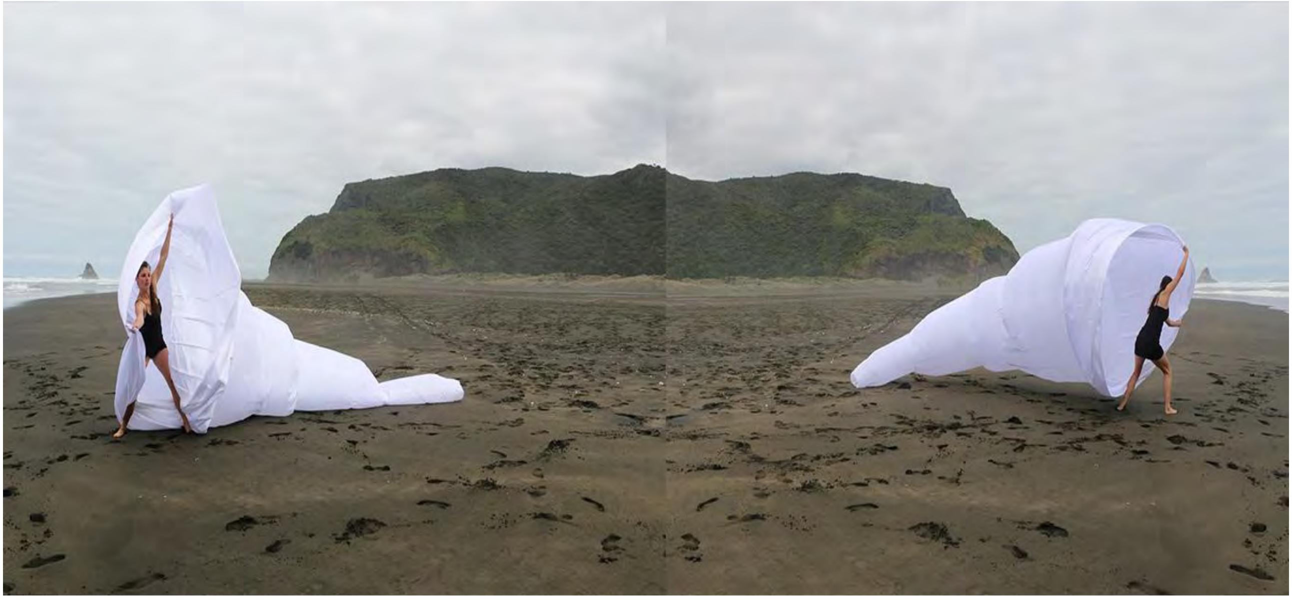

Fig 9. Hīnaki Dress, M Smitheram, 2018.

Collaboration with Kowhangatara: The Spinifex Dress

The kowhangatara or spinifex dress was slow to make. In April 2018 we tested a puffy cloud-like prototype form that stretched between rock, sand and stream. But it lost its shape when buffeted by the wind and rain. On previous visits we had noticed the wind's interaction with spinifex tumbleweeds, blowing them along the sand. We found a bedraggled tumbleweed on the beach - the very last of the season - and wondered what it would be like to involve more of them in shaping this dress. We noted the way they had grouped and clustered in gaps and hollows, their scaley offshoots gripping to each other, their star-burst shapes filling space while allowing air to circulate. These qualities suggested potential for inflating the prototype with volume without weight or density.

The spinifex plants grow on the sand dunes protecting them from erosion. When their spherical, spikey seed pods ripen, they break free from the plant and blown by the wind, first totter and then tumble along the beach to find new spaces to propagate. We waited until February 2019, when the tumbleweed was ripe and had broken free from parent plants to roll away, amassing under bushes or rocks. Echoing the downy spiders' nests found in the sand dunes, the dress was made of gathered tulle pockets. These were filled with tumbleweed, inflating the forms with their spindly shapes. We photographed this dress worn by the rocks and also worn by us. Placed in the pockets of the dress form, the tumbleweed weightlessly occupied space and volume, yet were still responsive to the gusts and billows of the wind. The bulbous shapes of the spinifex dress draped from the rock to connect with the sand and covered the human form echoing the shapes of the rocks and the clouds. The tulle catches and clings to the rock, the spinifex casts delicate shadows through tulle onto the sand, the dry spines of the spinifex scratch skin and in the sunshine give off a faint hay-like scent. Then we released the tumbleweeds back onto the beach and they rolled and bounced away.

Figure 10. Kowhangatara/ spinifex dress, worn by researcher (L) and volcanic rock (R). M Smitheram and F Joseph, 2019.

Conclusion

In developing an expanded notion of collaboration, the *Phenomenal Dress* project engages with phenomena and the agency of the material world at a critical moment of environmental crises. The artefacts produced are not functional or fashionable human-centred products, they are matter flows, formed refractively through engaging diverse perspectives, sensibilities and processes as material-discursive expressions.

The project works at a porous intersection of two specific frameworks: new materialism, in particular, concepts of making-with and intra-action; and mātauranga Māori, through approaches such as whakapapa as an ontological understanding, and te ao Māori protocols (tikanga). For the researchers, this has been an invaluable way to engage with theory from new materialism through situated making in a specific ecosystem with existing indigenous understandings of interconnection. This has highlighted the vitality of whakapapa, of Māori genealogies and socio-cultural narratives as deeply connected and evolving concepts with significance to reframing approaches to materiality in anthropocentric times. Starting from a place of acknowledgment of the mauri of Karekare Beach, material liveliness and elemental encounters have become palpable. This signals a design research journey that foregrounds sensitivity and responsiveness between human and non-human, situated local and temporal contexts, and care of relations and interdependence between people, places and things.

Whakapapa as an ontological understanding opens up a richness of place and things. We respond to nature as culture, as histories, as agential matter with meaning and cosmogony, by decentering design from a human perspective and instead following the materials (Ingold, 2010b). In addressing environmental concerns through this shift of design approach to include wider narratives “it is possible to see the links between human communities, land and sea as patterned by complex, multi-dimensional, dynamic systems in which people are related to other life forms, and our fates are tied together” (Salmond, 2017).

Through this ontological re-orientation we have reconsidered traditional notions of dress, with its primary relationship to the human body and associations with individuality, subjectivity and representation. We have worked with dress-actions, engaging the interconnected bodies of the diverse things that form the ecosystem. Dress becomes an active medium for exploring this trans-corporeality, interfacing with both human and non-human bodies through material aesthetic activations within the unique habitat of Karekare Beach.

The ecosystem is recognised as the primary collaborator, repositioning human and more-than-human relationships. Rather than our actions impacting on the ecosystem, the environment acts on us. We are changed through this engagement with matter, are affected rather than affecting. This project has been pivotal to the development of new decentred design approaches by the researchers. These processes have been incremental and organic in development. One cannot simply detach from a human-centric design position. Like the matter and ecosystem we collaborated with, the shift from instrumental design methods, to processes of observing, noticing, and responding to elemental and phenomenal actions through their agential materiality, has been a gradual re-orientation. Through the process of making-with we have moved from a reflective mode to a refractive approach to practice. Temporal scales have shifted away from imposed deadlines to a slower, matter-led timeframe. This attention to things, forces, intra-actions and embedded narratives, has opened a rich new vein within our practice of mediating materials.

Acknowledgements

Colleagues Dr John Perrott (Mātauranga Māori research advisor and Institute of Applied Ecology, Auckland University of Technology) and Dr Valance Smith (Te Ara Poutama, Auckland University of Technology) have advised and guided us in relation to mātauranga Māori protocols. Tanu Richardson and Jasmin Canuel from Atamira Dance Company have activated, explored and performed with us. We have also worked with Dr Craig Baguelly (School of Engineering at Auckland University of Technology) to make electro-magnets; Ms Yuan Tan (School of Engineering, Auckland University of Technology) producing high-res images; and geologist Joshua Laurenson on geological research and identification.

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Miranda Smitheram

Dr Miranda Smitheram is a designer, artist and researcher, with a practice centred around exploring embodiment, shapeshifting surfaces, and mediated matter. Miranda’s research moves between digital and physical, with a particular interest in the materiality that is developed through the flux of these processes. These mediated materials take shape as textile forms, structures and digital artworks that question the interaction and agency of human and nonhuman, place and space in a post-anthropocenic context. Coming from a design background in the fashion industry, Miranda moved into research areas of material futures, completing a Master of Design and Master of Philosophy at Auckland University of Technology. Miranda’s PhD research into ontology and aesthetics in digital and virtual materialities engaged with agency and tactility in motion capture and 3D spaces. Currently, Miranda holds a Māori Postdoctoral Research Fellowship, and her research has been centred around collaborations with natural phenomena to develop speculative posthuman surfaces.

Frances Joseph

Frances Joseph is professor of Art and Design and director of the Textile and Design Laboratory at Auckland University of Technology (AUT) New Zealand. She studied visual art at the University of Tasmania, majoring in sculpture, and worked professionally as an artist and designer for puppetry and large-scale public performances. Frances has an MFA from the University of New South Wales and a PhD from Auckland University of Technology. Her research focus on materiality and textility, involves areas of smart textiles, fabric structures, sustainability, interdisciplinary collaboration and creative practice.

“Poke it with a Stick”, Using Autoethnography in Research through Design

Natalia Triantafylli, Department of Product and Systems Design Engineering, University of the Aegean, Greece

Spyros Bofylatos, Department of Product and Systems Design Engineering, University of the Aegean, Greece

Abstract

This paper follows the design and creation of an artifact called “Poke it with a stick”, a promiscuous lighting fixture that invites users to play with its tactile operation switch. This ongoing research investigates how autoethnography could be adapted in the context of research through design while support practitioners regarding the contextualization of their work. Autoethnography, an introspective exploration, enables the emergence of narratives that support the understanding of the tacit aspects of creativity. This ongoing research investigates how autoethnography, as a critical approach (Denshire, 2013), could adapt in research through design methodologies, opening up a space evoking self-reflection while dealing with documentation issues.

Using autoethnography the designer/researcher is addressing issues such as materiality, functionality, strangeness and provocation. The presentation and the conclusions of such a personal story bring forward issues regarding objectivity, generalization of knowledge and authorship. Research through design practices are a space where “the internal decision making of the researcher is considered valid and noteworthy” (Duncan & Fellow, 2004).

The outcome of this specific autoethnographic research is an artifact, characterized by a narrative hybridity. Although the created artifact could be perceived as a concrete object, this paper investigates an alternative ontology; the esoteric narratives shaped through diaries accompany the artifact and are equally important to the crafting process by unmasking a creative process that is otherwise magical or enigmatic due to the internal decision making of the craft process.

Keywords

Autoethnography; Narrative Inquiry; Embodiment in Design; Self-Explication; Propositional Artifacts

This study is written by two people, the designer/researcher and the academic/analyst, this is a conscious choice based on contemporary approaches of autoethnography. This study aims to add new knowledge to the discourse of research through design by presented an application of autoethnography in the creation of a new artifact. By presenting thoughts and feelings that emerge during the creative process the aim is neither to put forward a new design methodology nor to come up with empirical rules on how to design better. The goal is to engage the reader to empathise with the designer/researcher, to guide the reader through the thoughts and emotions experience during the creation of the artifact. This work is rooted in a craft approach and the process of designing is undertaken in an open dialogue between the material and the craftsperson. The decisions taken through this process are tacit and making them explicit through reflection and discussion can to shine a light on personal practice and the relationship between the internal and the external.

First and foremost, we both enjoy being designers and we feel the need to share this. Autoethnography offers a perspective that through reflection brings forward the ‘aha!’ moments of the creative process (Cross 1982), these epiphanies are a mystical moment and by trying to understand where they come from we can better understand our practice.

Most often, autobiographers write about “epiphanies” – remembered moments perceived to have significantly impacted the trajectory of a person’s life While epiphanies are self-claimed phenomena in which one person may consider an experience transformative these epiphanies reveal ways a person could negotiate “intense situations” and “effects that linger – recollections, memories, images, feelings – long after a crucial incident is supposedly finished” (Bochner, 1984, p. 595). Autoethnographers must not only use their methodological tools and research literature to analyse experience, but also must consider ways others may experience similar epiphanies; they must use personal experience to illustrate facets of cultural experience, and, in so doing, make characteristics of a culture familiar for insiders and outsiders. (Ellis, Adams & Bochner, 2010). The emerging field of autoethnography has been adopted in many different fields creating a wide array of autoethnographic texts spanning from poems to autobiographies and more reflexive texts. We position this work under the ‘moderate autoethnography’ (Stahlke & Wall 2016) and towards the direction of ‘Juxtaposing tellings from more than one point of view’ (Denshire 2014).

The study of design leaves the interpretation of the nature of design open. (Cross, 2001) One reason for this is that design exists in relation to its application, it utilizes ’quasi subject matter’ (Buchanan1990) and is structured around the problem space it aims to address.

When people think of design, most believe it is about problem solving, twenty years of research have tried to shift the discourse but practice is rarely informed by the likes of Rittel (1973) and Checkland (1990) who claim that a solution to a problem cannot exist as defining a problem is a problem itself, as such we cannot claim to solve a problem but to aim to ‘transform a problematic situation to a more desirable one’. In this sense the value of this study lies not as a solution to a problem but in adding personal experience to an existing discourse about tacit materiality in design.

> *“I don’t aim to provide a manifesto but invite you to my journey to find one”.* (Excerpt from the Reflective Journals, entry 10, 4/9/18)

Fig 1. Poke it with a stick: the artifact.

Brief Introduction to Autoethnography

Autoethnography is an approach to research and writing that seeks to describe and systematically analyse (graphy) personal experience (auto) in order to understand cultural experience (ethno) (Ellis, Adams & Bochner, 2010). As a method it acknowledges the centrality of the researcher in the process of research and offers an array of tools that enable increased reflection and structure. In an autoethnography the researcher is writing about his or her experience and through analysis makes it transparent to the reader. The researcher is paramount to this process as the knowledge shared is situated within him or her. Especially in the domain of crafts many decisions are tacit and embodied and as such meaningless if not shared within the context.

Autoethnography is a form of qualitative research that is commonly linked with anthropology and social sciences in general. In contrast to ethnography where researchers analyse a culture as participant observers, Autoethnography shifts the focus to explicit and reflective self-observation. Autoethnography embrace subjectivity and emotionality into the research while recognizing that the personal experiences of the researcher have a great influence in the research process. (Ellis, Adams, Bochner, 2010; Anderson, 2006).

The most defining feature of Autoethnography is the reflective approach that wants the researcher to perform a narrative analysis of a phenomenon that he/she is intimately related to (Mcilveen, 2014). Autoethnography as a method is both the process and the product (Ellis, Adams, Bochner, 2010). The product of autoethnography could be a result of diverse interdisciplinary practices of documentation including reflective writing, interviewing, photography, gathering documents and artifacts, etc (Duncan & Fellow, 2004; Spry, 2001). This inseparable relation between the designer, the designed and the context offers a perspective that negotiates between the personal and the scientific. Reflecting on how theory informs practice in ways that might not be explicit has been a strong point for such methods.

Both autoethnography and ethnography are informed by the ideas of post-modernism. Post modernism brings forward the value of narrative methods. For Lyotard (1984) the absence of a grand narrative and the power of scientific narratives over other ways of knowing create the need to consider peoples stories and personal experiences concerning the ways that realities are constructed. For Feyerabend (1993) modern science is no more justified than witchcraft, and has denounced the ‘tyranny’ of abstract concepts such as ‘truth’, ‘reality’, or ‘objectivity’, which narrow people’s vision and ways of being in the world. This openness to personal narratives is what makes autoethnography a robust tool in the intersection of Research through design and material experiences.

Autoethnography and Research through Design

Considering that Design is closely related to anthropology (Zimmerman et al., 2007) it is not surprising that Autoethnography and Research through Design as methodologies share some common ground. Therefore, it would be fruitful to establish it through a literature review and then detect possible ways to conduct Autoethnography as a supporting method in a ‘research through design’ context.

Research through design is the closest thing to the actual professional design practice, recasting the design aspect of creation as research. Designers/researchers who use research through design create new products, experiment with new materials, processes, etc (Godin, 1993). The main difference between professional design practice and research through design is that in the former the product of the design process is not the means to an end but the end itself. The artifacts, models and concepts produced during a research through design process act as embodied rhetoric (Ballard & Koskela 2013; Buchanan, 1990, 1995, 2001, 2007; Crilly, et al., 2008; Foss, 2005; Friess, 2010 Hart-Davidson, 2007; Quek, 2010; Sheridan, 2010; Wrigley, et al., 2009), as propositions in material form (Walker, 2006) as tools for the prototyping, testing and evolution of new ideas, as ‘things to think with’ (Ratto, 2011). The hybrid made up of the theory, the researcher and the artifact create new, action related, knowledge that is inseparable from the context.

Furthermore, when the autoethnographic methods are applied in a craft design setting the tacit dimension of the negotiation between the wants of the maker and the possibilities of the material add an extra, invisible layer in the discourse. Extracting useful conclusions from such a process is challenging but the lessons that can arise are worthwhile.

Research through design (RtD) is an approach to scientific inquiry that takes advantage of the unique insights gained through design practice to provide a better understanding of complex and future-oriented issues in the design field (Godin & Zahedi, 2014) Similarly, design knowledge exists in designing activities, in which designers, their creation processes, and resulting artifacts are involved – it is considered ‘designerly way of knowing’ (Cross, 1982) associated with tacit ways of knowledge (Polanyi, 2009).

Autoethnography is a method that has the capacity to provide research through design by shedding light in personal practice, thought and emotions. It is a method that aims to pinpoint the mental connections that are generated subconsciously and make their way into the designed. Autoethnography can in sense bring increased rigor in practice based designerly research. In addition, the iterative analysis undertaken through autoethnography acts as a mechanism that articulates critical reflexivity that is necessary both for research through design and for theoretically informed creative practices.

Autoethnography as an approach transcends disciplines, as it permits a true ontological and epistemological background in an emerging theory as being socially constructed and in a dynamic dialogue between theory and practice. Autoethnography bridges this gap through the development of a critical discourse and the self-reflection that develops as a natural consequence of it.

Method of this Specific Autoethnography

Autoethnographers recognize that the researcher shapes and guides the process by deciding “who, what, when, where, and how to research” (Ellis, Adams, Bochner, 2010). This is evident from the beginning of in this specific research, where even the subject of the study itself is rooted at the need of the designer/researcher to find her own voice as a designer. As such the goal of this autoethnographic study was ill defined from the beginning. The method was the following, engage in the craft design of an artifact and keep journals about the process and the elicited thoughts.

> *I am currently in a very introspective phase where I reflect upon my creations and try to identify my personal perspective upon the design discipline in general. During the writing of my Thesis I realized that I was very interested in expressing my own struggles of the process, regarding both to academic writing and the creative process itself. This interest in sharing my personal experiences is also embodied in my designs where the inspiration of each concept is rooted in my lived experiences. [...].* (Excerpt from the Reflective Journals, entry 4, 15/5/18)

This clearly personal perspective led to autoethnography as a method of research. Research through design implies creating an artifact that cannot be wholly described and that enables the designer/researcher to engage in a dialog with the situation and learn from it (Godin, 1993). In this study Autoethnographic writing is used to support the designer/researcher’s embodied involvement in the creative process and it provides means of structuring and unlocking reflectivity. Reading, writing and making mutually supported and influence each other while their boundaries blur dialectically (Nimkulrat, 2012; Spry, 2001)

Without analyst autoethnography is just an autobiography (Anderson, 2006; Duncan & Fellow, 2004). The researcher deals with very intimate and self-related issues throughout the process, thus it is possible to lead to self-absorption and tunnel vision. Thus, following Andersons findings about analytic Autoethnography, there should be a ‘Dialogue with Informants Beyond the Self’ (Anderson, 2006). That role is assigned to the second researcher of this study who perceive the narrative texts as data and analyses it as such (Mcilveen, 2014). Therefore, in this study there is the designer/researcher (storyteller) and the academic/analyst (analyst), two distinctive roles assigned at the beginning of the research but through the process of experimentation they evolve.

The making process, consisted of the creation of two artifacts based on the same core concept. The process is presented in this section, the pictures and texts of the practical side of it are accompanied with parts of the reflective journals written during the making process. The process is described in accordance with the chronological order of the making. On the contrary, the selected quotes and thoughts belong to different reflective levels and are not necessarily were written after each specific act. The duration of the project was six months while the actual making process spanned over 30 days and the diaries were kept in regular intervals. Every four days the researcher and the designer would discuss the evolution of the process and all issues that emerged while making. Both the designer/researcher and the academic/analyst kept notes of these meetings for future reference. The designer/researcher journals consist of ten excessive entries in which the final two were reflections on the previous entries.

When the artifact was finished the diaries were sent for analysis from the designer/researcher to the academic analyst electronically. After that, the academic analysts sent his thoughts and comments back to the designer researcher. The results of this analysis and the reflection of the process and the adoption of the autoethnographic approach are presented in this paper.

Regarding the creation of the artifact, writing was the central reflective medium while sketching and making were supportive to this introspective exploration. The process of keeping a journal aimed to identify where and when tacit decisions were made. Through this process of reflection writing and analysis the tacit dimension of the process was made explicit creating new knowledge about the tacit dimension of making and adding to the discourse of design. Mäkelä points out that the spectatorial engagement together with thought, material and reflection is at the root of the process, and the research targets the unknown without knowing where the outcomes of the research might settle (Mäkelä & O'Riley 2012, 11). Both artifacts are propositional and not well-defined designs in the sense of function, they are tools of research and introspection.

Poke it with a stick: making the artifact

Finding the Concept

Fig 2. Experience in use.

From the beginning it was clear that there was a need for a propositional concept that calls for further analysis and reflection.

> *One day while I was trying to sleep, I was intuitively searching for ideas that will be used for future projects. I tried to recall memories in order to get inspiration. […] I would like to embrace oddness as a characteristic of this concept because I haven't the chance to experiment while I was working with more rigid design contexts. When it comes to oddness and fantasy I always look back to my childhood […]. I remembered myself holding a stick and pocking a toad, while trying to interact with him. Then, instantly I transformed this act into a luminous artifact where the switch would be located inside its body and the user could only reach it with a stick.* (Excerpt from the Reflective Journals, entry 4, 15/5/18)

This initial concept was selected as a starting point for this case study and although the whole study is characterized from the belief that design is not solely a problem-oriented practice, the analysis of the interpretation of this idea was very similar to reverse engineering.

First Artifact

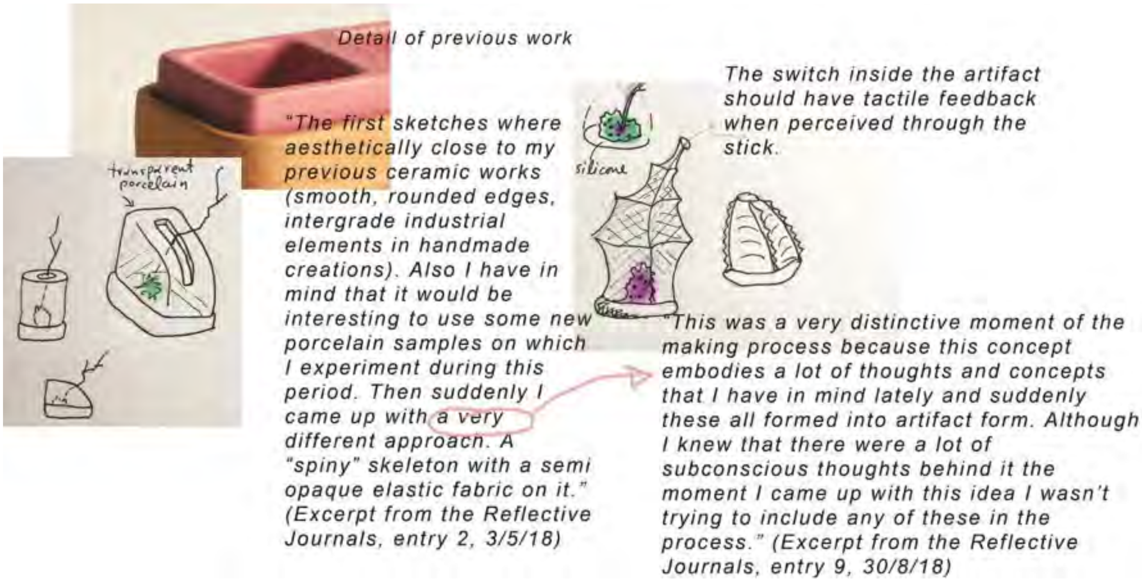

Fig 3. Ideation sketches.

The material that were selected is clay because of the designer/researcher ceramic skills.

Fig 4. Sculpting the rig (Excerpt from the Reflective Journals, entry 2, 3/5/18).

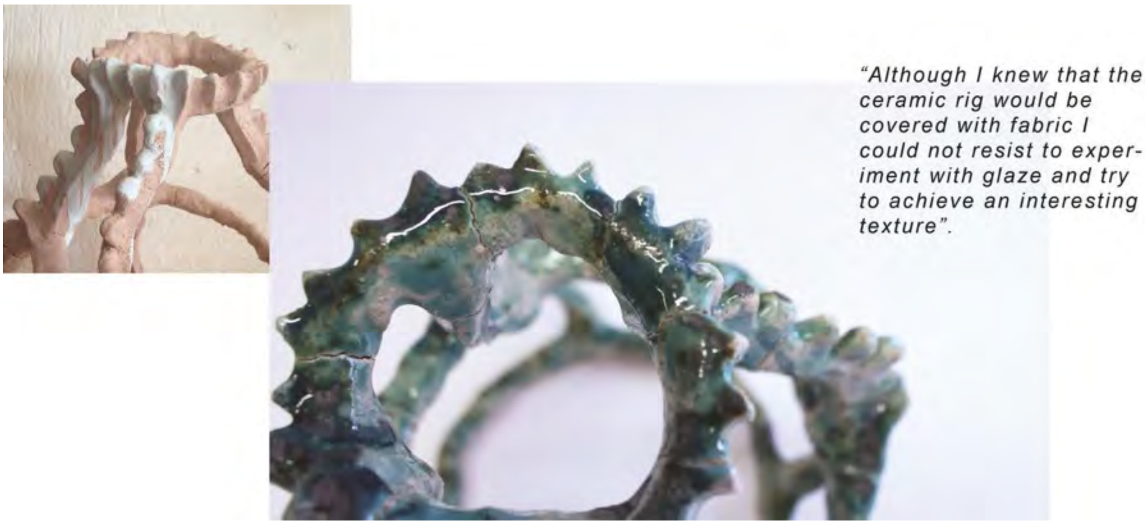

Fig 5. Sculpting the rig (Excerpt from the Reflective Journals, entry 2, 3/5/18).

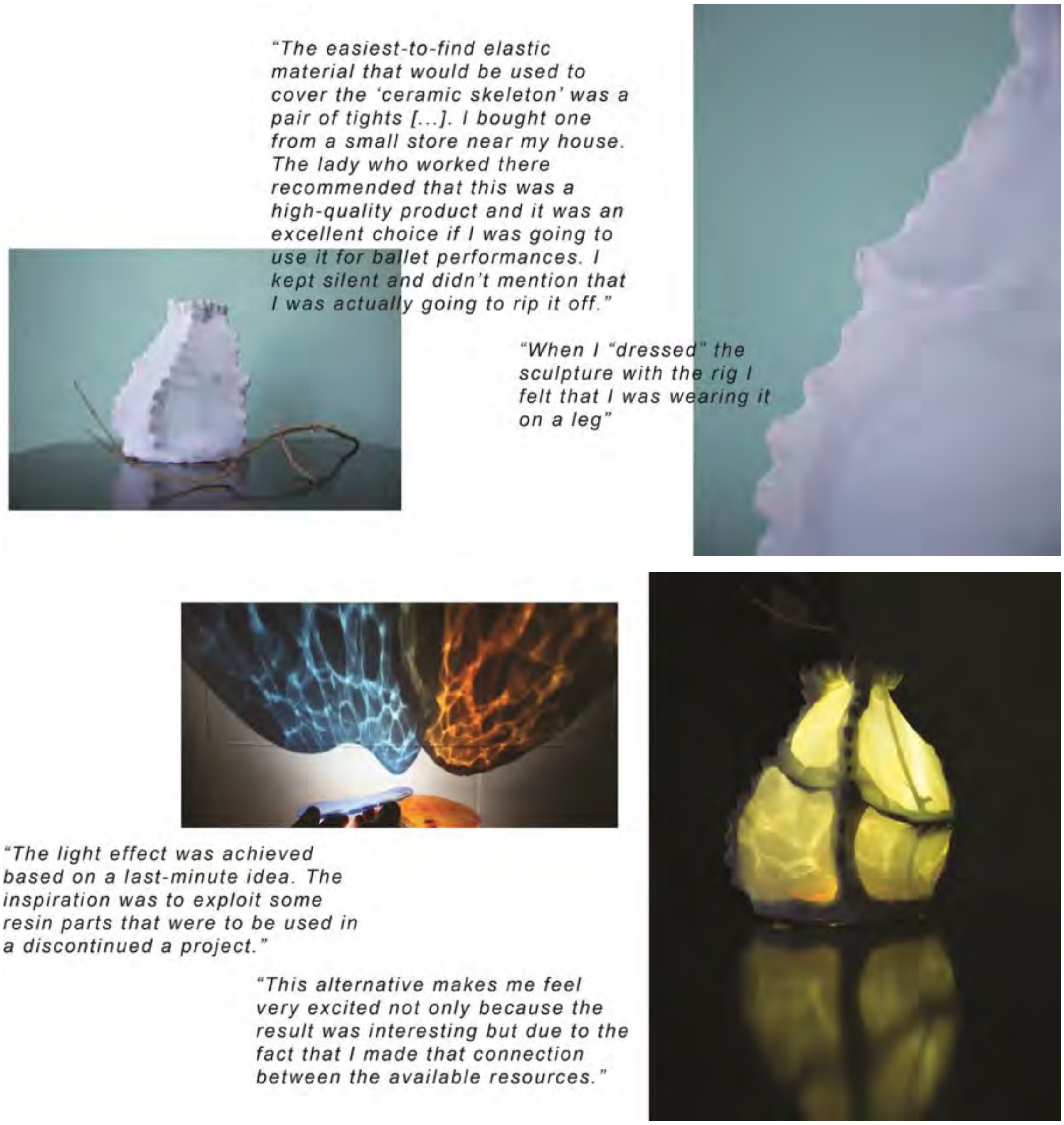

Fig 6. Making Process (Excerpt from the Reflective Journals, entry 6, 30/5/18).

Second Artifact

Another artifact was created. This was a chance to experiment with a different form. The aesthetic of the first one was opposed the symmetrical forms that the designer/researcher was following on her previous works. The second artifact was designed to be somewhere in between.

Fig 7. Forming the second artifact.

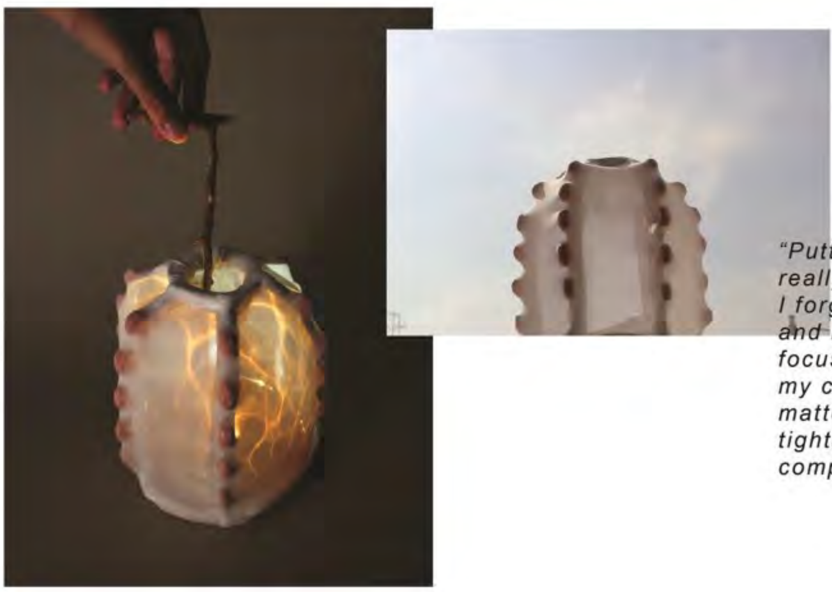

Fig 8. Forming the second artifact (Excerpt from the Reflective Journals, entry 7, 23/8/18).

Reflections on Making

In this section the first reflection on the issues that emerged throughout the experiment and their relationship with the theoretical context is discussed. During the experiment there where a continuous feedback between conceptual and linguistic-oriented thinking and physical and materially based making, similar to the one Ratto (2011) described with the term critical making. This process worked as a driver of 'self-explication' (Hayes & Fulton, 2015) in relation to aspects of embodied cognition and supported the creation of novel understandings in relation to the way the researcher-practitioner works (Ratto, 2011). These findings acknowledge and respect the tacit aspects of the process.

Starting from the practical issues, the dynamics of the situation such as material and equipment resources, the designer/ researcher's making skills, time issues etc. seemed to have a great influence on the process. The designer/researcher usually was aware of this influence; these constrictions sometimes were perceived as restrictive but other times acted as a creativity boost.

One thing of note is that in the reflective journals there are not many references in relation to ceramic as a discipline, although most of the making took place in the ceramic workshop.

This issue arises from the nature of the ceramic practice itself. Many practitioners referring to ceramics not only a discipline but mainly as a way of life. The connection with clay is characterized by a 'vital materiality' (Bennet, 2010) with an influence that is continuously evolving with the engagement with it, and although there are attempts to explain this tacit influence in the reflective journals, they fail to capture the essence. It is our view that this difficulty should not discourage practitioners writing about their work. Although the skills that have been developed through material exploration and tactile experiences are placed within the embodied mind and the knowing body are now taken for granted (Groth, 2016), the documentation of the works helps comparing how the evolution of knowledge of the making influences the perception of the maker (Falin, 2014). This is evident in the parts of the journals where the skills and perceptions acquired from previous work act as the base for new manifestations (technical, conceptual, aesthetic etc.) to come. This reflection on the designers' whole body of work helps to outline their evolution as creatives and also for the understanding about their artist's statements.

Figure 9 Interacting with the artifact.

The nature of this specific case study presented a high level of immersion and the boundaries between the artifact, the researcher-practitioner, practice and actual life were non-existent. The specific design practice is rooted far away from problem solving and the designer/ researcher uses her creative practice as a sense making tool and although the struggles of the process are present, the pleasure that she draws from it is evident. This presents characteristics similar to art but also similar to play. Groos (1919) agreed with Grosse (1914) that art's main evolutionary foundation is play and noted the common features binding art and play: Enjoyment of regularity, rhythm, imitation, illusion and attraction toward intensity and difficulty. (Nadal & Gomez- Puerto, 1991) and that playful character is also embodied at the artifact.

The tacit aspects do not end on the tangible side of design crafting but extend to its conceptual aspects in relation to synthetical acts. Throughout the journals the designer/researcher's feels the urge to find the roots of every concept and identify the unconscious thoughts that inform to choices that led the decisions that shaped the artifact in this specific way. "*Through our physical experiences of the material world, we create mental images that we rely on in the design process, thus the body provides information also in the planning phase of designing, even before material manipulation*" (Groth, 2016). After the form-making process it is possible to reflect on more connections (Tonkinwise, 2010) and understand the way some metaphors work that was not consciously intended but seem to be very well designed. During the making process the form emerged organically. By analysing the designed we notice how the researcher/practitioner's past experiences are embodied in the artifacts and translated into multi-sensorial characteristics. At the same time these embodied dynamics are also used as a blueprint for its future interactions with the viewers. These characteristics mystify the process and could be resembled as reversed engineering.

Now that designers and craft practitioners are also included in higher academia, they have the opportunity to conduct organised research on their own practice. The researcher/practitioner has an intrinsic motivation to reveal his/her experiential and embodied knowledge; thus, design and craft research gain access to the practitioner's point of view (Groth, Mäkelä & Seitamaa-Hakkaraien, 2015).

Writing the Autoethnographic Reflective Journals

In this section the designer/researcher and the academic/analyst present the main findings of this study. The conclusions emerged through a process of dialogue between the two, and by sharing notes and ideas around the reflective journals kept during the making. The reflections presented in this section are very project and person centered. A critical understanding is required to apply them in different contexts as they are rooted in a personal practice, influenced by time, character and other external factors.

Making and Writing Being Immersed into the Research Context

Throughout the process of reflective writing, the need of the researcher to understand autoethnography as a method by implementing it were evident. Also, this ongoing reflection on actions immersed the designer/researcher completely in the design process of the artifact of this specific study.

> *I moved from the autoethnography of the creation of an artifact to an autoethnography of writing a paper about it […] I realized that the notes that I took in order to define the paper's structure was actually another page of the reflective journal.* (Excerpt from the Reflective Journals, entry 10, 4/9/18)

The academic/analyst believes that this context specificity points to the difference between research through design and commercial design practice. The reflective journals are as much a part of the project as the clay that makes up the artifact. The process aims to create new knowledge not an artifact, so it stands to reason that making and writing are inseparable. The difficulty of this process for the designer/researcher is rooted in the fact that these types of explorations pose a different set of problems that traditional product-oriented design education does not address.

Issues Related with Time.

When writing an autobiography, an author retroactively and selectively writes about past experiences (Ellis, Adams & Bochner, 2010). The reflective journals took place after actions but there was an attempt to analyse the actions on the time frame they took place. Also, the need to define 'now' is evident. The need for a coherent time frame also arises from the narrative character of epiphanies, the struggle is documented at first and the solution later. We also consider it an epiphany when some abstract thoughts and statements of the researcher are grounded implicitly with findings of the literature review. These moments are characterized by excitement but in the reflective journals the need for the existence of these thoughts before the researcher reads them in literature is also evident. This also led to various restrictions during the writing of the reflective journals. For example, when the writing started the researcher tried not to read any research. Additionally, the designer/researcher did not read previous pages of the journals until the creation is finished.

> *"I narrate a making process that happened in the past. The presence is me narrating"; (entry 2, 21/7/18) "I have the need to distance myself from the action (mostly actions referring to making). I would like to "digest" them first and then re-embody them through written language"; "I cannot write every day"* (Excerpt from the Reflective Journals, entry 6, 3/5/18).

The issues of time, authorship and self-censorship would rise in every discussion the academic/analyst and the designer/researcher would have. Academic writing is usually very structured and formal, as such the designer/researcher kept second guessing the rawness of the journals kept. Also, she had trouble selecting the style of writing in relation to time. The fact that the reflective journals were written at the end of the day provides an excellent chance for reflection but can act as a filter on the thoughts and feelings that arise through the creative process at the time.

Continuous Effort to Avoid Generalizations and Being Explicit about What is Personal.

The designer/researcher actually mentions this in one of her entries tries to map the external and personal points of inspiration that inform her current project and the same time to *"avoid useless generalizations that are rooted in shallow connections, they interrupt my internal, tedious yet substantial quest for meaning"* (Excerpt from the Reflective Journals, entry 7, 23/8/18).

Writing in such a personal style is something that designers are usually taught to avoid, at the same time the academic/analyst mentions on the notes on the first analysis that he *"feels like an auteur looking through a glass"* and *"even though the journals were written for me to read I feel like I am invading a personal space" (*Analyst notes*).* The personal nature of the texts manages to bring forward new knowledge on professional design practice that is necessary but just as the author needs to be acclaimed to such a way of working so does the reader.

Issues Related to the Documentation of Tacit Aspects

When it comes for the description on tacit actions there is an idea that try to rationalize them and describe make these acts also lose their meaning and the narrative very technical. Although these tacit aspects were approached by describing the emotions and feelings experience during the procedure.

> *"When I describe the technical parts of making I feel that is waste of time and I do it only for consistency at the documentation"; "I feel that this type of clay inspires me to be more relaxed and I do not try to achieve a perfect smooth result"; "I was anxious and I have not enough patience"; "I was confused."* (Excerpt from the Reflective Journals)

> *"Although I knew that the ceramic rig would covered with fabric I could not resist to experiment with glaze and try to achieve an interesting texture"* (Excerpt from the Reflective Journals, entry 4, 19/6/18).

Emotions have been connected to sensory experiences, and even decision-making (Damasio, 1994, 1999). Emotions seem to guide the progress of the making situation, especially when the material qualities and affordances vary, and a successful outcome depends on the embodied knowledge of the maker (Groth, 2016). This was the main goals and point of emphasis of this study. We argued that using autoethnography in the context of research though design would provide a unique perspective to the tacit aspect of the creative process when undertaken in a craft setting. As discussed in the previous section it is hard not to jump to simple causation for the thoughts and decisions, we and autoethnography in general tries to avoid these as they can lessen the value of the raw experience. We managed to avoid the temptation of providing simplistic correlations for all the quirky or weird choices, but it was something that would always come up in our discussions.

Existence of an Imaginary Listener/Observer

Believing you are being watched can have the same effect as being watched on your behaviour. The reflective journals were written with the intention of doing an autoethnographic study and as such they are not pure internal thoughts that were written to never be read. The existence of an observer changes the discourse and sometimes felt even like correspondence that also called 'half dialogue'.

This imaginary audience is also present during the act of making, where it triggers the practitioner to describe to some extend with words what she was doing subconsciously. This imaginary audience could also be the very real but future users/viewers that will interact the designed artifact and this dialogue would be what will shape its meaning (Zingale & Domingues, 2015). Depending the form this imaginary audience takes it can help the designer/ researcher to direct her thoughts through different reflective levels through a continuous reflective zoom in and zoom out. The basic structure is based on the narrative of the creative process although the focus is not its description but the reflection on it. The researcher uses clearly defined acts to find a starting point that enable her to unlock reflexivity. This iterative cycle of divergence and convergence is central to design practice.

We always zoom in and out trying to reframe the problem space. This also applies to research, shifting layers of abstraction to try to find correlations and causation between different organisational layers. Writing as a medium inspire the researcher to focus and to trigger her analytic mechanisms.

> *"There is a fear for the blank page" Horror vacui "The majority of these thoughts belong to a secondary reflective level"* (comment of academic/analyst).

At the same time, most of the texts were already reflective, as mentioned on the second section: "issues related with time". Understanding the characteristics and the limits of these narratives is necessary in the process of writing and analysing. The academic/analyst cannot approach the text with naivety and must question the reflexivity embedded in every word. Not because the data have to be untainted but because a deeper understanding of the layers of meaning and action behind the words will lead to useful results and a bridging of the explicit reflection and the embodied action that through the dance of the creative endeavour brought forward a new artifact.

Thoughts on Analysing Autoethnographic Texts

The job of the academic/analyst in this project is, much easier than that of the designer/researcher. Textual analysis methods are a staple in humanistic sciences, however being the neutral arbiter is much harder in practice than it initially seems. In this section the analyst of the autoethnography reflects on the process and echoes the sentiments of the designer/researcher's as they were presented in the previous sections.

Firstly, we both shared the need to avoid rationalization, to try and make this process appear scientific and to rationalize parts of the process. One of the last notes on the academic/analyst's journal reads:

> *"I wonder if it would be possible to break down the designer/ researcher to parameters that inspire her and use them to compare different autoethnographies when we collect them. This seems like scientism and a counter intuitive, ABSOLUTELY AVOID IT"*

The analyst is an academic and working in a school of engineering has at times felt found himself pressured by the coils of scientific operationalism, this mental juxtaposition between hard science and the necessity of understanding the tacit dimensions of design are a constant internal struggle. The designer/ researcher does not share this stress, operating outside of academia her views are much different. This points to the Insider/ Outsider Dilemma (Maydell, 2010) that states that "*conducting research within my own cultural group presented both advantages and dilemmas*." For example, during our research, the academic/analyst's comments on the reflective journals show that he is more empathetic towards academic issues than making issues. And perhaps we create a new unity that can overcome our biases and point towards a complete designer-researcher-analyst that will be free of the literary and epistemological patterns of contemporary academia.

This insider-outsider relation was also apparent in our discussions of the initial reflective journals where the academic/ analyst would connect notions in the texts with bibliography that the designer/researcher was not aware of. We frame it as part of the 'Dialogue with Informants Beyond the Self' calls for dialogue with 'data' or 'others.' This relation provided many interesting directions and, in a sense, gave us a new appreciation of the bibliography taking it from the realm of theory and finding new interpretations rooted in real world experience.

However, not all issues were analysed, abstract issues and tacit knowledge are part of the making. There isn't always possible to define if the outcomes are referring to actions related to making, to thoughts in relation to autoethnography, or to academic writing in general. In addition, analysing an autoethnography does not provide answers or outcomes but more questions, this can be very negative in the context of modern academic publishing, but we staunchly believe that these questions and sharing of said questions are more useful than conclusions.

Reflection-Discussion

Poke it with a stick as a statement work in different intellectual levels and could also describe the whole process of autoethnographic writing. "During the reflexive journals it was like poking my brain with the stick in order to trigger the embodied and unconscious thoughts to reveal themselves in order to finally realize that it does not exactly work that way" (Excerpt from the Reflective Journals, entry 10, 4/9/18) Autoethnography does not try to confront and rationalized the ways the designers do their magic. Autoethnography points this magic. The whole study, from conducting autoethnography in design to the artifacts created is about to point out the need for empathy in design, design as a discipline, as a science as a product.

This case study is a critique to designing as well to the designed. Although the first intention of the concept was to make a critique of the designed world around us. It is surprising how well the artifact portrays autoethnography as a method of reflexivity. Curiosity, intimacy, epiphany as well as awkwardness indiscreetness and feeling lost are feelings meant to be evoked during the experience with the artifact but also are very present during this autoethnographic attempt. And that points out the ability of research through design to gain better understanding and reframing the research question.

Poke it with a stick: I design for the sake of design, a designer's statement:

> *Dealing with issues that balance between the rational and the irrational, order and entropy, reality and fiction I perceive Design as a space where these binary models could be overcome enabling be to experiment with the amalgamations happening whilst combining these constructions.*
>
> *As much as I am charmed by the creative process itself, I am enchanted by its outcomes as well. I am capable of identifying what is fictional and even so, I consciously choose to believe in it and even bring it to life without destroying its magical powers.*
>
> *With this artifact I aim to highlight the silent interactions we perform everyday with the inconspicuous man-made creations that coexist in the material world around us. The experience with this artifact calls for the encounter to further explore it in order to find out how it functions. This experience presents a variety of sensorial aspects that*

increase the awareness of the bodily role of the final perception of the interaction. The result of the interaction is related with light and vision, but the rest of the experience is clearly tactile aiming to provide the sense of being in a play but also a sense of control over this material experience.

Curiosity, pleasure and control are characteristics of the experience that aim on a positive affect [sic]*. At the same time these characteristics act as a critique on how demanding we are in relation to design. What someone could perceive as curiosity another could translate it as lack of tact. The fact that the artifact embodies characteristics of a living organism triggers empathetic emotions and also highlights a sense of responsibility on the material world in general. The stick could be perceived as a symbol of design evolution posing a fundamental question about what should be perceived as a design object.*

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Natalia Triantafylli

Natalia Triantafylli is a designer-maker from Athens, Greece. Her practice – combining craft and design research - manifests the dynamic of design to provoke questions over finding solutions. Through her recent works in which skilled craftsmanship coexist with improvised substitutes she aims on revealing the unexpected out of the ordinary while exploring the tacit aspects of creativity. She has graduated from the Department of Product and System Design Engineering of the University of Aegean and from September 2019 she is going to study for a MA degree in Design Products at the Royal College of Art.

Spyros Bofylatos

Dr. Spyros Bofylatos holds a doctorate in theory of Design from the Department of Products and System Design Engineering of the University of the Aegean. His research sprawls around design for sustainability, craft, service design and social innovation. His work is based on creating meaningful dialogue between the theoretical framework and the sociotechnical propositional artifacts that embody different research questions. At the very core of this process is the notion that we live in transitional times and fostering the discourse that leads to networks of artifacts and communities that embody alternative systems of values is necessary to move away from today’s unsustainable society.

Improvisation: Autonomy, Heteronomy and Wilful Naïveté

Dr Ian Lambert, College for Creative Studies, Detroit, USA

Abstract

This paper discusses theoretical perspectives on improvisation as a powerful generator of new knowledge in practice-based research and its enhancement through *wilful naïveté*. The paper discusses a wilfully naïve approach to making with reference to Ingold's morphogeneticism (making as a process of growth; 2009, pp. 21-22), and Peters' (2009) balance of autonomy and heteronomy in the passage of creativity.

The sandcasting as a making process was a new field of practice chosen deliberately to help avoid the effect of entrenched practices on the process of growth. The paper discusses new theoretical insights with reference to his experimental work and the influence of others, i.e. a heteronymous lineage of practice. As an auto-ethnographic heuristic making enquiry, the author writes of their work and practice in the first person.

Keywords

Improvisation; Making-as-Growth, Autonomy, Heteronomy, Wilful Naïveté

This paper discusses a theoretical perspective on improvisation as a powerful generator of new knowledge in practice-based research and its enhancement through *wilful naïveté*. The paper discusses a wilfully naïve approach to making with reference to Ingold's morphogeneticism (making as a process of growth; 2009, pp. 21-22), and Peters' (2009) balance of autonomy and heteronomy in the passage of creativity.

The heteronomous actors in my process were other designers and makers who work formed the prefigurative elements in the making: Studio Swine's Can City (2013), with cast aluminium furniture, Max Lamb's Pewter Stool (2007) cast on a beach in Cornwall, and Rony Plesl's Bubble Bowl (2012), a glass bowl derived from bubble-wrap packaging. All heteronomously advanced the development of my practice through improvisation leading to the making of a series of cast aluminium bowls (Fig 1).

The discussion that follows focuses less on the practice itself, and more the theoretical insights arising from it.

Improvisation

To improvise literally means to not foresee[1] (Douglas & Nil Gulari, 2015, p.395), but there are nuanced variations in the definition of the word. Improvisation can refer to where something is created spontaneously, or without preparation, in response to a certain unexpected predicament. In acting, improvisation is an unscripted performance which may occur spontaneously by going off-script, or deliberately entering into a performance without script, as what Peters (2009, p.10) would describe as an originating process. Peters makes an ontological distinction between the *power* and

[1] The Latin for improvisation is improvisus: im- as in 'not', and provisus, which stems from provedre, meaning 'to foresee' (Douglas & Nil Gulari, 2015, p.395).

the *predicament* of the improviser (p.10). In my work it is the former that is of significance. My work with sand casting discussed in this paper has not been a response to an unexpected predicament, and any notion of improvisation as being “the makeshift, the cobbled together, the temporary solutions to problems that remain unsolved” (Peters, 2009, p.9) is of no significance. Instead, improvisation has been used as a *generative* force according to Ingold’s making as a process of growth (2012; 2013, p. 21). Ingold (2012) describes improvisation as “finding one’s way”, adding that creativity is not in innovation or giving rise to the novel, but rather it is about growing: “creativity lies in the improvisation, the improvisatory nature of the processes” (ibid). That is not to say that an artwork grows spontaneously: as Peters tells us, “all improvisers must face the demand for a work from within the confines of a limited material universe” (2009, p. 11), and so the creation of an artwork requires a certain “marking of space” (ibid, p.13) which arises from this. For this making-as-research, the confines have been in the process of sand casting as a methodological choice. Furthermore, as will be discussed below, there is a difference between origination as a form of genesis, and origination as a form of becoming (Peters, 2009, p. 62). For example, as will be discussed below, the pewter sand casting used by Max Lamb becomes something else in my own. While Peters (2009, p.62) refers to improvisation as origination, here improvisation is as generative. So, for the maker as a lone practitioner, improvisation occurs along a line of “[…] the potential for mutation and recombination” (Ingold & Hallum, 2008, p. 6). In this sense, improvisation is also *relational*, in that it needs to make sense within the societal constraints that it seeks to disconform to (ibid, pp. 6-7). Edwin Hutchins argues that human cognition is a social and cultural process that is inextricably tied to the extended history of a task (Randell & Lewandowsky, 1996). Latour (2009, p. 5) sums it up more simply: “to design is to redesign”.

Fig 1. Sand cast aluminium bowl using bubble wrap as a waste mould (Lambert, 2015).

While I claim above that there have been no unexpected predicaments, there have been some practical ones. To make the most of improvisation as a generative force I needed greater autonomy in my practice – in other words, the independence to be *disobedient* (cf. Peters, 2009, p. 11). This inherent disobedience sets improvisation against the rule-following of craft (Dormer, 1997, p. 219). To achieve a personal autonomy of practice I used a home- made foundry (I stop short of *makeshift* as it is certainly not cobbled together or insufficiently prepared – see Peters, 2009, p.9) and sand-casting pits – this is improvisation of sorts, but as a facilitating rather than a generative force. This aligns with the temporal nature of improvisation as an enactment, a sequence of innovations (Ingold & Hallum, 2008, p. 10) and is tied up in the ephemerality of the making process itself.

Peters (2009, pp. 9-73) discusses improvisation as a type of freedom, "[…] the clearing of an aesthetic space that brings the improviser to the 'moment of decision'" (ibid, p. 73). However, in one respect, improvisation is not guaranteed to provide satisfaction or success: an improvised culinary process can be disappointing for the diner (ibid, p. 75). Equally, improvisation as a methodological choice is not to throw creativity into the wind and see what happens, nor is it to absolve oneself from the deliberation of forethought; while an "over-determination" of the process risks either a turning back and starting again (Peters, p. 71), or that improvisation is lost altogether. Ratto refers to some of his project outcomes (that ended up as useful real-life interventions) as being less planned and emerging accidently from "the sort of *drunkard's walk*, consistent with my own critical making process" (2016, p. 32). This is perhaps part serendipity, but the consistent unplanned/drunken-walk approach seems a methodological choice.

In his book *Improvisation*, jazz musician Derek Bailey (1992, p. 66) provides a dictionary definition of improvisation in music as being "The art of thinking and performing simultaneously". In many ways, improvisation is simply unavoidable in an exploratory making process. Ingold and Hallum (2008) go as far as to say that improvisation is the default setting for the way that humans work. Not only is there no script for social and cultural life, life is "unscriptable" (2008, p. 12). Jazz musician and academic Dr Haftor Medbøe (personal communication, 2018) adds that even composition is improvisation written down. Indeed, Bailey (1992, p. 83) adds that historically improvisation predates any other music: "[…] [hu]mankind's first musical performance couldn't have been anything other than a free improvisation."

This view that improvisation is pervasive in all human endeavour is not entirely helpful when attempting to pin-point it as a specific element of a type of creativity, but two points do arise: i) that creativity occurs along a line of historical activity; and ii) that improvisation is generative. There is a contrast between the work of, say, Studio Swine, who plan and carefully direct the filming their projects, and that of Max Lamb (2018), who states that he never knows what is going to happen when he enters a creative process. That is not to say that Studio Swine do not improvise in the development of their scripted narratives – they do – but Lamb is immersed in improvisation. With both, new and stimulating ideas have emerged.

The Generative Value of Improvisation

What is the value of improvisation as a knowledge-generating factor in making? Or put simply: How does improvisation generate knowledge? Ingold's morphogenetic mode has provided a template to explore making as a means of generating knowledge in itself. With respect to this, to be clear, making does not only occur in binary terms of *making as growth* (morphogenetic), and *making as project* (hylomorphic) as described by Ingold (2010; 2013, pp. 21-22), or indeed Arendt's (1958, p. 136) *making as thinking* and *making as labour* (cf. Sennett, 2009, pp. 6-7). Morphogeneticism is improvisation, but, as discussed later, improvisation in making occurs in varying degrees of intensity.

Improvisation focusses the practice on process as opposed to outcome. Ingold and Hallam (2008, p. 2) discuss creativity in terms of improvisation and innovation, firstly referring to Liep's argument that creativity is associated with the production of novelty (2001, p. 5, cited in Ingold & Hallam, 2008, p.2), as opposed to more conventional forms of everyday problem- solving. Here, Liep refers to creativity as innovation, which he regards as “a virtual synonym for creativity” (ibid, 2008, p. 2), and everyday problem solving is improvisation. Ingold and Hallam challenge this, firstly in terms of the perceived polarity of innovation and improvisation, arguing that differences lie elsewhere: where innovation is characterised by products, improvisation is characterised by processes. Secondly, they argue that to read creativity as innovation is to read it backwards, in terms of its results, instead of forwards, in terms of its “movements” (ibid, pp. 2-3). That is to say, innovation is defined and evidenced by its outcome, whereas creativity is temporal. To place an end point to the process is to extinguish the generative processes of creativity. Instead, they argue that “harnessing our understanding of creativity to improvisation gives a forward reading of creativity that recovers productive processes that have hitherto been ignored” (2008, p. 3).

It is important also to briefly clarify the use of the word inspiration. Inspiration is not discussed specifically by Ingold in the morphogenetic process of growth, because inspiration is not really a generative factor - It is interesting to note that the word inspiration or its derivatives appears only 8 times in Ingold’s book *Making* (2013), not once in relation to making itself. The word inspiration is often misused to define a sudden or spontaneously stimulated moment of creative *poiesis*. However, Max Lamb casting on a beach can inspire a practitioner to attempt something similar – to *go and do* something, or take action, but the actual outcomes are generated through improvisation. For example, I was moved to cast aluminium using bubble wrap packaging as a waste mould, having seen Rony Plesl’s glass bubble bowl. This did not arise through inspiration, it is relational improvisation, it is *redesign* (Fig 2).

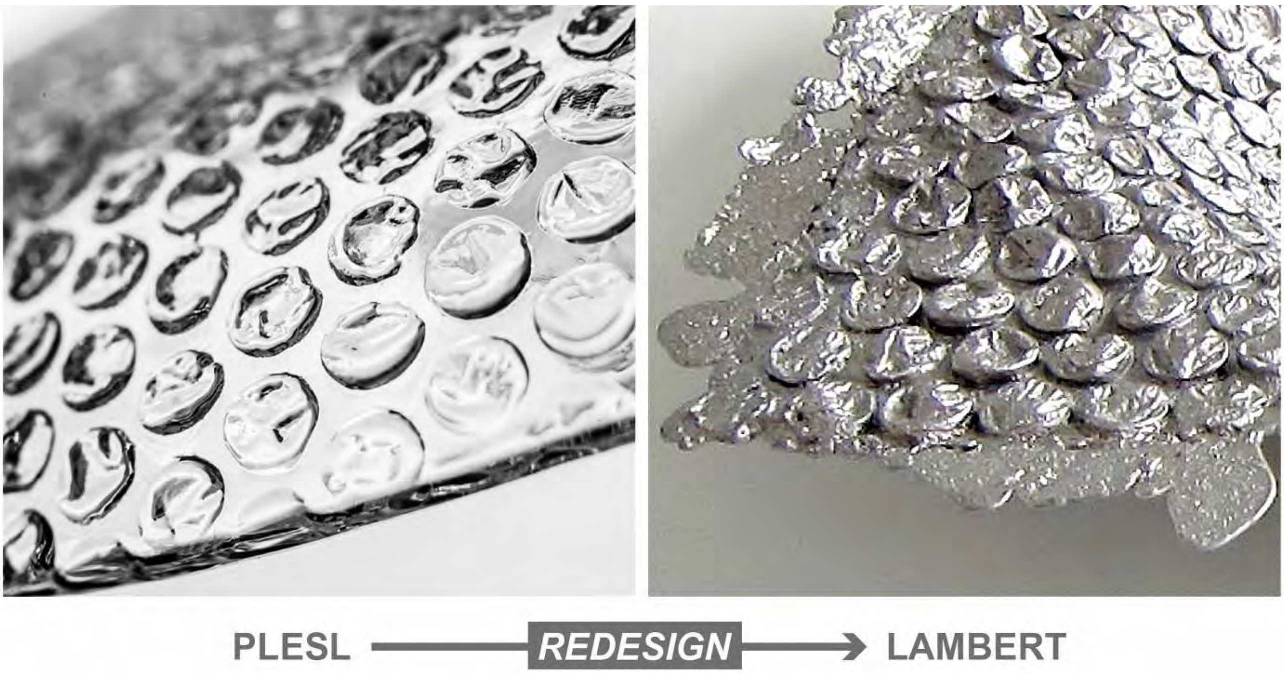

Fig 2. Plesl’s bowl to Lambert’s bowl as redesign, not inspiration (Lambert, 2018).

So, one might be inspired into creative action, but the creative outcome arises from improvisation (cf. Ingold & Hallum, 2008, p. 3). Creative action does not exist in a vacuum: “To design is never to create *ex nihilo*” (Latour, 2009, p. 5); that is, creative work is relational to a prior experience or (others’) prefigurative work (Peters, 2009, p. 62). Improvisation generates the *becoming* of new ideas, but this is always from that which came before: or, as Latour would have it, “to design is to redesign” (2009, p. 5). In other words, creativity is a heteronomous process involving several makers.

The overall body of the practice-as-research here is indebted to external influences and ideas of practitioners who have gone before with accomplished bodies of work, as illustrated in fig 2. Max Lamb’s work with pewter stools has been mentioned as being influential, along with Rony Plesl’s

Bubble Bowl above – the work would not have arisen as it is without these reference points in the lineage of practice. Nelson (2013) asserts that practice-as-research has to be located in a lineage: "[…] if we wish to claim that our praxis manifests *new knowledge* or *substantial new insights*, the implication is that we know what the established knowledge and insights are" (ibid, p. 31). Ingold and Hallum (2008, p. 9) go on to quote Boden: "the mind's creations must be produced by the mind's resources", i.e. what is known already from others. To expand further: Peters refers to an interplay of *autonomy* and *heteronomy*. He starts by saying that "all material contains, sedimented within it, historical patterns of human engagement and creativity that impose limits on what can and cannot be done on the occasion of the material's subsequent reworking" (2009, p. 11). Peters then quotes Theodor Adorno: "The demands made upon the subject by the material are conditioned much more by the fact that the material is itself the crystallisation of the creative impulse, *an element predetermined through the consciousness of man*" (ibid, p. 11; emphasis added). Peters later states: "Origin is an eddy in the stream of becoming, and in its current it swallows the material involved in the process of its genesis" (ibid, p. 60). He then cites Walter Benjamin to clarify: "The term origin is not intended to describe the process by which the existent came into being" (ibid, p. 62). To this end, influences from precedents are essential as a foundation for the practitioner to set forth into autonomous thinking. For example, there is a long-standing precedent for using expanded polystyrene (EPS) for waste moulds in sand-casting, but it is a point from which to act. Max Lamb, having already made bronze bowls with EPS waste moulds, is emphatic that he does not own sandcasting, adding that others can and should try it (Lamb, 2018). With reference to my work with bubble wrap, while Plesl provided the prefigurative starting point, the impulse to do so and the work that followed came about from autonomous actions and thoughts that were fundamentally different and new in approach. This is the interplay of autonomy and heteronomy given by Peters (2009, p. 11). In terms of heteronomy, I made the connection having already worked with one form of aerated packaging (EPS) and seeing the potential to move towards another (bubble-wrap). The artefacts and modified processes arise in an autonomous stage, or "eddy" (ibid, p. 11), in this lineage of practice, as a novel advancement of precedents.

Lineage of *ideas* in practice is not to be conflated with a lineage of practice, that is, the passing down (instruction) of techniques and rules from master to apprentice through guilds, where "the standards of excellence that one tried to attain were set by other people" (Dormer, 1997, p. 220). Rules, Dormer argues, do not encourage creativity, "[…] no harm and probably some good can be achieved by shaking these activities free from the assumptions of instruction and the framework of rules and formulas" (ibid, p. 221). This is relevant for those operating in the academy, whose role is to challenge and question conventions. It is the relative constraints of rules that help to mark (delimit) the space for creativity (Peters, 2009, p. 12). If creativity occurs along a lineage of practice, those who go before are always nudging the next to advance it, not repeat it. Plesl, Lamb, Studio Swine, and others have heteronomously nudged this work towards autonomous action, and indeed, others may nudge this further.

Deriving a creative course of action from precedents does not render a process or outcome unoriginal: all creative practice is dependent on its lineage. It is in the uniqueness and originality of the autonomy of an individual's practice that novelty can be evidenced, as is the case with the creative practice in this thesis.

Having demonstrated how improvisation has been generative, then, if, as Ingold and Hallum (2008, p. 12) claim, improvisation is, broadly speaking, "the way we work" in everything, it is important to discuss the shades of intensity of improvisation in different modes of making.

Rule-Following and Wilful Naïveté

The practice-as-research here not only methodologically embraces improvised methods for material transformation, it enhances this by extending towards naïveté in strategically choosing a new area of practice (i.e. sand casting), to maximise the generative potential. In other words, it is *wilful naïveté*, a deliberate unawareness of the rules to widen the possibilities of discovery.

Conversely, as a mode of making, the skilled level of craftsmanship demonstrated by, say, David Pye (1968) is essentially rule-following, a form of tacit knowledge that is acquired through repetition of practice (Janik 1989, p. 216; also cited by Dormer, 1997, pp. 219-221). The word naïveté is not used here in the sense of lacking in wisdom, but as an attitude or position adopted by the maker to widen the scope or delimitation of improvisation. By stepping out of my own established practice (I trained in furniture design and making) and stepping into a new one, I have become *wilfully* naïve.

For the making-as-research in this thesis, the objects are tools of inquiry intertwined with a process driven exploration, where improvisation is embraced. Therefore, the made artefacts have a different status from objects purposed as end products, in that they arise from a creativity where the process is the focus of the inquiry. Materiality leads the work, but the unfinished state of earlier attempts at making the bowls, inadvertently suspended in production, foregrounds process. However, as with Lamb's 2008 film, the narrative brings an additional aesthetic dimension. All of the bowls could be advanced to towards completion by trimming off the rough-edged overflows and vents and polishing them, but from the perspective of research it is helpful to retain elements that narrate the process: for example, the form-feeding umbilical sprues are particularly powerful indicators of the making (Fig. 3).

Fig 3. Incomplete cast with sprue, as an indicator of its making (Lambert, 2015).

The casting of the bowls through found objects is relatively quick and easy, accessible to many with a competent practical aptitude. By contrast, David Pye (1968, p. 20) and Peter Korn (2017, p. 50) describe a highly tactile relationship with tools and materials acquired over time. As they patiently author intricately crafted work, the procedural conversation is with the mastery of the materials into objects of humble use, yet excellent workmanship.

It is a devotion to a repetitive making process that establishes the rule-following. However, Dreyfus and Dreyfus (2005, pp. 787-788) describe how the rules of *subtle* skills[2] acquired as a novice decompose into experience. Like Janik (1989, p. 223), they refer to Socrates' frustration of the inability of experts to describe their rules (Dreyfus and Dreyfus, 2005, p. 780), concluding that "The expert is simply not following any rules!" (ibid, p. 788). This is not contrary to Janik, but another way of describing rule-following as a form of tacit knowledge. This underpins an important distinction between craft and making observed in the making-as-research here. The words *making* and *craft* have many meanings and uses and can be positioned differently in terms of research. All craft is a type of making, but not all making is craft. However, while improvisation takes place within craft in the sense put forward by Janik: "[…] mastery of the rules brings with it a freedom to extend them" (1989, p. 215) – at the other end of the scale, more widely improvised making is characterised by a certain naïveté. In Fig 4, the diagram shows a scale of improvisation between rule-following and naïveté, wider in delimitation and intensified at the naïve end of the scale, narrowing in delimitation while lightening in intensity at the rule-following end. Wilfully naïve improvisation is characterised by a fast and crude practice (as found in this research); improvisation in rule-following is characterised by slow movement (patience) and subtlety.

Fig. 4. Improvisation on a scale of rule-following and naïveté, with delimitation (Lambert, 2018).

In relation to the practice-as-research the methodological choice of sand casting gives rise to wilful naïveté. It commences at the naïve end of the scale in a wider delimitation of inquiry. Here, so-called failure is more frequent. However, over time, as the inquiry continues, the success of the casts becomes more frequent as a result of acquired knowledge and practice in the technique. In repeating the processes, a script starts to form, while the delimitation narrows. The sand-casting practice edges along this scale from left to right towards the rule- following end. To widen the delimitation and wilfully intensify the naïveté, it is necessary to shift the zone of practice, for example, by moving from sand casting to using ludo moulds.

Obedience and Disobedience

Disobedience is not to be confused as another opposite to rule-following. Peters (2009, p.11),

[2] 2 Subtle skills being those of music, chess and sports, as opposed to the crude skills such as walking and driving. In subtle skills, a tiny difference in what you do can make a huge difference to the result. Driving can be performed while thinking of something else, music requires deep concentration. (Dreyfus & Dreyfus, 2005, pp. 788-789).

citing Adorno, refers to disobedience as one of the necessary elements of improvisation; this would be most profound at an autonomous moment. The heteronomous element ("the previous subjectivity"; ibid, p. 12) of making sets the delimitation of the endeavour and counters disobedience with obedience, in "[…] a shifting dialectical relation that precisely because of its interminable mobility, demands both obedience and disobedience to ensure one never collapses into the other: the death of improvisation" (ibid, p.12). In other words, improvisation without delimitation (obedience) is chaotic and indeterminable; without disobedience it is rigid conformity and mimesis. Again, obedience is different to rule-following, and the two should not be confused. Rule-following is led by acquired skill, and as already mentioned, is a form of tacit-knowledge, whereas obedience is keeping to the delimited boundaries.

I am arguing that when there is more naïveté in practice, the delimitation of improvisation widens, in that the practice is not constrained by prior knowledge, (hence wilful naïveté).

If rule-following is tacit knowledge, and wilful naïveté a lack of it ("tacit naïveté" is an appealing term but an oxymoron, as we cannot know *less* than we can tell), it stands to reason, that the scope and intensity of improvisation is affected by the depth of tacit knowledge. However, it is not quite that simple. For example, like skilled makers, experienced actors will bring their own nuanced and subtle variation to an established script this is still improvisation – but without any script at all they fully improvise: some actors specialise in this as a form of entertainment, often very adeptly and successfully. For improvisation to work at its best, the delimitation needs to be refreshed. Actors improvising on a repeated theme (delimitation) will soon exhaust the generative possibilities – if they keep going over the same ground, the improvisation becomes a script. It is the same in music: as Medbøe (personal communication, 2018) says: "composition is improvisation slowed down". Similarly, as the process of improvisation in the aluminium sand casting is repeated, it starts to become a set of rules. The generative power of improvisation diminishes as we become more adept in its use in any one delimitation.

The Axis of Making: Rule-Following v. Naïveté across Risk v. Certainty

Improvisation is by definition a process with risk, because the outcome is unforeseen. Indeed, risk-taking is important to any creative inquiry: little that is ground-breaking in creative practice came about from taking the safe course of action. Design is a goal-directed process of trial and error, which cannot succeed if entirely averse to the risk of failure. The practice here treats failure as a positive: where the process ascends outcome, what might be deemed a failing by some makers, is for the maker-researcher simply data: "Knowing one has failed is useful, positive knowledge" (Gore, 2004, p. 43).

David Pye (1968, pp. 20-24) describes the "workmanship of risk" and the "workmanship of certainty", (also cited by Ingold, 2011, p.59; and with Hallum, 2008, pp.12-13) as a way to differentiate between craftsmanship and mass-production. In "approximating" his own meaning to the word craftsmanship, Pye gives:

> […] workmanship 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 works. The general idea is that the quality of the result is continually at risk during the process of making. (1968, p. 20)

Hence, workmanship of risk. Crucially, Pye explains the that workmanship of risk has an immense and various range of qualities, without which "[…] the art of design becomes arid and impoverished" (ibid, p. 23). That is to say, there is a degree of the unknown at the outset of the making process, which chimes with the *unforeseen* as the etymological root of improvisation.

Workmanship of certainty is found in "quantity", i.e. mass production, its most reliably consistent form being in automation, "[…] the quality of the result is exactly pre-determined before a single saleable thing is made" (ibid, p. 20).[3]

Pye's binary terms of risk and certainty can be placed across the linear scale of rule- following and wilful naïveté form an *axis of improvised making*. In Fig 5, the blue shaded area on the axis represents improvisation, operating in a wider delimitation in the darker areas, and subtler delimitation in the paler areas.

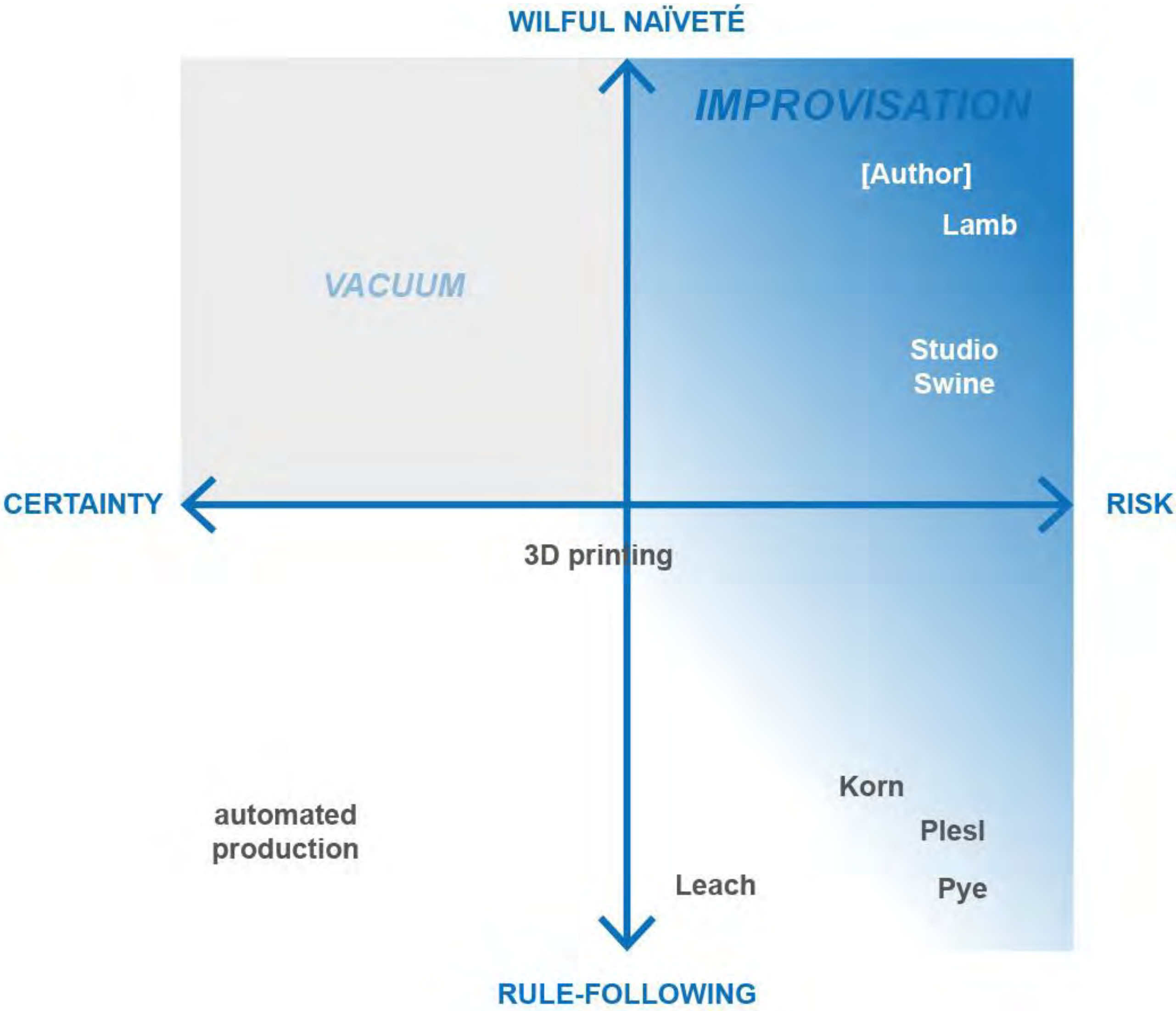

Fig. 5. Axis of improvised making (Lambert, 2018).

Also, the greater the improvisation, the more risk (and less risk-aversion). When asked to comment on improvisation as a generative force in making, Max Lamb (2018) replied that that he never knows what the outcome will be when he sets out to make.[4] This very much accords with Ingold's morphogenetic mode (i.e. improvisation), and thus the research here. Nor does Lamb claim any material or process as a specialism, as might define a conventional crafts practitioner, and he is at liberty to explore (improvise) as his interest meanders through practice. To this end he uses a

[3] Although helpful, this definition has exceptions today – the unexpected (uncertainty) can occur in automated making. Automation, when Pye was writing in 1968, was altogether different to the customisable and digitally controlled kind that exists today. The spontaneous auto-aborting of a task that can occur with a desk-top 3D printer is a risk.

[4] 4 Question posed by me during a public talk in Edinburgh, in conversation with Geoff Mann. 14th May 2018.

degree of wilful naïveté. Any competent maker may choose to be (i.e. be wilfully) naïve, as has been the case with the sand casting in this research. Wilful naïveté is an attitude and, with this mindset, the maker-researcher looks more closely at their own actions. But in following flows of the process, and by embracing risk, the *generative power* of improvisation is increased. As already mentioned, it is embracing failings as positive outcomes that has given rise to much of the discussion leading to new insights in this project. My work (the bowls), along with Lamb and Studio Swine, is situated in an area of naïve improvisation. Like Lamb, I was never certain of the outcomes, but it was necessary to adopt a degree of naïveté to create a wider delimitation of practice.

Conversely, to turn a pear-wood bowl, for example, the practitioner must learn the use of a lathe while gaining a workable understanding of the qualities of the material (cf. Pye, 1968, p. 35) and how it responds to well-maintained cutting tools: i.e. you need to learn to follow the rules. Contrary to Pye (1968, pp. 20-24), it can be argued that as the practitioner becomes adept at this, the risk diminishes, and there is more certainty that the process will result in a serviceable bowl each time. Of course, there is room for experiment and improvisation within this (see the lower right quadrant in Fig. 5), even with long-established processes, depending on the imposed delimitation. The greater the delimitation, the less predictable the outcome, thus the greater degree of risk. Rule-following can occur with certainty and risk (and of course naïveté is partly characterised by risk), but on the diagram above there is also a vacuum in the upper left quadrant. While the line of certainty v risk across naïveté v rule- following forms a coherent axis, the quadrant between certainty and naïveté cannot be occupied, for to improvise with certainty is not possible.

The risk, as discussed above, does not just refer to a chance of failure, but also the unknown. The top right quadrant in Fig. 5, between naïveté and risk, both unknowns, is the most intense zone of improvisation – the unforeseen. Peters talks of embracing failure as being liberating. “To fail ‘gracefully’ is to fail successfully. It is to recognise that such failure is necessary for the work to continue” (Peters, 2009, p. 60). In this respect, it can be argued that to be fully liberated of failure is to refute its existence. Peters continues: “[…] such liberation might be best understood as an emancipation from the illusions of success (ibid, p. 60). If failure does not exist in the morphogenetic (improvised) mode, the focus then is on process rather than outcome.

Conclusion

That improvisation is generative is beyond doubt. The new theoretical insight I provide through my work is firstly to illustrate through the work of Lamb, Studio Swine and Plesl, and my own work the interplay of heteronomy and autonomy as improvisation, and not inspiration. I was not inspired to use bubble wrap as a sandcasting waste mould; more so, my actions were part of a heteronymous lineage of improvisation. Secondly, I have illustrated how the generative power of improvisation is amplified on a scale of rule-following to wilful naïveté, with the caveat that total disobedience can undermine the whole process.

This insight helps to calibrate improvisation as a method for practice-based research: firstly, it liberates the practitioner from failure to the point where failure can be removed altogether as an entity in the making process. Thus, secondly, this denotes a focal shift onto process, for when an object has no agency to fail or succeed, the way that it *became* is the centre of our attention. In this research, the improvised processes have led to rough (although not bad: Pye, 1968, p.30) outcomes that exist as tools of the research. This act of making is embodied in the *things* arising from this practice (Fig 1).

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Dr Ian Lambert, College for Creative Studies (CCS), Detroit, USA

Ian Lambert is Professor and Dean of Graduate Studies at CCS, Detroit. Prior to this he was at Edinburgh Napier University in Scotland, where this research was undertaken. His research focuses on maker-led product design and sustainability. He has recently completed a Carnegie funded project on design with ocean plastic.

Redirecting Textile Knowledge; An Innovative Approach to Recycling

Donna Cleveland, Auckland University of Technology, New Zealand

Abstract

This paper identifies an opportunity to design a localised textile waste system in New Zealand which provides the raw material required to develop a value added, closed loop, innovative and sustainable textile product. Sustainability is a key challenge of our time. The mass production processes of the apparel industry create large volumes of waste posing significant sustainability issues at all levels. New Zealand is a wasteful country that has up until recently managed textile waste recycling by exporting or landfilling the problem. Ministry for the Environment records indicate 100 million kilos of textile waste is disposed of into New Zealand's landfill annually. At present options for unwanted textile waste in New Zealand are limited. The emergent crisis of textile waste stream management requires systems change and new forms of collaboration to be researched, designed and actuated. This paper challenges some of the complexities surrounding an unsustainable manufacturing cycle and the associated problems of textile waste. This research directly engages with individual New Zealand companies and re-circuit their waste manufacturing streams. A customised design solution that tangibly maximises the utility of an individual company's textile waste is illustrated. The intervention into the established system reveals itself as a reconfiguration of sustainable practice. The paper explores the nature of new knowledge generation in this area, how it was gained, distributed and deployed. Tacit and experiential materials knowledge about textiles is extended by the designers' phenomenological experience and subsequent knowledge brought about by iterative practice. Design led strategies serve as a platform to demonstrate how to re-design and initiate a new pathway for the New Zealand apparel sectors textile waste, to initiate change.

Keywords

Textiles; Knowledge; Design futures; Sustainability; Recycling

This paper presents specific findings related to textile knowledge from a recent project 'Transformational Cloth' which intended to understand textile recycling practices and explore innovative approaches to reconfiguring the current linear system into a circular model. Two of the aims of this project, were to re-think and re-value textile waste. To realise this, the designer literally located herself in the process to redefine the status quo and establish an approach of doing and making, thereby focusing on the materiality of the textile waste. This shift in practice enabled a new understanding of the materials and highlighted the potential for re-thinking and re-valuing them. In doing so the research project considers textile waste as the result of a systemic design flaw and as a source of raw material. This paper articulates how tacit knowledge blended with experiential knowledge used in the process of textile recycling can contribute to solving issues of unsustainability.

Background

For the first time in the history of the earth, we are witness to significant geological changes to our planet caused by a single biological species. Human beings have caused a distinct change to the physical layer of the Earth's geological strata leading to unprecedented climate change. This is arguably the most important, and existential challenge that humans and non- humans currently face. This period has been termed the Anthropocene: "The formal establishment of an Anthropocene Epoch ... mark[s] a fundamental change in the relationship between humans and the Earth system" (Lewis & Maslin, 2015, p. 171). It is by definition a 'wicked', complex, multidisciplinary problem, which raises the question of how design can be best used to sustain ourselves and others on this planet. Sustainability as a concept is nebulous and complex. It has been defined and deployed in very different and often contradictory ways. Fry suggests "the word 'sustainability' has been evacuated of any substantial meaning it may once have had. It's been appropriated by a ragbag of 'green- washing' market interests, opportunists and political hacks. As a result of this we frequently find ourselves 'sustaining the unsustainable'" (2011, para 1).

In addition, the notion of fashion is the very antithesis of sustainability. There are inherent contradictions in the term sustainable fashion, as fashion is about obsolescence: "its lexicon is new every year, like that of a language which always keeps the same system but suddenly and regularly changes the 'currency' of its words" (Barthes, 1990, p.34). The system of rapid change surrounding the fashion industry, with frequent new seasonal ranges, means constant renewal and the discarding of clothes; a 'wear it today throw it out tomorrow' approach (Blanchard, 2008). Conversely, perceptions of sustainability are associated with preservation and longevity. Herein lies a paradox that has motivated this inquiry. Sustainable fashion design and its associated practices are of current global concern (Fletcher, 2014; Gwilt, 2014; Niinimäki, 2013); the issues are complex, and the possible solutions necessitate continual adjusting and transforming. The principles of sustainable fashion design seem like a moving target that is difficult to work towards. This is due to both a myriad of possible interpretations of the subject and the vastness of the situation, which can seem overwhelming. In this context, the role of the designer as someone who only looks forward in their practice and does not engage with the experience and implications of materials and materialism, requires a recalibration (Fry, 2014). It is this redirection in practice and the subsequent new textile thinking that this paper aims to convey through the mechanism of material recycling.

Fashion Manufacturing Cycle

With regard to the precept of our fashion system, Niinimäki (2013) maintains that our present-day fashion design, apparel manufacturing systems and economic models have directed us towards an unsustainable level of fashion consumption and its resultant waste stream. The current linear system, commonly referred to as the "take, make and waste model" (The World Economic Forum, n.d.) extracts predominantly virgin fibres for textile manufacturing, produce clothing en masse, have a short use phase and ultimately discard the clothing into landfill (refer to Figure 1, to see how this linear system currently operates).

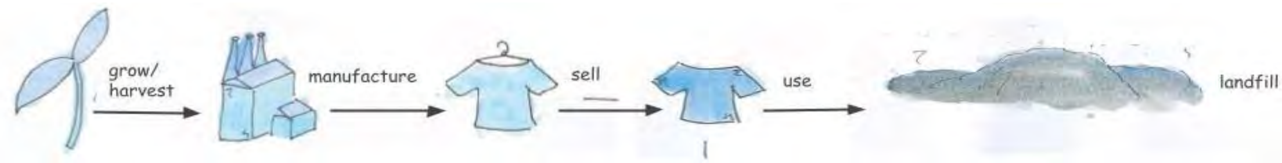

Fig 1. Current linear take, make and waste model

Along with the loss of materials, we squander their inherent economic value when we discard them. In fact, a recent industry report written by the Global Fashion Agenda, 'Pulse of the fashion industry', estimated that "the overall benefit to the world economy could be about EUR 160 billion (USD 192 billion) in 2030 if the fashion industry were to address the environmental and societal fallout of the current status quo" (as cited in Ellen MacArthur Foundation, 2017, p. 19). The Global Fashion Agenda suggests that it is small to medium- sized producers and manufacturers that have had the least uptake of sustainable strategies (Global Fashion Agenda, & The Boston Consulting Group, 2017). This highlights that engaging small to medium-sized businesses in sustainable enterprise, would be advantageous as a model to effectively illustrate a sustainable strategy. Fashion industry writers propose that, the solution to the issues raised by this linear system, is the shift towards a circular model (Ellen MacArthur Foundation, 2017; Global Fashion Agenda, & The Boston Consulting Group, 2017; McDonough, & Braungart, 2012). The 'New Textiles Economy' report 2017 positions "low levels of recycling, the current wasteful, linear system [as] the root cause of this massive and ever-expanding pressure on resources" (Ellen MacArthur Foundation, 2017, p. 20).

Barriers to a Circular Systemic Approach

One possible way to engage industry lies in the reframing of sustainable fashion and textile systems as 'positive feedback loops' with a potential to make change through knowledge growth and alteration of practice (Fletcher, 2014). Tackling multiple smaller problems cumulatively could have a big impact on consumer behaviour. Peter Senge's 'Systems Thinking' approach (1990) describes reinforcing loops as being a fundamental function of a modern organisation and suggests how to run a more efficient and effective management system that has evolved from the quality control circle style of organisational behaviour. He defines complete systems holistically with positive impact that transforms little cycles within a system; when analysed and palpated they flow in a harmonious manner. He proposes that this shift in organisational behaviour requires a quantum leap of leadership in all tiers of management and labour, not just the top and not just the bottom. He advocates a need for all levels to 'buy in' to the concept of wholeness and engagement, and apply strategic goals. When you apply the principles of what he terms 'leverage,' "actions and changes in structures can lead to significant, enduring improvements" (Senge, 1990, p. 104) in business growth, capacity and culture. In theory, this establishes a concept that is very applicable to an existing organisation and suggests that drivers towards sustainability could be applied to it in a reinforcing and positive way, one step at a time. However, these admirable shifts in occupational culture rely on 'buy in' from all tiers within the organisation. This is problematic until corporate perceptions around waste management shift awayfrom that of concealment and move into a more transparent mode. Whilst there are still negative perceptions towards waste management and a direct resistance to change we will continue to encounter challenges as companies prefer to send their waste to landfill rather than have the details of their waste recorded. This denial of access would be detrimental to any pragmatic solution of leverage being actionable within a system.

Design Futuring

Fry's design philosophy proposes a pathology that is reinventive in nature, and suggests a redirective premise of design, 'design futuring' that is anchored in practice. He argues that the status quo of design is engaged in the act of unsustainable 'de-futuring' and details 'a new design intelligence' which is focused on the being of a designer and the world we live in now (Fry, 2014). He suggests designers need to make fundamental changes in their own being, that are not only involved in materiality but also have a new awareness of what is being designed and what the implications are of that design, in a world that has finite resources. This re-imaged design ontology promotes singular transdisciplinary practice as a mode of operation as "by its very character, redirective practice can never be universally or theoretically generalised - it can only ever be situated and circumstantially reactive" (Fry, 2014, p.10). This presents an opportunity for a redirected, action style of materials research with a designed sustainable outcome.

Supplementary to this, Kane and Philpott propose a heuristic style of interdisciplinary practice, seated in textiles and sustainability that they call 'textile thinking'. They propose that "until recently this knowledge or way of thinking - 'textile thinking' - has remained largely unarticulated" (Kane & Philpott, 2013, p.1). They suggest practitioners working directly with textiles hold a 'specific blend' of materials' knowledge essential for developing sustainable solutions. They state that "hand-making and craftsmanship are key processes used by textile practitioners to develop understanding of both materiality and concept" (Kane & Philpott, 2013, p.5). Their acknowledgement of mastery and a heightened metacognitive state are relevant to this research as it suggests that techne is a vital component and goes hand in hand with design principles in the emerging field of sustainable textile creation. Doing and making, bound together with the craft knowledge generated through material practice uses a physical approach. Cameron Tonkinwise describes this relationship of design practice as one where "designing involves the tacit discernment of aesthetics, a prejudicial yet flexible analogue of ethical hermeneutics [where] there is clearly an art and craft to the science of practicing design" (Tonkinwise, 2003).

A useful tool to reconfigure sustainable design is to embrace Fry's (2014) premise of redirecting practice, where the emphasis shifts away from blue sky ideals and holistic systems into an actionable approach that is reflexive to circumstance. As two of the aims of this project, were to re-think and re-value textile waste, the designer adopted Fry's theory and literally located herself in the process to redefine the status quo and establish an approach of doing and making, thereby focusing on the materiality of the textile waste. This shift in practice enabled a new understanding of the materials and highlighted the potential for re-thinking and re-valuing them. In doing so the researcher became aware of the textiles potential as a raw material.

The Role of the Design and the Designer

Designers often turn to theorising about design in a departure from the practice of design. Banerjee, suggests design researchers should stay connected by operating in a mode that accommodates both theory and practice (2008). The worldwide problem of textile waste offered this research tangible context. It was critical that the research practice was undertaken using genuine textile waste from industrial streams. It was also paramount in working towards another one of the project's aims, to develop a model where the scale of textile waste is matched with the scale of intervention, that the textile waste was processed on available machinery that could offer scalability and repeatability. This approach to knowledge generation has at its core, values anchored in sustainable practice.

Research Approach

The project was situated in New Zealand and was localised to the Auckland area. It should be noted that at the time this research was conducted there was no significant civic infrastructure to recycle textile waste. Throughout the design led project the textile designer, collected and redirected several streams of industrial textile waste, diverting it from the expected linear route to landfill and explored ways to reanimate the fibres into new textile outcomes. The project involved working with: industrial partners to gain their trust to work with their materials, different processing plants in different locations to recycle the materials and multiple material specialists with unique fibre knowledge. In this process the designer/researcher utilised existing infrastructure and specialists that were not previously known to each other or connected in any way. Building these new pathways meant that the designer needed to manage each interaction with boutique machinery operators, consider fibre specialist knowledge and develop new process centric terminologies (refer to Figure 2).

Whilst collecting the textile waste new methods of gathering and recording the data were developed. Quantitative and qualitative data was harvested and recorded in new material libraries of knowledge. The qualitative mapping included methods, such as grading the fibre compositions and fabric structures, colour categorising and evaluating the potential recyclability. The agency of these methods was founded on not only expert technical advice on possible machine capabilities, but also the researcher's tacit knowledge blended with thinking about what was possible. Fry (2014) recognises tacit knowledge as being a product of skilled practice. Polanyi, who introduced the notion of tacit knowledge, suggests that this type of knowledge "cannot be told" (2009, p.4). Fry fuses this understanding with the explicit knowledge of technical mastery as one of the foundations of 're-futuring design' as a redirective methodology (Fry, 2014).

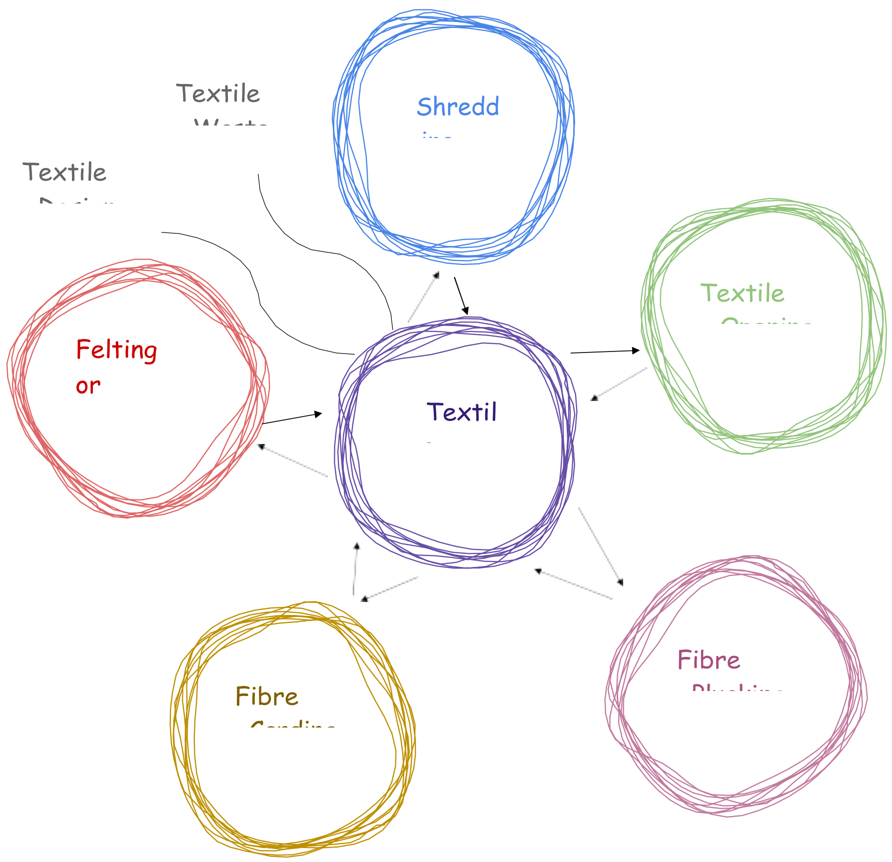

Fig 2. The design-centred system showing how the materials move through different mechanized processes.

This combination of materials knowledge influenced the choice of methods used and their application. These initial mapping methods considered the inherent value of the fibres and the possible synthesis that could further add value. Of the collected waste streams the one that affected the designer the most was from an academic regalia hire company. The textiles that had the biggest impact on the designer's experience with the materials were the black trenchers and gowns. These items required considerable disassembly by the researcher before being able to recover recyclable textile materials. During this time the materials shifted the designer's perspective on textile recycling from small pieces of post-consumer textile waste into powerful pieces of transformational cloth.

Knowledge through Disassembly – Black Trencher

This section discusses the disassembly of a particular item of academic regalia and the phenomenological experience the designer had when stripping them for salvageable material. When disassembling an academic black trencher, the initial approach was to apply the minimum number of cuts required to take the components apart. This gave a production- type imperative to the work. The workflow proceeded from a careful dissection into seven definitive and repeatable steps (refer to Figure 3).

Fig 3. The stages of disassembling an academic black trencher.

1. Make a circular cut around the base of the skull cap detaching the mortarboard
2. Turn the trencher over and remove the button
3. Separate the tassel from the button.
4. Make four diagonal cuts away from the centre making sure you slice around the button.
5. Remove the cardboard inner
6. Remove the binding off the skull cap
7. Remove all the labels

Each of these steps was repeated 590 times (refer to Figure 4 and 5). This gave the researcher ample time to develop a technique, becoming very efficient with the disassembly. The process changed from initially taking nearly five minutes, to only taking three minutes towards the end of the disassembly phase. This freshly acquired autodidactic skill set became second nature. Fry recognises the value of such skills gained through practice, stating “it is this condition that provides the ground for the ability to innovate, create, exploit and critically deploy the capability gained” (2014, p.19). This building block of new habitual practice allowed a deeper understanding of the world of the textile processing labourer, which is one of repetition and specialisation (Hawley, 2006). This was a very new mode for the researcher and gave not only a new appreciation of the materials but also transformed the identity of the designer. This translation of agency was important to this project as it augmented the relationship the researcher had with the materials and their inherent qualities. This was a compound of iterative practice and handling the materials while manually manipulating them. Through processing the trenchers, the researcher began to be able to sense small variations in each item without having to look closely.

Fig 4. A pile of button componentry from the academic trencher.

Fig 5. A pile of black tassels from the academic trencher

This cognitive shift happened in tandem with a shift from being regimented and goal-oriented to being in a creative-thinking mode, that was temporally emergent. This thinking was flexible and opened up the researcher's mind to a discourse centred around the possibilities. Kane and Philpott describe this internal dialogue as being a usual state of mind that develops from both a sensitivity towards the materials and an elastic cognitive process which reveals itself as "a pliable style of thought that twists, turns, stretches and folds in on itself" (2013, p. 6). The purpose of extracting squares of fabric to obtain a maximum yield of recoverable fibres gave way to the possibilities of the componentry and an awareness that the materials held stories and had a presence of their own. The researcher's thoughts moved from thinking about how dusty and dirty the materials were and what they were constructed of, to thinking about all the people who had worn the trenchers and the challenges they would have overcome to be in a position to have worn the trencher. The wear of the trenchers was subtle and unique for each item, such as slightly worn on the front corner perhaps from constant readjusting on the head or the faint indentation left on the cap from the hairpins used to hold it in place (refer to Figure 6).

Fig 6. Slightly worn front corner on the academic trencher perhaps from a constant readjusting on the head

These traces humanised each trencher as each imprint revealed itself. This experience affected the researcher by introducing a new narrative. Carole Hunt, describes this mnemonic phenomenon as "the capacity of textiles to retain and communicate memory, both privately and publicly" (Hunt, 2014 p.207). Hunt's described phenomena materialised in this research project while the researcher was engaged in repetitive processes; in turn, this stimulated reflective practice. This determined the direction the researcher took when making decisions about the textile outcomes. It also created a new sense of knowledge and a desire to value the fibres. The effect of this experience and reflection was to transform the researcher's mindset from using the materials to being used by them. The materials, through the agency of disassembly, revealed themselves not only as having new material potential but also as a form of material memory bank. The researcher considered whether the fibres themselves could hold memories (Hunt, 2014). With the action of disassembling each trencher, new abstract and tangible stories unfolded. The researcher became conscious of the need to save the fibres from an impoverished destiny as waste, and instead celebrate their individuality and potential. These insights into previous use and wear were gained from unconsciously reading clues and impressions transferred onto the textile by its past users (Hunt, 2014). This experience reconnected the researcher with the vitality and value of the fibres and the need to re-future them (Fry, 2009). This ignited a new appreciation for not only the trenchers as objects that contained narrative, but also the energy involved in manufacturing them. The origins of the fibres were unclear, but there was no doubt that extensive energy had gone into the life of the fibres and this would be squandered when sent to landfill. The disassembly, grading and cutting had a significant phenomenological outcome where touch and sense triggered cognitive resonance and a change in direction.

In other words, by handling the materials, the designer, began to understand their composition, and allowed the senses of touch, smell, seeing and feeling, to guide the making and innovative decisions about the design. This is often a less acknowledged aspect of decision making within a textile designer's role. The resulting 'textile thinking' had a cognitive elasticity that provided new experience for the researcher. In this way, cognitive models can command methodology through the premise of 'textile thinking' (Kane and Philpott, 2013).

This mode promotes a re-directed textile narrative that explores the advantages of what Kane and Philpott describe as 'sack' and 'box' thinking (2013). This premise, informed by the writings of Gilles Deleuze (2003), presents 'box' thinking as a structured, rigid system that is determinate and leaves no room for conjecture. When this is applied to processes that have clearly defined boundaries, it is "measurable, amenable to precise mathematical prediction and practically applicable" (Kane and Philpott, 2013, p.6). On the other hand, 'sack' thinking offers a realm where quantification is less specific and the results are range based; in that, the model "does not replicate, in detail, the particular outcome that occurs in reality" (Kane and Philpott, 2013, p.6). The recognition that working with textiles involves indeterminate complexity due to their nature led this research to seek and deploy modes of operation that valued "the malleability of textiles and textile modes of thinking… creating an approach where connectivity and continuity are key to the development of novel and innovative ideas" (Kane and Philpott, 2013, p.6). This metaphysical approach produced a new sentience that affected the researcher's vision of what the practice was achieving and informed how best to unfurl the new knowledge generated within the world it operates in.

The predetermined design outcomes the researcher had initially held shifted, as the physical handling of the materials evoked a deeper connection with the history of the fibres and the inherent knowledge they held. This interdependence of process and understanding became a key lens through which the designer could inform the re-animation of the recycled fibre.

Overcoming Perceived Barriers in the Processing of Textile Waste

Engaging commercial entities with the view of processing the textile waste was often difficult. The vendors who had the machinery to shred, card or spin the recycled fibres had their own ideals around the scale, quality and value of processing recycled textile waste. These were based on their depth of technical experience, their specific machine knowledge and their preconceived ideas on the advantages of recycling textile fibres, specifically using a mechanical process. For example, the companies that were approached with regard to spinning the fibres considered the fibres would be too short to spin as they had been mechanically shredded and opened. Previous experience and technical knowledge had led to a negative opinion surrounding the commercial value of re-claiming the short recycled fibres. This precept was based on technical considerations about the strength of any yarn produced from mechanically recycled fibres (Langley, Kim, & Lewis, 2000). A limitation revealed during this research was the commercial spinners' ingrained ideas around the outcome of spinning the fibres.

Fibre Recycling Narrative

To facilitate the logistics of the recycled fibre processing system the researcher needed to communicate with the vendors, often face to face. Each of these commercial enterprises required forms of information and language specific to their individual conditions. For example, when discussing the fibres with a small customised service provider, such as a local carding mill, colloquial language was used to label each waste stream. This approach was not acceptable when dealing with a larger productivity-driven company, such as industrial textile waste shredders, where a formal description using numerical data was considered appropriate. However, regardless of which service provider it was imperative that the incorporeal value and future possibilities of the fibres were given a positive narrative. Portraying the journey of the fibres and acknowledging their inherent value became a prerogative of the research in communicating with the vendors about processing the fibres. Positive language was used to communicate with each of the vendors about their machinery and the nature of the textiles involved in this project.

New terminology evolved to enable the researcher and the vendors to communicate about how the fibres behaved through their machinery. Not only had some of the vendors not put recycled textiles through their machinery before but they had often never put that type of fibre even in a virgin state through their machine before. One of the mills who carded the fibres for this research had previously only put virgin wool and alpaca through their machine. Carding shorter recycled textiles was a first, as was attempting to card possum or polyester blends, virgin or recycled.

Fig 7. The mixed composition recycled materials being carded on a wool carding machine.

Fig 8 and 9. The fibres were blended with other recycled fibres from other waste streams, re-carded and felted.

When a complication did arise, as was the case when the black polyester waste from the academic trenchers, fell through the carder, it was important to use positive language about the textile waste to change ingrained perceptions around the value of fibres. Using terminology that referred to the origin of the fibres such as ‘academic fibres’, when discussing the textiles rather than demoting them using terms like ‘black shoddy’ encouraged a shift in revaluing the fibres. In addition, the focus moved from merely the technical to advocating ways to recycle the fibres and save them from their predestined pathway to landfill. This approach allowed the researcher and expert to engage in an exchange of knowledge around the future possibilities of the fibres rather than dismissing the fibres as technically unsatisfactory. This knowledge informed a new cycle of fibre experimentation which explored blending the fibres and re-carding them. By giving the fibres a hero status, the vendors underwent a transformation in attitude and willingness to work with this project to re-future (Fry, 2014) the recycled materials.

Re-thinking the Textile Waste

It was imperative to gain buy-in from the vendors as processing textile waste of this type was new to them. Empathy combined with data and samples were key factors in persuading vendors to convert their lines to process the fibres. For some, the shift from high production into a pattern of sampling for research practice meant extending machinery and service to meet the needs of this research project. The vendors’ expert opinions about particular plant and its operation, was essential knowledge that the researcher used to re-configure practice while minimising the impact on commercial operations.

Fig 10. A stool designed and made using reanimated academic fibres felted into new materials

Conclusion

This project embraced the premise of utilising mixed methods with the aim of creating a platform to effect change that is supportive of this paradigm shift. This seats the designer as an agent of change, and the methods selected as agencies that support this aim. The resulting gestalt of cognition, methodology, framework, and practice indicates a type of strategic behaviour needed by the designer to operate as a change maker. Design culture, positioned between the sciences and humanities, encourages interdisciplinary practice. At a macro level this is realised by the building of a theoretical platform that could inform future research or be enacted by others. Throughout this project the designer also operated at a micro level of practice by changing modes from designer to manual labourer, as well as researcher. This research demonstrates the experiential nature of textile materiality and the impact this could have on designers operating in an ever-changing materials environment. Handling the materials and sensing their inherent knowledge has the potential to reimagine what the fibres can become. In this way designers have the ability to re-think and re-value recycled textiles therefore driving systems change.

It is intended this research project could be used to inform future initiatives to enable New Zealand to achieve waste reduction goals in the future. It is envisaged that the outcomes of the project could be grafted with or onto existing or emerging textile waste management initiatives and offer a fresh perspective on materials knowledge. There is future research potential in establishing a network sharing knowledge between the suppliers, producers, service providers and artisans, where new sustainable strategies could be trialed and new ways of engaging with sustainability considered. This research project, showed that textile waste recovered from industry can be considered a valuable resource to feed circular systems. Future research needs to be undertaken to shift industry perceptions around textile waste recycling, specifically in New Zealand where it has been identified that scale is a problem. This research demonstrated the possibilities of operating with commercial partners to change a system, this could be taken further and translated into the wider industry.

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Donna Cleveland

Dr Donna Cleveland is a lecturer and researcher within the School of Future Environments, at Auckland University of Technology, in New Zealand. Her research engages with innovative design led strategies, interdisciplinary practice, sustainability and designing for systems change. Her areas of expertise include smart textiles application and fabrication, sustainable fashion and textiles design, and developing more effective systems of fashion textiles waste management. Her passion lies in sustainable design education and the fusion of traditional applications with emerging technologies, such as e-textiles to redefine the future landscape of design. Her interests include functional textiles and wearable technologies.

Interdisciplinary Collaboration as a Framework for Creating Future Materials: *Hacking Silk* Case Study

Marie Vinter, Faculty of Design, Estonian Academy of Arts, Estonia

Kairi Koort, School of Natural Sciences and Health, Tallinn University, Estonia

Abstract

The fast progress of bioengineering and technology is predisposing new, biology-based production methods, which enables us to create ecologically compatible materials with tuneable properties. Ongoing research on new alternative resources and emerging new materials speak for achieving sustainable development within circular economy. This paper offers practice-based design solutions through interdisciplinary collaboration for utilizing proteinbased materials capable of environment sensing-adapting and proposes new morphologies of spider and silkworm silk as promising future materials. The theoretical part of the study explores silk, spider silk in particular, and its fibrous structure. Following protocols developed for biomedical applications, the exploratory part of the project investigates silk assembly through morphological material experiments. The project culminated with material-driven design proposal for the applications of such new types of non-natural silk shapes. To visualize the concept of laboratory-created silk morphologies, silkworm *Bombyx mori* silk was utilized. Rather than the bio-fabrication of silk proteins, manipulation of isolated polymers was the subject of the study. Although sustainability itself was not the main research object of this project, it drove the research by trying to address the problem of fast consumption of resources in the design and fashion industry. The merger and execution of the project was facilitated by interdisciplinary collaboration between textile designers and natural scientists, implementing the know-how, craft and skills from respective disciplines.

Keywords

Biodesign; Bio-Based Materials; Silk; Interdisciplinarity; Sustainability

Thirsty and exhaustive textile industry, demanding more fibres and materials mostly for the fashion business, sets new challenges for the environment, consumers, manufacturers and designers (Morlet, 2017). The world's economy in its current form, rapidly consuming natural renewable and non-renewable resources, is wearing down the environment which is why we should set new standards for energy efficiency, waste elimination and take a stance for the protection of biodiversity (Myers, 2012).

It is difficult to say who should take responsibility for the current complex system of consumption. However, designers, who are key figures in production stage where new concepts are created and the choice over materials is made (Tobler-Rohr, 2011), possess a great potential to act as promoters and catalysts of social change (Fletcher, 2008). Over the past decade the material-driven bio-design community has started to look for ways to create more intelligent materials with smaller ecological footprint (Veelaert et al., 2017).

Defining and choosing materials is one of the first steps of production process and focusing on this stage could have a pivotal influence on the rest of the production cycle. To initiate a positive change, we need mindful and knowledgeable designers with insight in material making process who help to create meaningful and intelligent material-driven products with definable biodegradability, durability and function.

Spider silk, a protein-based fibre with many outstanding properties became the object of inspiration for this paper. Once we know how to cost-effectively reproduce it, spider silk has the potential to become a material of the future with applications in various spheres, including the vast field of design. As farming spiders for spider silk mass-production or gathering silk from the nature is still incredibly inefficient, the experiments for this project were conducted using silkworm silk. Although spiders and silkworms are not closely related, they are both outstanding material systems (Omenetto & Kaplan, 2010) and provide large silk proteins that combine fibres with superior toughness compared to most manmade fibres (Andersson et al., 2016). The silk from *Bombyx mori* silkworms is one of the oldest materials known to humankind and has been used for various applications for centuries, therefore using silk as a substance matter for (re)defining future materials is an intriguing prospect (Omenetto & Kaplan, 2010).

Current study summarizes the properties of these naturally occurring fibres and investigates the purified proteins, similar in both species. The laboratory-created new silk protein morphologies demonstrate that restructuring the silk polymer sheets, properties and strength of the material morphologies can be tuned and defined. As materials are almost inseparable from the act of creation and craft (Adamson, 2007), the context of this paper is interdisciplinary practice-based creation involving textile designers form the Estonian Academy of Arts and natural sciences researchers from Tallinn University.

Future Materials

Professor of Biomedical Engineering at Tufts University, Dr. Fiorenzo Omenetto, who has studied a wide range of materials, points out several characteristics suitable for future materials.

Such new innovative materials should be:

- self-repairing
- feel their surroundings
- transform themselves
- disappear harmlessly
- have a non-obvious function (being multifunctional) (Omenetto & Kaplan 2010).

Bioengineering enables us to produce intelligent, environmentally compatible and biodegradable materials that could be suitable for applications without sacrificing technological performance, look or feel. This is notably important within the fashion industry, where the haptic, sensory and visual qualities of the materials – whether it be clothing or accessories – carry a great deal of significance and can't be ignored.

Recent progress in biotechnology and synthetic biology enables us to design bio-based materials as we have previously been designing oil-derived ones. Natural protein based fibres such as silk and hair (wool, angora, cashmere *etc*) are a result of millions of years of evolution. These biofibres have developed a range of outstanding properties often not only outshining man-made material but serving also as inspiration sources for the creation of new intelligent materials (Omenetto & Kaplan 2010). The revolution of synthetic fibres has been appealing to the consumers and has altered fibre consumption patterns, today the breakthroughs in synthetic biology promise to bring natural materials in their new morphologies and compositions to the market and soon also closer to the consumer (Fig. 1).

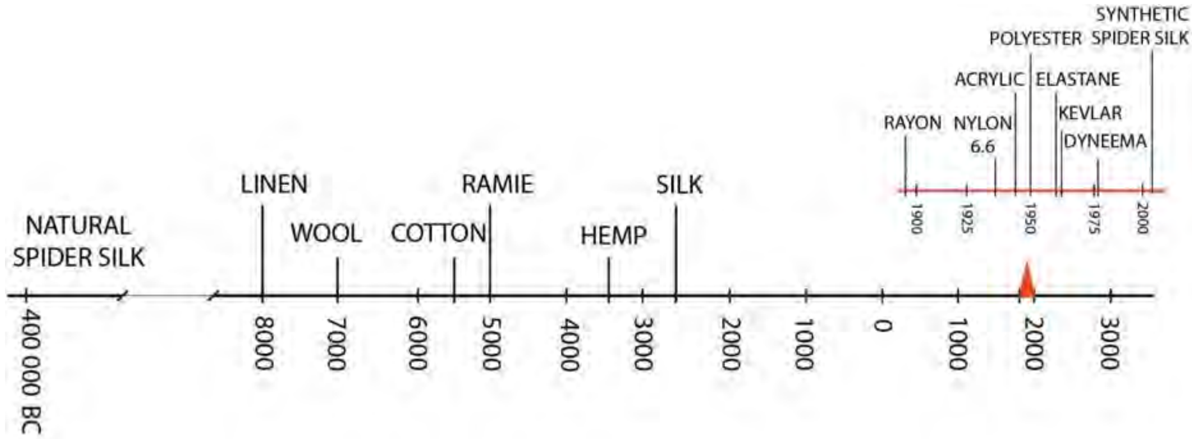

Fig 1. Fibre availability timeline (Compiled by the author based on the information from Teksiilikiud: käsiraamat by Irma Boncamper, 2000).

Fiorenzo Omenetto and David Kaplan, scientists who have been researching new protein-based materials for two decades, advocate for their excellent properties and potential. According to their research, the advantages of the polymorphic proteins lie in their functionality – they are sustainable, entirely processed in water, controllably biodegradable, edible and implantable. The biggest advantage of such novel biomaterials, over for example plastic, is their ability to sense and respond to environmental stimuli, a absent trait in synthetic materials (Bourzac, 2015). Also, the life cycle and biodegradation timeline can be predetermined for biomaterials during the design process (Römer & Scheibel, 2008). Applying biomaterials in other contexts besides medicine could provide items with precise fit for purpose and function whilst not sacrificing society's consumerist behaviour.

Furthermore, by optimising molecular interfaces between structural proteins, multiprotein based useful composite materials could be fabricated. Therefore, generation of multifunctional, biodegradable structural protein composite biomaterials is an emerging trend in the field. (Hu et al*.,* 2012).

We discuss two types of silk that have the makings of becoming the materials of the future – spider silk (*Nephila clavipes*) and *Bombyx mori* silkworm silk. Over the past 20 years silks have been studied to explore their potential as biomaterials. The process of silk protein self-assembly has become more clear, however due to the highly repetitive character of individual silk molecules (especially in spider silk) and the detailed microstructure, the exact mechanics of the silk spinning remain unclear (Omenetto & Kaplan, 2010).

Silk

Spider silk's dragline silk, recognized as the strongest natural fibre in the world, carries a great potential for shaping our future environment (Fig. 2) (Tokareva, 2013). Spiders have six or seven sets of glands, which enable them to synthesize different types of silk to fit a specific function and due to the specialized mixture of protein in each of these types of silks, they all display distinct and individualized properties (Daravamm, 2006). The dragline, mostly because of its impressive combination of strength and toughness, is the most intensively researched silk type (Agnarsson, 2010).

However, as spiders are carnivores displaying aggressive behaviour and are territorial by nature they cannot be farmed like silkworms (Gould, 2002). Gathering spider silk manually involves painlessly immobilising spiders and then carefully pulling filament from their abdomen and rolling it around a spool. Therewith, the reeling tempo and environmental conditions influence the quality of the silk.

Unlike silkworm silk proteins that are easily obtainable on the commercial market, the spider silk protein has to be sourced biotechnologically using genetic engineering methods. The attempts of spider silk protein production in laboratory include cloning the spidroin gene for protein expression into bacteria (*Escherichia coli*), yeast (*Pichia pastoris*), insects (silkworm larvae), plants (tobacco, soybean, potato), mammalian cell lines (hamster) or transgenic animals (mice, goats) (Tokareva, 2013).

Recombinant spider silk currently remains a pricey luxury product under development, only few laboratories have succeeded in spidroin laboratory production (e.g. BoltThreads, AM Silk, Spiber). It is reasonable to assume that the price of recombinant spidroin production technology will follow Moore's law (Moore, 1998) similarly to other technologies (transistors, semiconductors, DNA sequencing) where the price has reduced up to 300 folds over 15 years (Muers, 2011).

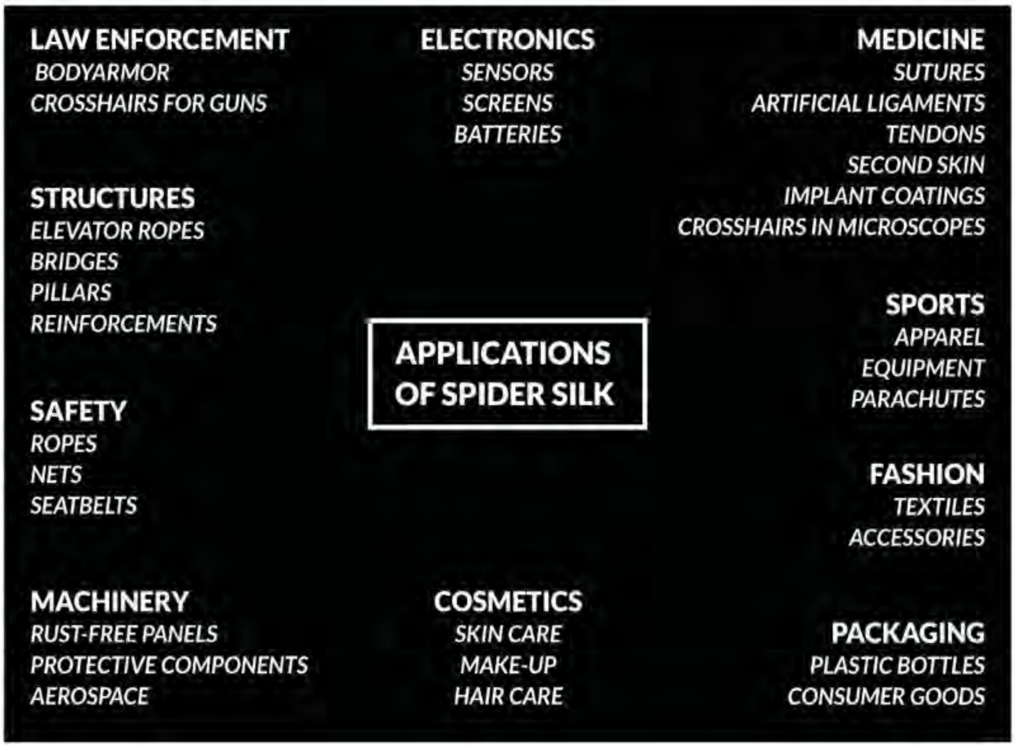

Fig 2. Envisioned applications of synthetic spider silk. (Vinter, 2017)

The main protein component of the silkworm silk, fibroin, is a widely studied polymer used in biomedical applications. Spider dragline silk consists mostly of spidroin I & II, which are also types of fibroin. The similarities between these silk proteins are considerable as both consist of repetitive blocks of amino acids alanine and glycine. Structural toughness of both fibres is achieved by characteristic secondary and tertiary level protein structures. Although it shows remarkable set of mechanical properties, silkworm silk fibre is in many ways simpler, weaker and not as elastic as the spider silk (Fig. 3). The molecules of the silkworm silk fibre are arranged somewhat differently as it contains additionally to fibroin large quantities of sericin proteins (Römer & Scheibel, 2008). The material fabrication from silkworm silk and spider silk have been described and compared in articles "Decoding the Secrets of Spider Silk" (Eisoldt et al., 2011), "Silk as a Biomaterial" (Vepari & Kaplan, 2007) and "Spiders: Web of intrigue" (Bourzac, 2015), that suggest the same protocols could be used and potentially even new morphologies created using spider silk or other silks. The procedures enable the investigation of purified restructured fibroin with the aim of creating non-natural, laboratory made silk morphologies that dramatically differ from natural silk fibre. The *de novo* synthesis of silk protein is not the topic of this investigation, however the iteration of experiments using laboratory synthesized recombinant spider silk is feasible in the future. Meanwhile, material experimentations using silkworm protein can commence.

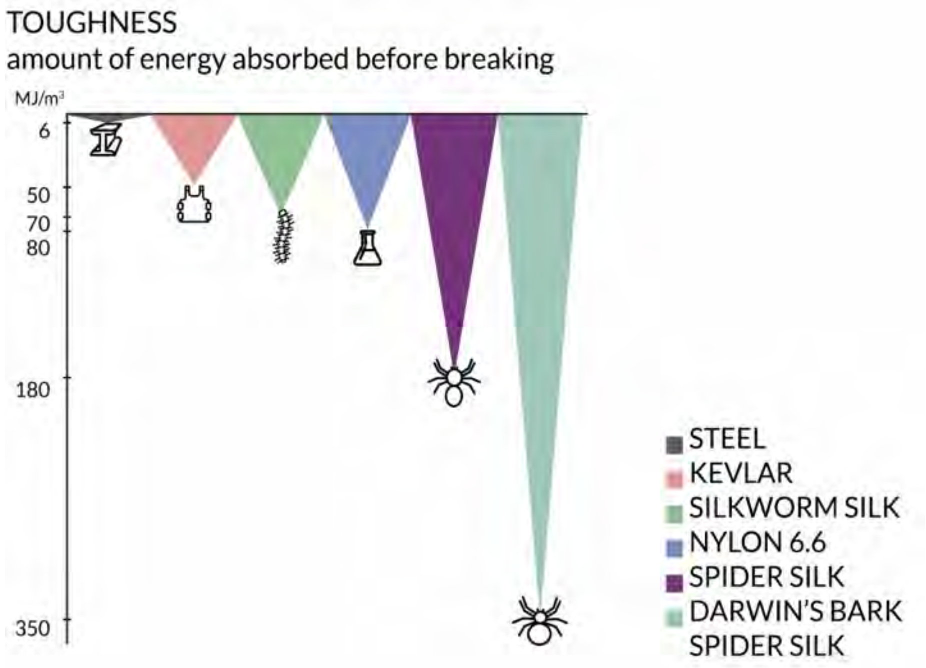

Fig 3. Comparison of fibre toughness (adapted from: Vepari & Kaplan, 2007; Agnarsson et al., 2010).

Practice-Based Design Research

Hacking Silk case study focused on consolidating knowledge on biomaterials and interdisciplinary methods through practical material experiments.

The framework of the project was Tallinn University's freshly launched programme Learning in Interdisciplinary Focused Environment (LIFE) and a specific study group for the execution of *Hacking Silk* case study was established. LIFE is project- and problem-based learning initiative, where students from different study areas collaborate with academics and partners and carry out interdisciplinary projects (Reiska et al., 2018).

Four academic disciplines – Biology, Molecular Biochemistry and Ecology, Environmental Management (Tallinn University) and Textile Design (Estonian Academy of Arts) were represented in the work-group and the project advisor was Tallinn University Lecturer of Systems Biology, Kairi Koort.

The project aimed to explore different silk morphologies with the intention of selecting the most appropriate ones for physical object creation. The brainstorming, concept mapping and protocol (Rockwood, 2011) analysis started November 2016 and the practical work in Tallinn University Laboratory of Molecular Sciences commenced January 2017.

The original idea of restructuring silk has been extensively explored by David Kaplan and Fiorenzo Omenetto, whose studies were the foundation of the project. Artificial silk morphologies developed for biomedical applications (to execute drug delivery, build artificial ligaments and tendons *etc*) served as an inspiration for the *Hacking Silk* case study where their potential utilization for speculative and applied (textile) design was tested (Fig. 4). The sustainability of investigated material was assessed during the design process as it was difficult to measure before the execution of experiments.

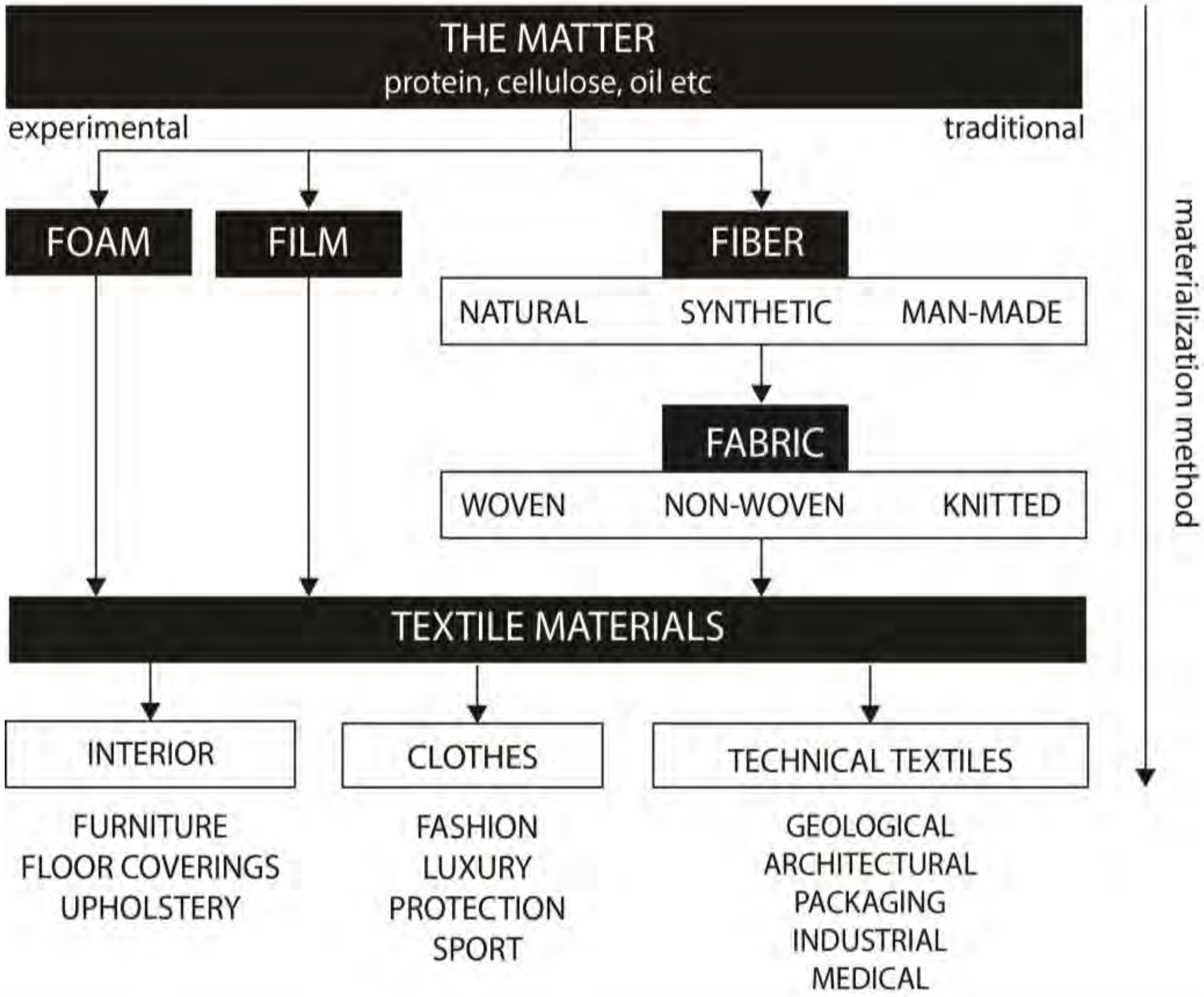

Fig 4. The process of materialization via traditional versus experimental method. (Vinter 2017)

Hacking Silk is an iterative design process both by nature and in its practical realization (Vaughan 2017) where during a cyclic prototyping process the most recent iteration and successive refined material design versions were implemented.

Consultations with Estonian environmental biologist Aleksei Turovski revealed furthermost West Estonia as the strongest dragline spider silk location in the region. This material is nevertheless not as tough as the dragline silk produced by few other spider species and described in scientific research papers. Also, the limited availability, the amount of collected material (0.5 grams in couple of weeks) did not allow for further material explorations. For large scale experiments, alternative silks were considered. Considering the affordability, availability and functionality, silkworm *Bombyx mori* silk was the most reasonable choice. For materialization, three different types of silkworm silk were used.

After receiving the silkworm silk cocoons (Fig. 5), experiments started with cutting of the cocoons into smaller pieces, followed by washing out of sericin proteins (degumming) (Fig. 5), dissolving of silk fibres in lithium bromide (LiBr) (Fig. 6) and purification resulting in pure silk fibroin solution. From that various new silk morphologies could be produced.

Fig 5. Silk cocoons(left); degumming of silk cocoons (right).

The preparation of the purified silk fibroin solution as a 5-day process (Fig. 7), which made every millilitre of the solution very valuable. Due to laboratory equipment capacity, two five-gram silk patches were produced at a time (Fig. 6). This resulted in approximately 50 millilitres of 20% silk solution. As the liquid solution production was time and resource consuming, experiments were meticulously planned and calculated to ensure an outcome proportional to the time and resources needed for the execution. This created a rather analytical creative process where detailed calculations were more valued than impulsive decisions.

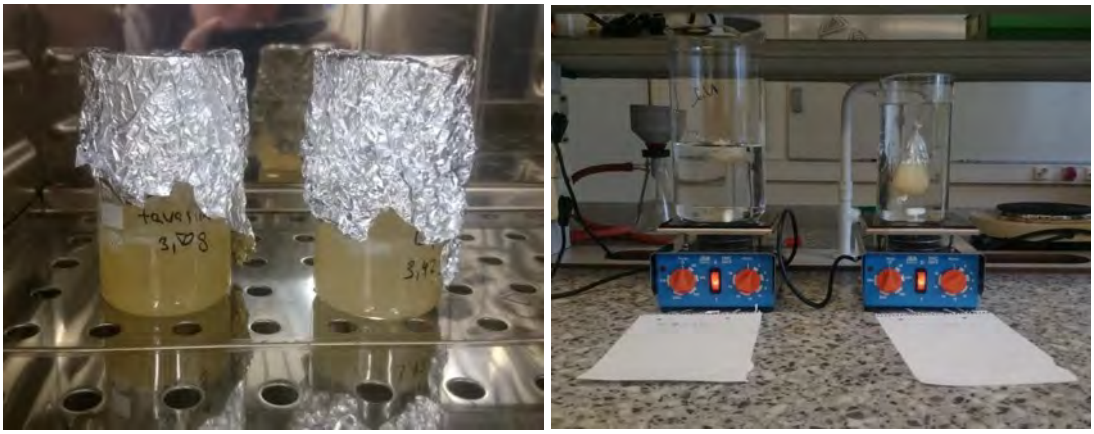

Fig 6. Dissolving silk in LiBr (left); dialyzing the silk solution (right).

The main experimental challenge was to achieve a silk fibroin solution within the appropriate concentration range (6-7%). During the first experimentations the solution turned into gel and could not be subsequently modified. Further iterations produced a solution too liquid, containing excessive water. The protocol modifications required daily changes of small nuances. For example, the first cocoons used (from China) were already purified as they were manufactured and marketed for cosmetic skin-cleaning application. These cocoons appeared to contain chemicals added in the manufacturing stage that caused problems in dissolving the silk fibre. After the purchase of natural (*Bombyx mori* moth containing) types of cocoons from Peru, the experiments advanced successfully.

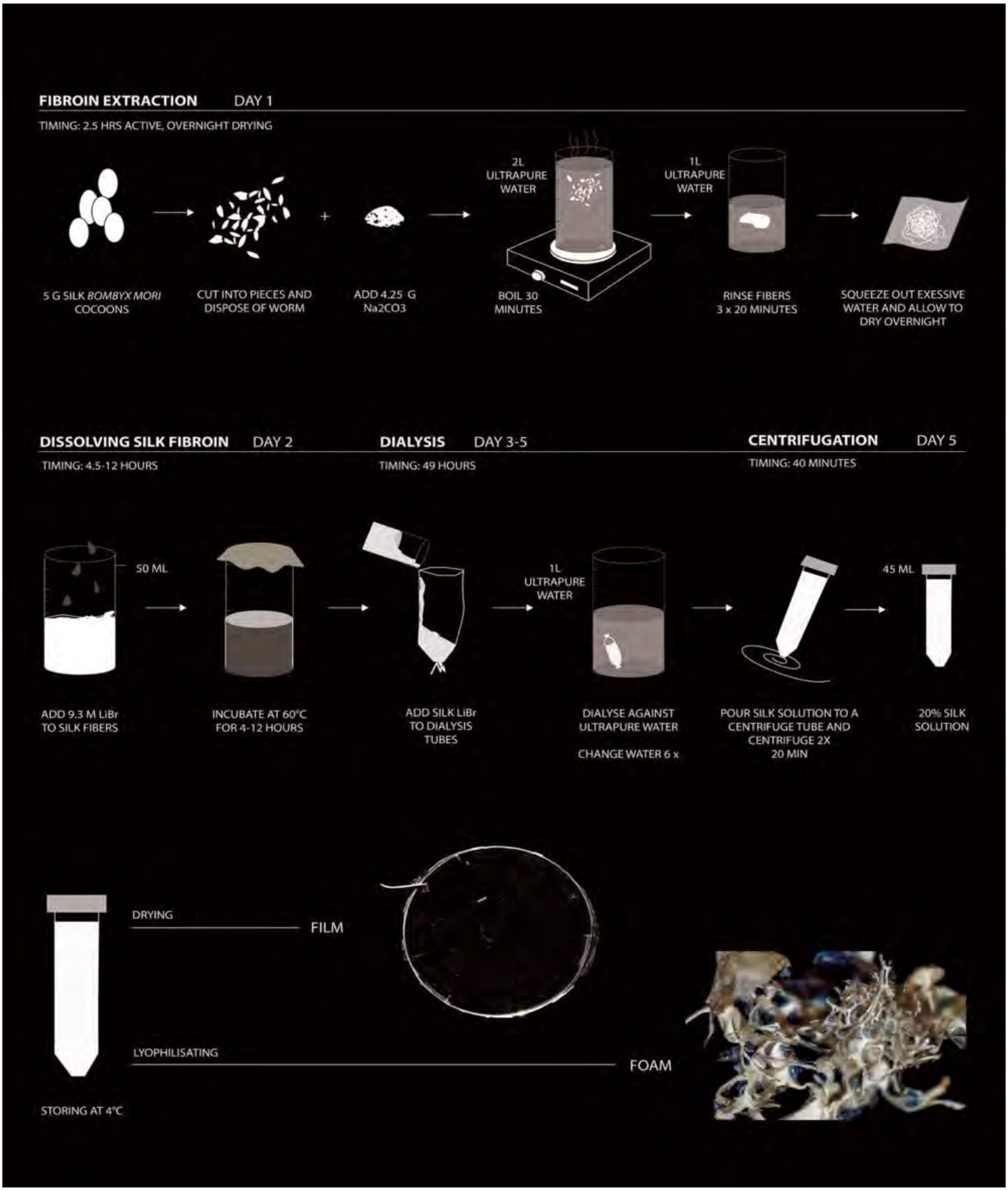

Fig 7. Schematic of the silk metamorphosis protocol (based on Vinter, 2017).

All the produced solutions were used and hardly anything got thrown away. Hardened silk protein gels and broken pieces were re-liquified and used to make alternative tests in composition with some other materials. However, these samples dried unevenly, often turning brittle and had an uneven yellowish appearance (Fig. 8).

Fig 8. A variety of experiments drying (left); test to repurpose the pre-died failed tests (right).

Mostly three different types of structures were created – film, sponge and foam (Fig. 9). The most intriguing structure was the **foam** (Fig. 10). The attractiveness of the foam was best demonstrated in its appearance which contrasted to the conventional appearance of silk and hence provided a lot of inspiring aesthetical information.

Fig 9. Various morphology designs: sponge (left); lyophilized fibroin (middle); silk film with copper fibres (right).

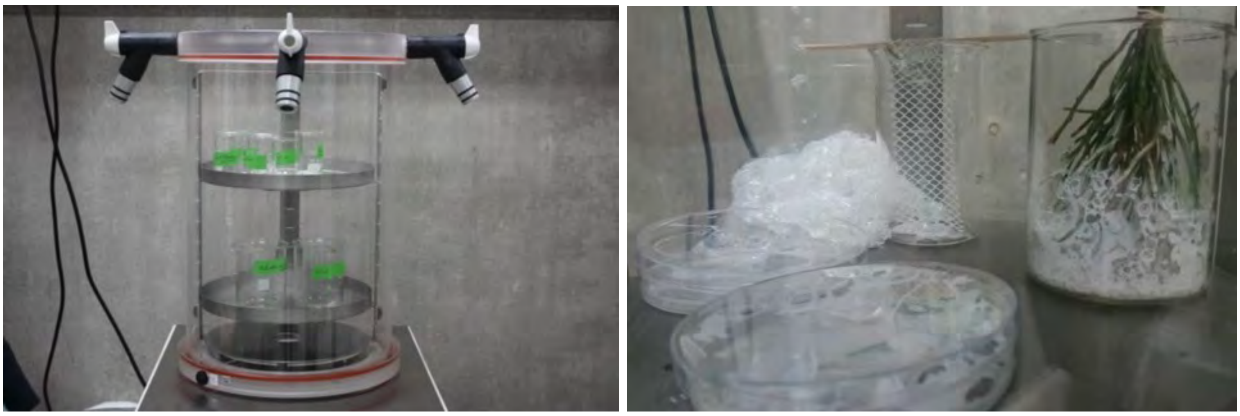

Fig 10. Preparation of the freeze-drying solution (left); various process of lyophilization tests (right).

The silk foam was created through the process of lyophilization under high pressure at -100°C for 4-12 hours using a freeze-dryer. The longer the freeze-drying process lasted, the more stable material was attained.

As the percentage of the silk solution varied, the resulting foams were of very different qualities and properties (Fig. 11). However, they were all sensitive to the environment and demonstrated a sticky character. The material was especially sensitive to humidity and in contact with water the foam dissolved quickly. The lyophilized silk was very light and fragile. The attempts to colour the foam failed as the pigment made the solution heavier stopping the silk solution to bubble into foam. The foams displayed dispersing optical properties.


Fig 11. Heavier silk foam morphology (left); lighter silk foam (right).

Producing **film** was less labour intensive and did not require any additional machinery, however it was time consuming. To achieve a film-like structure, the fibroin solution was left to dry on a mould until solidified. The drying time depended on the amount of solution, the mould and on whether it contained any additives. 20 millilitres of film usually dried in 2 days. Drying could not be accelerated as it notably weakens the physical qualities of the resulting morphology. In the first iterations where pure silk solution alone was used (Fig. 12), the film often turned brittle or cracked during the drying process. After adding glycerol to the solution (Fig. 12), the experiments showed much more elasticity and strength. After various attempts of combining glycerol with silk solution, a 7% glycerol solution was found to be most suitable. Finally, the creation of films with different elasticities and toughness was achieved.


Fig 12. Heavier silk film with added glycerol (left); silk film with no additives (left).

Making composites with various fibres (Fig. 13) helped to strengthen the product material and added aesthetic value. Using supporting materials (e.g. stainless-steel fibres) or additional agents (e.g. heat-sensitive pigment) (Fig. 13) also helped to achieve a suitable relationship of compounds for making thin yet relatively elastic examples.

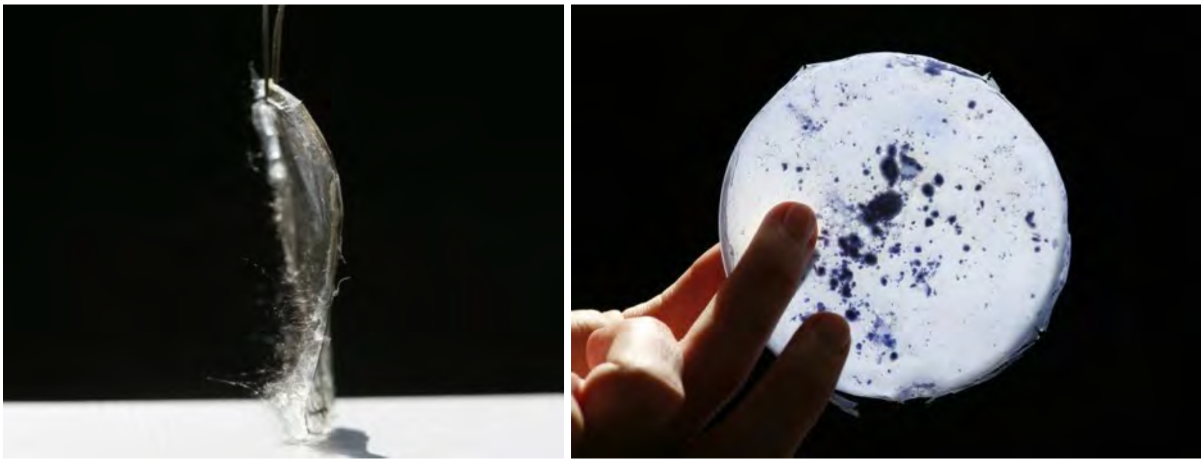

Fig 13. Film composite with stainless steel fibre (left); silk film with heat sensitive pigment (left).

The experimentation with new silk morphologies demonstrate their aesthetic and visual potential, encourage the search for more stable compositions and functional material application explorations in the context of future sustainable economy. Such silk morphologies do not fit into production methods and commercial relations of today, therefore looking into the future, sustainability perspective lies in utilizing green-chemistry production methods, tailor-made made functionality potential and following the principles of circular economy.

Through manual work and craft the *Hacking Silk* team came fundamentally closer to understanding the material holistically - what does it exactly consist of, how to manipulate and handle it and how lengthy is the production process. Collaboration between designers and scientists provided awareness, assisted on articulating abstract concepts and created new knowledge for all.

Lighting concept

One of the possibilities how to protect fragile silk foam is to develop a structure engulfing it. The lyophilization of silk inside protective glass bulbs which were discarded due to minor defects from the biochemistry laboratory, was chosen as a sustainable product development solution. The idea of lighting benefits the unique optical qualities of the silk structure. Freeze-drying silk solution inside the glass enabled to control the process and lead it towards desired solution leaving the foam protected inside the pulb. For optimization, various tests were undertaken. At the end, input of five millilitres of silk solution was considered as an economical solution. In terms of sustainable product design, utilizing different leftover laboratory equipment, added value to the sustainable production process as well as created favourable conditions for and unexpected outcomes. The concept development resulted in five authentic lamps with unique pattern and character (Fig. 14).

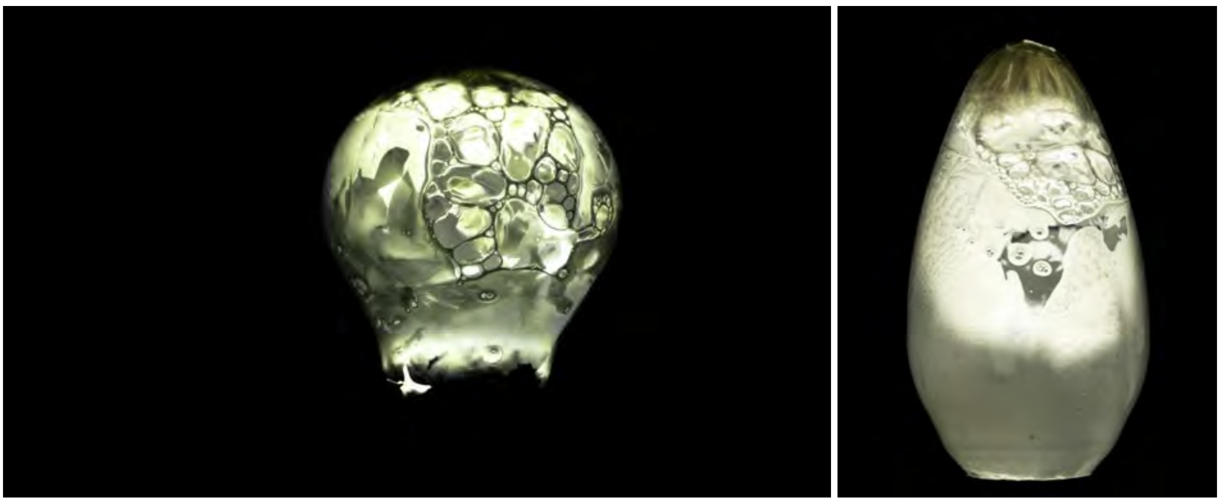

Fig 14. Documentation of the mood light concept (photo by Marko Veinbergs).

Besides the aesthetic value of lamps, they enable to visualize and present the process of silk lyophilization in a compact way serving as a didactic tool aiding learning and comprehension of the process. This method can be used to illustrate the nature of proteins and their reaction to freeze-drying.

Second skin from sequins concept

Sequins, luxury decoration embellishments are commonly applied in the delicate crafts of haute couture as well as in more traditional fields of textile arts such as folk art. The troubling sustainability aspect for sequins using is that the fabrics they are attached to, can’t be recycled. Sequins are either made from glass which makes them heavy yet fragile and difficult to maintain or from plastic (Fletcher, 2008). The demand for sustainable sequins is high and they fill a very specific market niche in *haute couture* where luxury, new innovative materials and traditional handcraft are equally valued.

Fig 15. Concept for second skin-like body armour made from translucent silk film sequins that adapt its optical qualities, to the light stimuli exposure – like a change in the colour (right).

Inspired by the fish scale structural diversity (Wainwright, Lauder & Weaver, 2017) the second skin sequin concept applies the extraordinary optical properties of the silk film (Omenetto & Kaplan, 2010). Silk film in combination with natural pigments, minerals and other additives has a great potential in constituting an optically transformative material that reacts to the angle and intensity of the light.

The sequins by concept come in various organic shapes (Fig. 16) that overlapping with each other form a unified fabric that react to outer stimuli of light and movement. This fabric could be assembled into a second-skin type of body armor that adopt according to the outer stimuli (Fig. 15). Green chemistry production methods and zero-waste textile producing principles enable smart bespoke production with minimal waste. The concept is continuously being developed and tested.

The production of these sequins is labor and resource intensive which makes detail orientated *haute couture* fashion houses a worthy field of application. Luxury fashion brands have also shown elevated interest in sustainable future materials recognizing the urgent need to change from linear to circular economy models (Morlet, 2017).

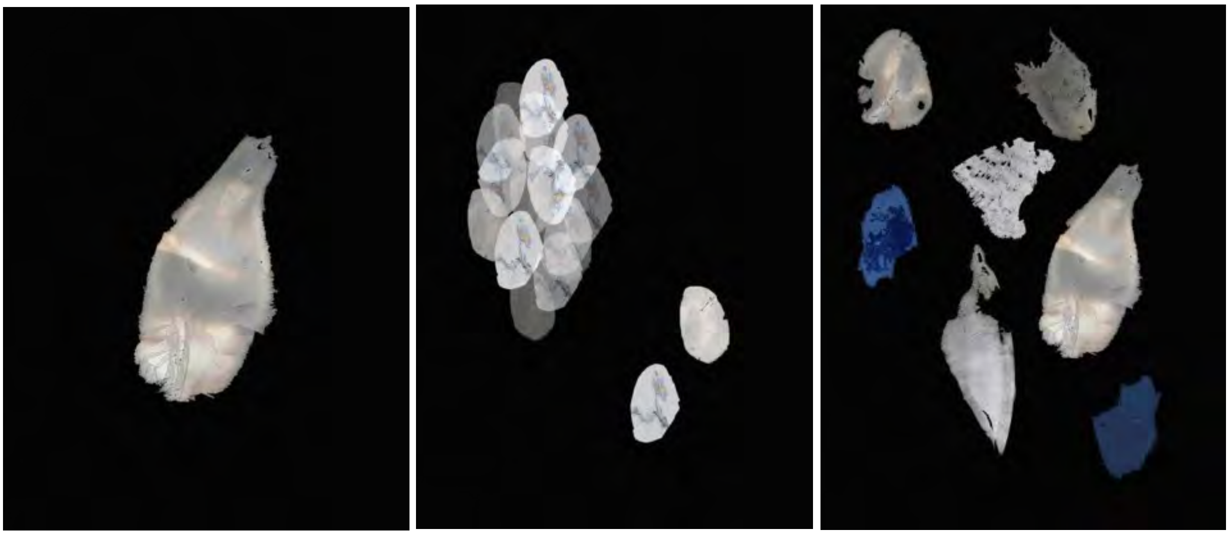

Fig 16. Silk embellishment visualization, organic shape of a single sequin (left), overlapping and organic shapes of sequins (middle), various typology of sequins (right).

Discussion

The interdisciplinary thinking is nothing new, considering that until about the 18th century, the Renaissance-like consilience between science and applied arts was widespread. Then, with the Scientific Revolution, scientists rapidly specialized into numerous independent fields (Myers, 2012) that today, after profound in-field development, are looking for ways of intermingling again.

Using visual strategies (photograph, film, material experimentation), *Hacking Silk* aimed to contextualize protocols and research created for biomedical applications and facilitate this information to wider audiences. The visual representation of complex information in different forms and through creating narratives is a central feature of design activity (Vaughan, 2017). The insights gained from *Hacking Silk* execution suggest that material-driven visual mapping and data visualization through practice-based design narrative is an appropriate method for contextualising knowledge that could help establish new relations and create new realities.

Silks made by spiders and silkworms have a great potential to become future programmable materials of design or textile industry. The advantage of protein-based materials over oil-based fibres lie in their functionality and flexible adjustability. At the moment, there is a general vision of what great importance spider silk could carry. Currently several world-leading laboratories competitively study synthetic silk protein production strategies.

Silk proteins, depending on the morphologies they are arranged into, offer great prospects for various technical and biomedical applications. The material experiments conducted with the *Bombyx mori* silk show sufficient chemo-physical properties for prototyping. However, for larger practical applications further protocol development is needed. For example, the physical resistance to environmental factors needs to be improved. The outcome of current experiments is the proposal of potential material shapes and the visual abstraction protein materials of the future. Specifically, further alternative silk structure laboratory investigation in would be necessary.

The *Hacking Silk* design and research process demonstrated the potential of silk as a biomaterial and opened many future perspectives, especially for product development.

The ecological benefits of such silk morphologies could be sustainability and functionality. Tailor-made renewable biopolymers could respond to requirements set by the consumer and provide personal, unique and functional future materials. For example, garments made from silk films could be created following 0-waste principles, the size of individual pieces could be determined by using moulds, printers or patterns and silk morphologies. Silk film could be a suitable material for bespoke second skin like products, adapting perfectly to the wearer's body, at the same time sensing the external environment (for example releasing medications), pieces of the material simultaneously performing several assignments, interactively responding to the environment.

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Marie Vinter

Marie Vinter is a textile designer and sustainable material researcher, working in the intersection of biology, design, wearable electronics and textile research. She has obtained an MA in Textile Design form Estonian Academy of Arts, Estonia and was a research fellow at the Brooklyn Fashion+Design Accelerator founded by the Pratt Institute from January 2018 to December 2018. Over the recent years her focus has shifted from smart- and e-textiles towards biotextiles such as protein-based functional materials and their alternative morphologies in the context of sustainable fashion and accessory design.

Kairi Koort

Kairi Koort is a research fellow in systems biology and since 2015 acts as head of biology at Tallinn University, Estonia. She undertook her doctoral studies at Karolinska Institute, Stockholm, and was a Marie Curie research fellow at the European Bioinformatics Institute and the University of Cambridge, Great Britain for nearly ten years. Her research focuses on biomedical studies investigating transcriptional regulation of hormone regulated cancers and in recent years on human microbiota investigations and on the development of reproductive tract probiotics. Over the past 5 years, she has advised and participated in numerous interdisciplinary projects in collaborating with artists, humanitarians, social and educational researchers.

MYCELIUM
Exploring the New, Alternative Fungal Hyphae-Based Material's Potentials

Niki Boukouvala, Department of Product and Systems Design Engineering University of the Aegean, Greece

Spyros Bofylatos, Department of Product and Systems Design Engineering University of the Aegean, Greece

Nikolaos Zacharopoulos, Department of Product and Systems Design Engineering University of the Aegean, Greece

Abstract

This paper aims to provide new knowledge in the field of mycelium both in the context of DIY and biofabrication. The approach of biofabrication is closely tied with the transition towards sustainability and ways of designing that incorporate different values and aesthetics. At the same time, closing the material loops is a prerequisite of the circular economy. These parameters point to a need of new knowledge for designers, in order to lower the entry barriers for the creation of DIY materials. Experts in a field, such as mycologists in this case study, come from an established field with a given methodology, jargon and issues. Collaborating with experts can pose many different barriers and opportunities. Sharing the narratives, experiences, and thoughts that emerged during a fruitful collaboration is necessary for the evolution and the broadening of the field of experiential knowledge and DIY biofabrication. Through this study and comparison, a female undergraduate student of a design engineering department presents practical lessons, for anyone who is interested in engaging in the field.

Keywords

DIY materials; Mycelium, Design for Sustainability; Material Driven Design

The human species is not just another inhabitant of planet Earth. We, modern humans, have shaped the earth and prevailed on it since the beginning of the Anthropocene. Our activities have changed the environment in many ways, while important problems on a planetary scale express themselves as reactions to human development. The presence of our species on the planet is responsible for the sixth mass extinction to come and has triggered the quickest climate change in the history of the planet.

Two centuries ago – by the end of the Industrial Revolution, humans began polluting the world with an unprecedented effectiveness. The development of industry resulted in worldwide atmospheric changes, such as the rise of Carbon Dioxide (CO_2) and Methane (CH_4) levels in the consistency of the air we breathe. The sudden rise of human population and activities, such as the use of non-renewable energy sources, crude oil extractions, inadequate geological and industrial waste handling, deforestation and urbanization, extended use of chemicals, huge amounts of energy used and released, non-biodegradable materials, low recycling rate etc., influence the planet's' health and morphology, now more than ever. Important atmospheric, soil and seawater changes are occurring, while the acidity of the oceans is rising, ecosystems are being polluted and ruined, the biochemical element cycles are being disrupted, plant and animal species are threatened with extinction, the temperatures keep rising and the polar ice is melting etc., are just a few of the fallouts of the activities mentioned and these changes can be permanent.

The rise of the internet and the social media has played an important part on informing the world about the crisis we are dealing with. Every day we come across videos, photographs and articles about marine mammals and other animals washed up on shores with their stomachs full of plastic or trapped in ghost nets, animals in places that seem nothing like their natural habitat, major oil spills, desolated land and marine ecosystems and national parks, the bleaching and death of coral reefs etc. All that, along with scientific data, have reached critical mass, heralding the necessity of a more sustainable production and consumption model, aiming to reverse the current situation. The governments enact new rules and laws about waste management, mass production, raw materials origin and use etc. in the context of circular economy. As a result, various ecological movements, as well as individual efforts that promote alternative energy and material sources, have emerged. This led to an overall drift towards ecology, but also towards the need of new, alternative, non- pollutive, biodegradable materials.

During the past decade, the creation of materials from alternative sources is of great interest, as a means of the reduction of the environmental footprint of conventional materials' *(*Camere, Karana, 2018). These materials are usually plant or animal based or come from other recycled and renewable sources. For the creation of such materials, designers, material scientists and engineers are collaborating with other scientists and share their skills and knowledge. Therefore, this collaboration results in new materials and each part gains interdisciplinary knowledge.

This paper presents an exploration in the emerging world of mycelium undertaken during the master's thesis. The goal of the project is to create new knowledge, both collaborative and personal, about designing with this amazing, living material. The collaboration between design engineers and mycologists, aiming to a full recreation of a mycelium-based material by scratch, through scientific methods, in a small scale, DIY manner. At the same time in order to evaluate the experiential characteristics of mycelium we grew some in a home setting. This provides an overlapping perspective between DIY and clinical Biofabrication processes synthesizing a unique understanding of the differences and similarities. The central contribution of this paper is the experiential aspects of the process of working with mycelium as a material in a Material Driven Design (Karana et al. 2015) process and the different perspective in a collaboration between a designer entering the field and experts in the field. This knowledge is necessary in an emerging field and we hope our experiences will inform and enable other designers who want to engage in DIY Biofabrication by mapping the issues of entering a new field and collaborating with experts.

DIY & Sustainability

The concept of sustainability has a twofold meaning, as many use it to describe economic growth, while others refer to it through environmental preservation. Either way, it aims to address many issues on a societal, environmental and personal level. The notion of sustainability is much more influential, compared to that of eco-friendliness and, therefore, it is in the spotlight for the past few years and has gained great significance (Dresner, 2008). Sustainability nowadays is a heavily contested concept. A spectrum that encompasses all these ideas has been proposed (Bofylatos et. a., 2017; 2019). On one side*,* Eco modernist approaches aim to minimise the unsustainability of our systems of production and consumption. On the other side, that of the eco-modernity-sustainment spectrum, we find the transformative and radical ideas that emerge from the notion that reducing unsustainability to zero does not solve the root causes of unsustainability (Ehrenfeld 2013), but a new society has to be created based around a new system of values compatible with sustainability. The transition towards Sustainment may be equated in scale with the epochal shift of the 18th century Enlightenment movement, which founded many of the concepts and institutions that persist into the 21st century" (Fry, 2004).

Sustainability needs a deep shift in our material culture in order to truly achieve the transitions necessary. Do It Yourself is a term used to describe any act of creation, design, construction, modification or reparation, in specific ways, without the help of professionals or specialists

(Kuznetsov & Paulos, 2010). The DIY movement helped the younger generation of the 90s bypass the mainstream culture promoted by the industry of the time, and was, therefore, labeled as counterculture (Oakes, 2009). It pushes people to take matters – and technology with the maker movement – in their own hands. In the present days, were mass production, globalisation and consumerism have taken over the world, we can rediscover the importance of handcrafted artefacts, both aesthetically and ideologically, through DIY practices. That is because DIY is deeply connected with tradition, via techniques used for the fabrication of goods, like woodworking, pottery, knitting, embroidery etc. Doing it ourselves, we can feel the beauty of creativity as we produce something unique. It is everywhere around us, from the food we eat to urban and architectural design and it is affiliated with a more sustainable lifestyle by being eco-friendly and promoting sustainability.

The maker movement is the technological manifestation of the DIY movement. It concerns all sorts of broken, unused and discarded electronics, plastics and, theoretically, anything that comes from electronic and technological devices. The DIY movement though, is extending beyond the products themselves, to the materials that they consist of (Brownell, 2015). In the creation of a DIY material, the person in charge is a designer and not a scientist or an engineer. The rise of demand on customizable products has played a great part in the creation of these new, DIY alternative materials and the democratization of technological practices, through the increase of Fab Labs (common spaces with cheap and affordable facilities, as well as open source and infinite knowledge) – or DIY Labs or Maker Spaces – combined with anyone's desire for personalised creations, offers a great chance for experimentation.

While creating a DIY material, the designers' capabilities can be affected and reshaped alternately and accordingly, through "knowledge by doing" or "knowledge by interacting". The creators express their personality in this task of making unique materials and products. The DIY materials have aesthetic imperfections that depict the designer's performance and ability to create unique, personal and nonrepetitive applications. They also make the material true, as opposed to the perfectly shaped industrial materials. These imperfections though are not a negative attribution of them, but, instead, they add value to the product they constitute and highlight the process of creation and the sense of uniqueness. In this manner, the products that consist of such materials fit to the Japanese wabi-sabi philosophy, which accepts and praises the imperfection and impermanence of any object (Tsakanaki & Fernaeus, 2016). These aspects of DIY point to its capacity to put forward a system of values that is incompatible with that of modernity and the shift in cultural patterns from the sensate to the ideational (Sorokin 1937), a shift that is tied into the transition towards sustainability, degrowth (Kallis, 2011) and the reconstitution of the domains of everyday life (Kossof, 2015).

DIY materials come from self and collective practices and constitute an alternative to conventional material engineering. They usually result from unconventional sources through tinkering, and can be completely new materials, altered or upgraded versions of existing ones. Their existence sweeps through the designer world as a sustainable alternative, a medium of unique expressions or as an opposition to mass production.

There are 5 kingdoms/categories of DIY materials and each material is sorted based on the origin of its primary sources. This classification is actually an aid to the designer that contributes to the comprehension of the material in hand and its primary sources, as well as the creation procedure. Not all DIY materials strictly belong to one category, but they can belong to more than one and they can be combined (Garcia et al., 2017). The five kingdoms, according to Garcia, Rognoli and Karana are the following:

1. Kingdom Vegetabile – *PLANTS & FUNGI* | Designers can collaborate with farmers or other scientists for the creation of the materials.
2. Kingdom Animale – *ANIMALS & BACTERIA* | Collaboration of designers and living organisms or animal parts like hair, bones etc.
3. Kingdom Lapideum – *MINERALS* | stone, sand, clay | This kingdom is linked to crafts because the materials in it have a long tradition in our material culture.

4. Kingdom Recuperavit – *WASTE* | plastic, metal, organic | Waste can be transformed into a valuable resource is used to create new materials.
5. Kingdom Mutantis – *HYBRIDS & MIXES* | The materials are created from different technological mixes and hybridization of industrial, interactive or smart sources.

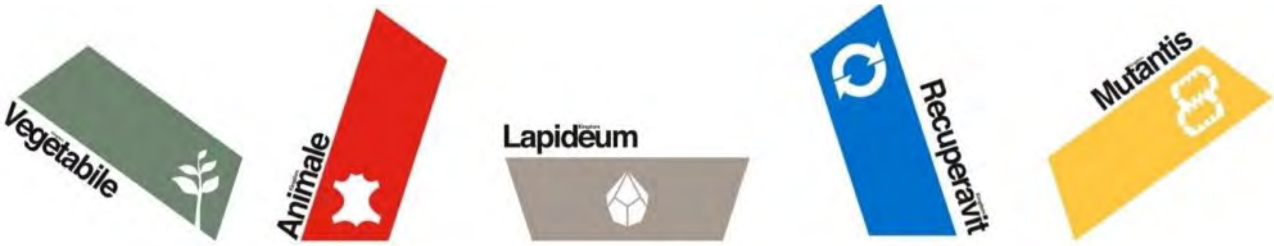

Fig 1. The five kingdoms of materials.

Biofabrication & Growing Design

Biotechnology, combining the principles of mechanics, biology and material science, has contributed, in a great degree, in the fabrication of sustainable materials, through the Biofabrication technology. Biofabrication refers to the production of composite materials and artifacts by the development of living organisms, tissue and cells (Mironov et al., 2009; Pavlovich et al., 2016; Fujii et al., 2016). This kind of materials was initially used in biomedicine, but their applications relate to other fields as well, such as energy production by biofuels and the development of sustainable materials. The production of these materials does not require the extraction of precious minerals and pure sources, but instead it is based on renewable raw materials that feed the microorganisms being used.

The power consumption is reduced, thanks to the exploitation of the metabolic rates of biological systems for the material production (Jones et al., 2017; Jiang et al., 2013), which leads to a lower ecological footprint. Biofabrication materials are eco-friendly, fully biodegradable and by the end of their life cycle they act as a nourishing substance for the production of new sources (Camere, Karana, 2018). Some of them, under specific circumstances, are able to interconnect and compound a mass (Jones et al., 2017; Lee, 2011) as well as to fully grow into specific shapes (Benjamin, 2014; Lopez-Nava et al., 2016).

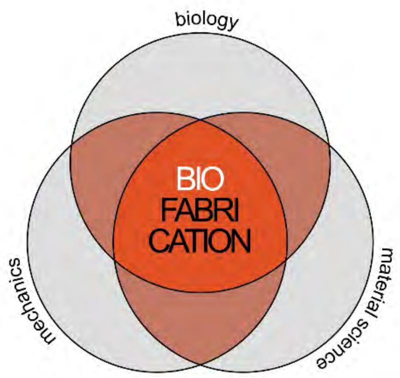

Fig 2. Biofabrication process.

Growing design is a subcategory of Biofabrication. It is a design practice which requires the cultivation of alive biological organisms for product development, in order to achieve unique properties, expressions and sustainable solutions for product design. It concerns particular sources such as fungi, bacteria and algae, and it seems to have borrowed other contemporary design and process practices that also concern natural sources like wood or plants (Camere & Karana, 2018). The ‘Growing Design’ framework is a field that brings about new design approaches in respect to the aesthetic and experiential aspects of materials, the creation of a human scale model of production and consumption, provides opportunities for the creation of a local, circular economy through the creation of local, vertical waste management. MDD and Biofabrication have the capacity to create the forms, materials and experiences that break down the barriers between the natural and the artificial providing the emerging ecological values of the next epoch of human development (Camere & Karana, 2018) to negotiate the new relation between human and nature shifting from slavery towards collaboration.

The procedure followed for the creation of such materials is more like the creation of a simple D I Y material. Mycelium is the vegetative part of fungi which consists of branch-like structures called hyphae. These materials can be either pure mycelium, cultivated on liquid substrates, or composite materials, cultivated on solid substrates. The second type results in a more consistent material with the properties like the ones of styrofoam. The production of a mycelium-based material is completed in four phases (Camere & Karana, 2018):

1. preparation phase - designers set the conditions for the materials' fabrication
2. growing stage - the organism fabricates the material
3. drying phase - to deactivate the organism and achieve the resulting material
4. the final shaping of the material - through different techniques

Case Study

We had heard about mycelium-based materials before and we thought: why not try making it ourselves? So, we began researching in similar papers to find instructions and work out the way to do it. We found out that in almost every similar paper the Grow It Yourself kit, by Ecovative Design, was used to recreate the material. We reached a team of mycologists from the Agricultural University of Athens to ask for their help, based on their experience on cultivating mushrooms and their overall knowledge on fungi. They didn’t know about mycelium materials but they understood right away what we were trying to achieve and they were thrilled to participate in that effort.

Fig 3. Substrates.

We scheduled a meeting to set our goals and come to the arrangements needed to be made. Would we use the GIY kit or would we do it by scratch? The mycologists insisted not to use the kit because, if we did, we would not be able to recreate the material considering that we wouldn't know exactly what is in that mix and in what percentage, and we, also, would not be able to control every variable. So, by listening to the experts points we decided to do it by scratch and settle on the species and the substrates we would use, which methods we would follow etc. We agreed to make enough samples to analyse the mechanical properties of the species-substrate combinations we chose as well as to investigate the users' experience with the material through tactile, olfactory and visual interactions. The mycologists believed that the mechanical tests were more important, but we, as designers, were just as interested in the second part of the project.

We discussed the species and the substrates that we could use to test the mechanical properties and agreed to use the following:

FUNGI – Pleurotus Ostreatus, Ganoderma Lucidum and Abortiporus Biennis,

SUBSTRATES – Beech wood chips and wheat straw.

For the user experience tests we tried to use a variety of different substrates, such as cereal (oatmeal), seeds (quinoa, flax, poppy), herbs (rosemary and tea mix), flowers (chamomile, lavender, amaranth, hibiscus, bougainvillea) and other plant fibers (pine needles, red lentils, corn silk, peanut shells) in different shapes and sizes, to determine the difference a substrate can make. The fabrication procedure was a bit different for the specimens of each cause. It was because we had little time in our hands that we chose to complete one part of the project under laboratory circumstances. That part was the creation of the specimens for the mechanical tests, in which we were all equally interested. It was the logical choice because the specimens should grow properly with no interference of external factors, to get accurate results. Everything had to be done with extra caution to prevent any contamination by another microorganism, bacteria or fungus. That being said, we used a lot of alcohol before we had any contact with the spawn or the substrate, and as we mentioned the inoculation was completed within a sterile chamber. In that point we have to stress our disappointment regarding the flower substrates. Their submersion and sterilization made their colors disappear, and they had all turned brownish.

During these two efforts, we tried to keep our desktop and equipment as clean as possible and free of contamination sources. We used alcohol every time we had to touch something and we sprayed everything with it. We had to be really careful with the use of alcohol because if the spawn came in contact with it, the fungus would die.

In this sense this could be seen as two inseparable case studies, one of clinically growing mycelium to be subjected in mechanical tests and a DIY attempt to explore the different aesthetic characteristics that different combinations between fungi and substrates combinations. These two are inseparable because they were undertaken by the sane group of people at the same time and because they were in an open dialogue between themselves.

Mechanical Tests

PHASE 1 | *Preparation*

The preparation procedure was completed within three days since we had already collected the substrates and the mycelium spawn. So, to start with, we gathered everything we needed, including substrates, moulds and the mycelium spawn. On the first day, we checked our moulds and made some adjustments while we put the substrates in water overnight to obtain the moisture needed for the fungus to develop. The next day we took them out, drained the excess water and put them in the moulds within sterilisable bags and then in an autoclave to sterilize them in 121 °C (1 atm) for an hour. After that hour passed, we left them in the autoclave to cool down until the next morning, where we inoculated them with the spawn, within a sterile chamber.

Fig 4. Growing phase.

PHASE 2 | *Growing*

After the inoculation we put all the moulds in a clean room with controllable conditions of temperature and humidity. It took a month for the specimens to be ready and we had some loss, of course, since a small number of the specimens was contaminated and some had not even started growing. We also lost all the specimens of Ganoderma Lucidum – wheat straw. The choice to let the fungi grow for exactly 23 days even if they had not reached a full growth was made in order to standardise the mechanical tests. However, the voracity of the different species differs causing very different mechanical properties to the different combinations of fungi and substrate.

Fig 5. Drying phase.

PHASE 3 | *Drying*

The drying took place in a lab oven and only the mycologists were present during that process, therefore we do not know exactly how much time it took them to completely dry and in how many degrees making it a blind spot for this study.

User Experience Tests

PHASE 1 | *Preparation*

The process of the user experience tests specimens was conducted in more DIY manner. After we had completed the first part of our project, we knew better than before what we should avoid and what we should do. The preparation and sterilization of the substrates was completed in two different efforts with two different ways. First of all, we put everything in water, same way as before, but for less hours and only sprayed the flowers to prevent the color loss. For the first try we put every substrate in a bag and then every bag on a pressure cooker for five seconds, because sudden exposure to high temperatures is said to kill microorganisms. After we took them out of the pressure cooker, we let them cool down and then inoculated them with the spawn. In the second effort, the sterilization was made in a house oven on 200 °C for half an hour and the inoculation the same way as before.

PHASE 2 | *Growing*

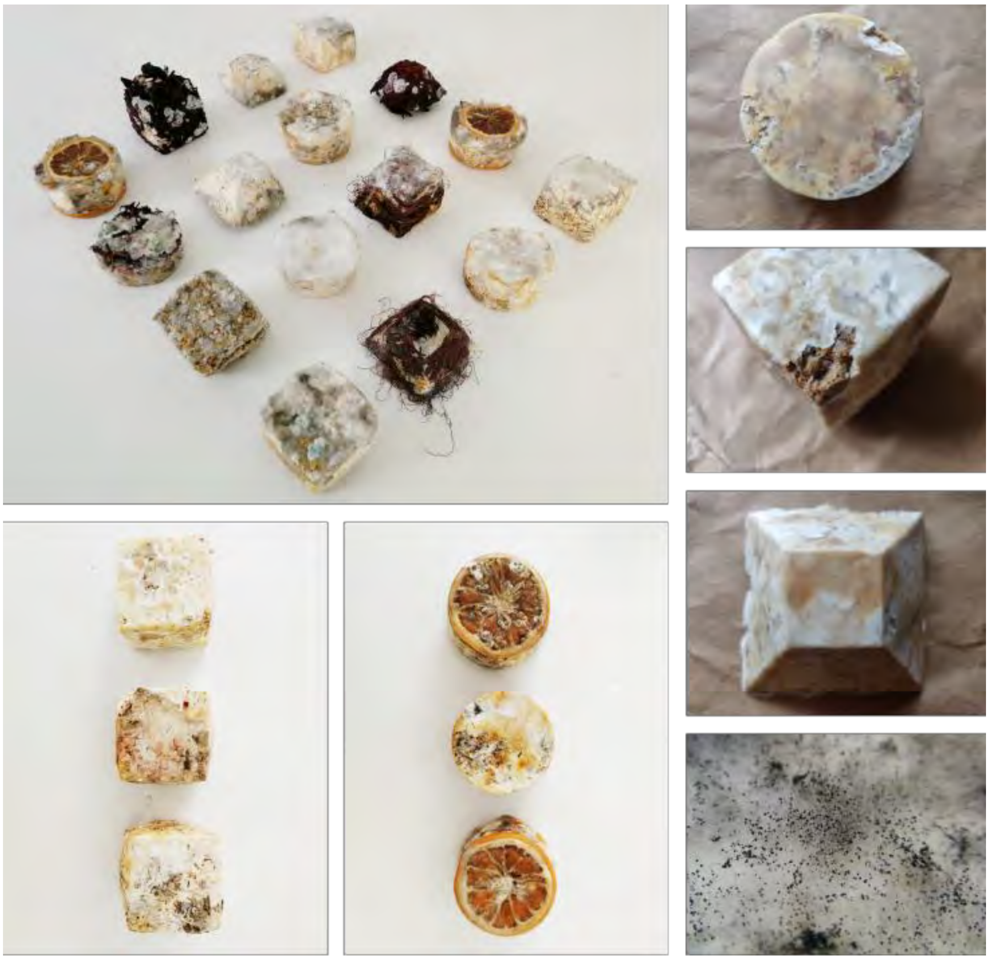

Fig 6. Specimens for use test before drying.

On the first try we put the bags of spawn and substrate mix in the fridge and left them there to grow. We knew now that the fungi need a humid, cool and dark place to grow, so a small fridge looked ideal. They grew really nice, indeed, and once they became white, we put them on the molds and then back in the fridge to let them grow some more. On the second attempt, we put the mix of spawn and substrate directly in the molds and then in a dark and humid room in a basement. This was a little risky because none of the conditions there could be controlled. The final products were all a little contaminated due to the lack of clean rooms.

PHASE 3* | *Drying

Fig 7. Specimens for user test after drying.

We put them all in a household oven to dry, on 100 °C for at least thirty minutes. That was not enough, as we could still feel the moisture when we touched them. We put them again on the oven and waited until they looked dry enough. That was not enough either and after a few days we saw some more mould grow. That being said, none of the specimens was fit for a user test and therefore the second part of our project was left unfinished. This, in our view is the first practical takeaway for this study. Fungi are fickle and sensitive, making them grow even in a lab, let alone in your house under your bed, can prove challenging. This is tied with the very idea of designing WITH another organism, we cannot treat a living thing as merely a parameter in an equation. During this whole process we begun to attribute psychological characteristics at different varieties of fungi, looking at them as collaborators in this process not just a material. This points to what epistemologists working in the field of sustainability refer to as a change of values and ontologies. Changing our perspective of nature has long been deemed a necessary step in the transition towards sustainability (Bookchin, 1982).

Test Results

In this section the results of the mechanical tests undertaken are presented and discussed. Two tests were undertaken, a strain test with five different types and a bending with four different types of specimens.

Strain Tests

The cross section of the specimens that were submitted in strain tests, was 7.5 cm x 7.5 cm with max. height 7.5 cm (wheat straw) and 8.5 cm (beech wood chips). The results from these tests are the following:

- The wheat straw specimens were much more consistent than the ones with the beech wood chips and the material was restrained and coherent. On the contrary, the wood specimens, almost immediately, lost their coherence and split. They all split in a similar way, which was probably because of a thicker layer of mycelium formed in their upper side, which holds the pieces together.
- The average load the wood specimens withstood was far lower than that of the wheat straw combinations.

- The more consistent were the ones with the wheat straw, which did not show great divergence.
- While under tension, the wheat straw specimens were quite compressed, but only the straws that were parallel to the direction of the applied force were detached, without compromising the materials coherence. After the load was removed, these specimens regained a percentage of their initial volume and although permanent deformation was observed, there were clear evidence of elastic behaviour. The average elastic deformation of the Abortiporus Biennis specimens was 20.4 %, while that of Pleurotus Ostreatus was 29.4 %.

	avg. MAX FORCE F (N)	avg. MAX STRESS σ (MPa)	typical deviation of STRESS Sσ(MPa)	MAX STROKE δ (mm)	MAX STROKE STRAIN %	avg. Young's Modulus E (MPa)	typical deviation of Young's modulus SE(MPa)
abortiporus biennis WHEAT STRAW	4236.77	0.75	0.14	46.97	58.7	-	-
abortiporus biennis BEECH WOOD CHIPS	825.39	0.14	0.1	50.01	62.5	0.29	0.1
pleurotus ostreatus WHEAT STRAW	5326.63	0.94	0.17	50.02	62.5	-	-
pleurotus ostreatus BEECH WOOD CHIPS	148.15	0.03	0	16.79	20.8	0.23	0.1
ganoderma lucidum BEECH WOO D CHIPS	391.35	0.06	0	27.17	34	1.72	0.94

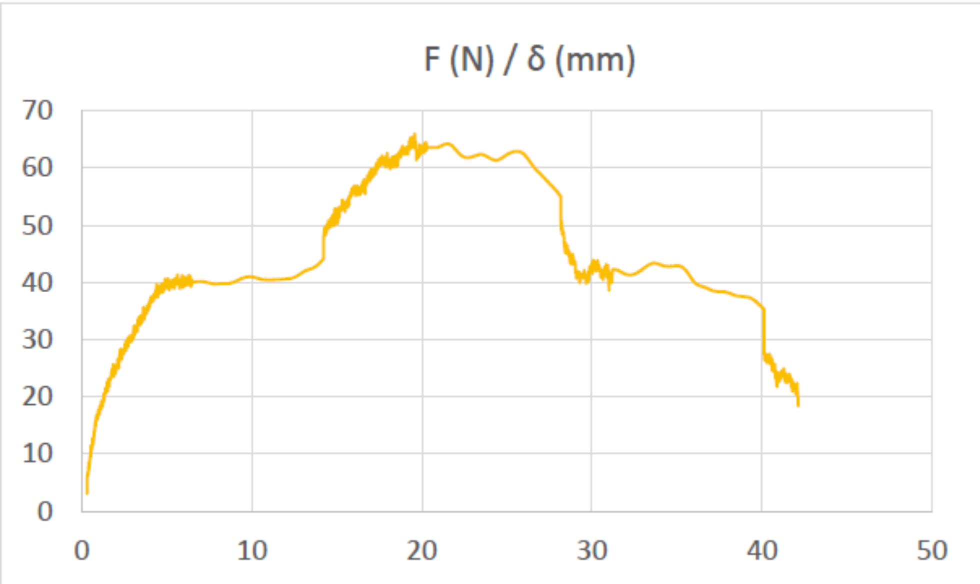

Fig 8 Typical diagram of a wood specimen in strain test.

Fig 9. Photos of the specimens during the tests.

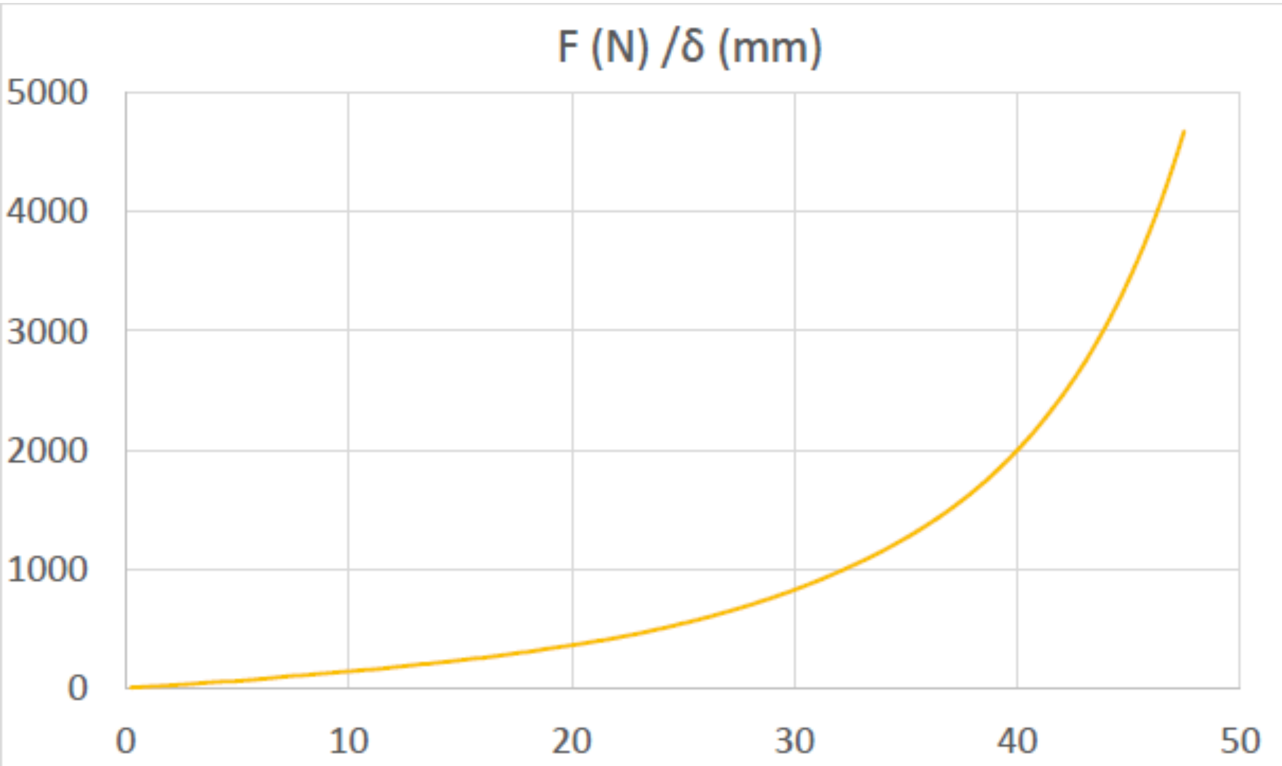

Fig 10. Typical diagram of a wheat straw specimen in strain test.

Bending Tests

In contrast with the strain tests, the specimens submitted to bending endured very low loads. We used cylinders of 2.5 cm diameter and maximum length 14 cm, as well as rectangular specimens 2.5 cm x 2.5 cm x 14 cm. The results are the following:

- The crack that is created from the applied force is transmitted in a slower rate on the wheat straw specimens, as opposed to the ones with the beech wood substrate. Therefore, the wheat straw – mycelium material is more resistant to fracture.

- The wheat straw can withstand greater load for bigger strain.

	avg. MAX FORCE F (N)	avg. MAX STRESS o (MPa)	typical deviation of STRESS Sσ(MPa)	MAX STROKE δ (mm)	MAX STROKE STRAIN %
abortiporus biennis WHEAT STRAW	4236.77	0.4	0.1	46.97	58.7
abortiporus biennis BEECH WOOD CHIPS cylindrical	825.39	0.18	0	50.01	62.5
abortiporus biennis BEECH WOOD CHIPS squared	5326.63	0.33	0.54	50.02	62.5
pleurotus ostreatus WHEAT STRAW	148.15	0.16	0	16.79	20.8

In conclusion, through these tests, the fact that such materials have a completely different behaviour depending on the substrate that is used, became clear to us. Specifically, the mycelium was not able to connect the distinct wood pieces that were use, because of their size, but also their random distribution in the mold. On the other hand, the filament like structures of straw form a kind of net, while being placed in it. This contributes in the coherence of the materials, and makes it easier for the mycelium to “glue” them together, forming a strong material.

The strain test results suggest that the material discussed had a linear behavior, for little stress, that is represented near the axis, and therefore is not visible. The Abortiporus Biennis strain seemed to be more developed in wood, compared to the other strains. Maybe that is the reason these specimens were more coherent and had a better overall performance. According to the graphs that were produced during the tests, the wood specimens were brittle and resemble ceramic materials, while the wheat straw ones resemble elastomeric foams.

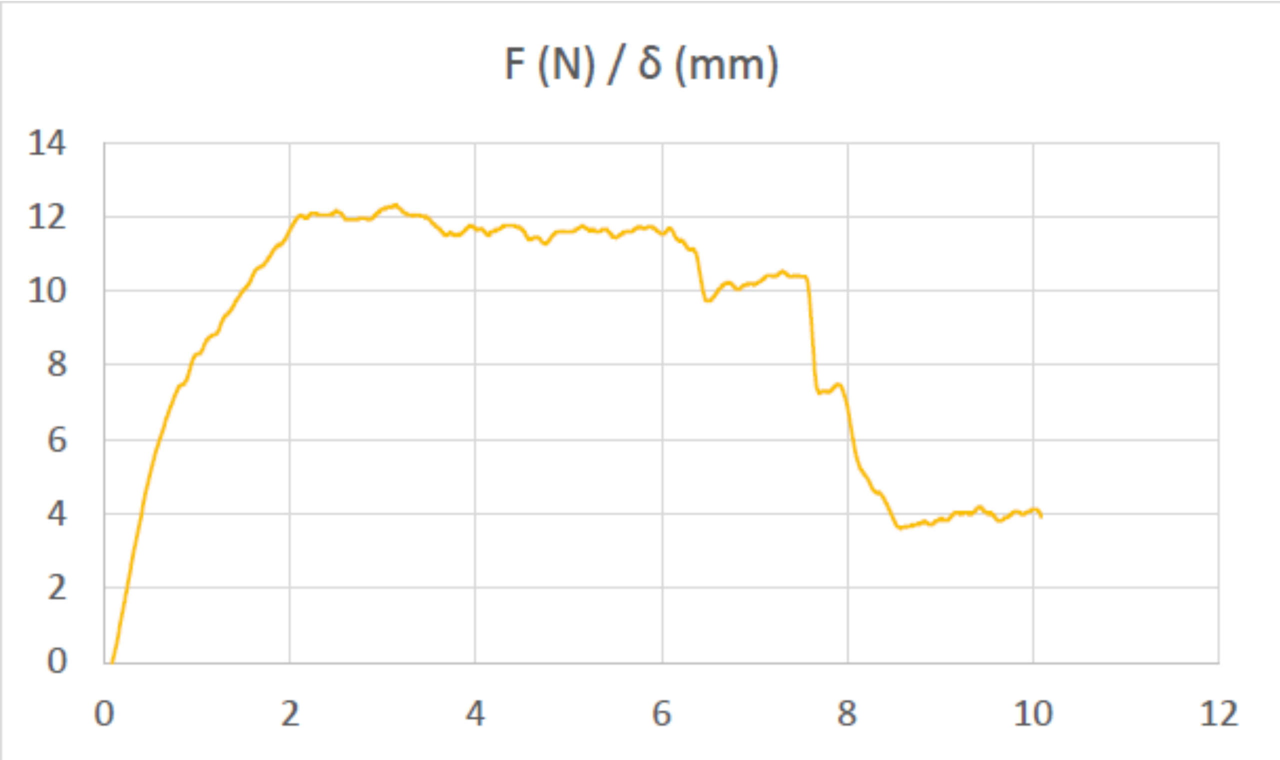

Fig 10. Typical diagram of a wheat straw specimen in bending test.

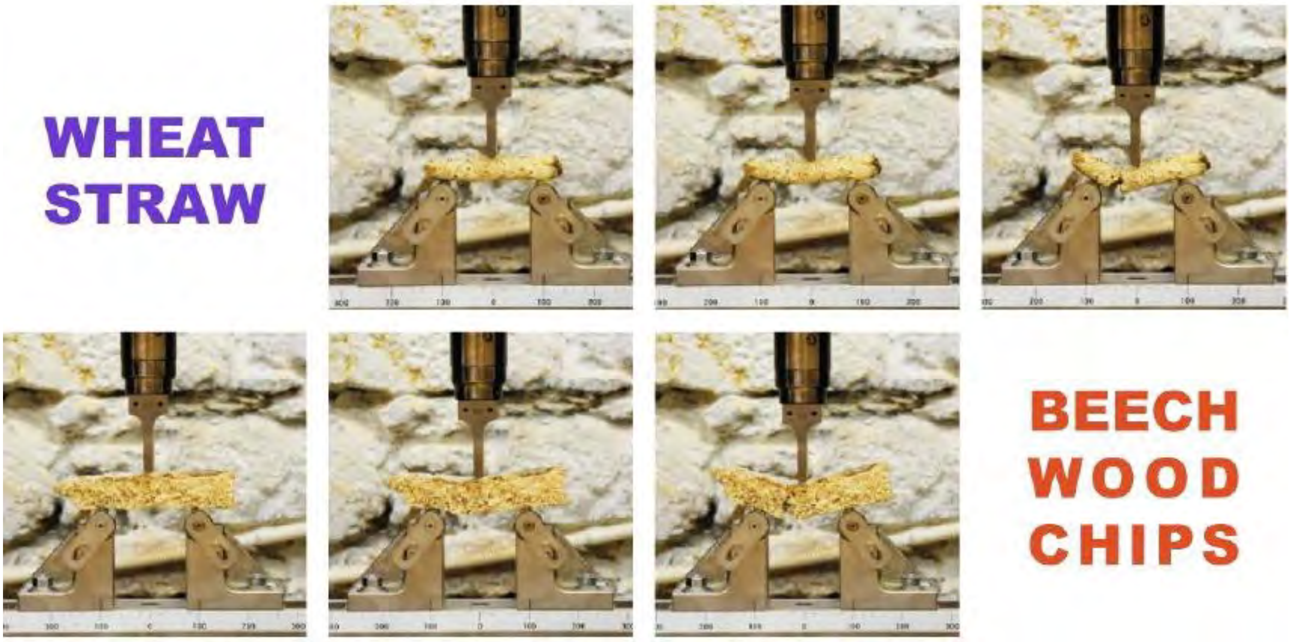

Fig 11. Photos of the specimens during bending test.

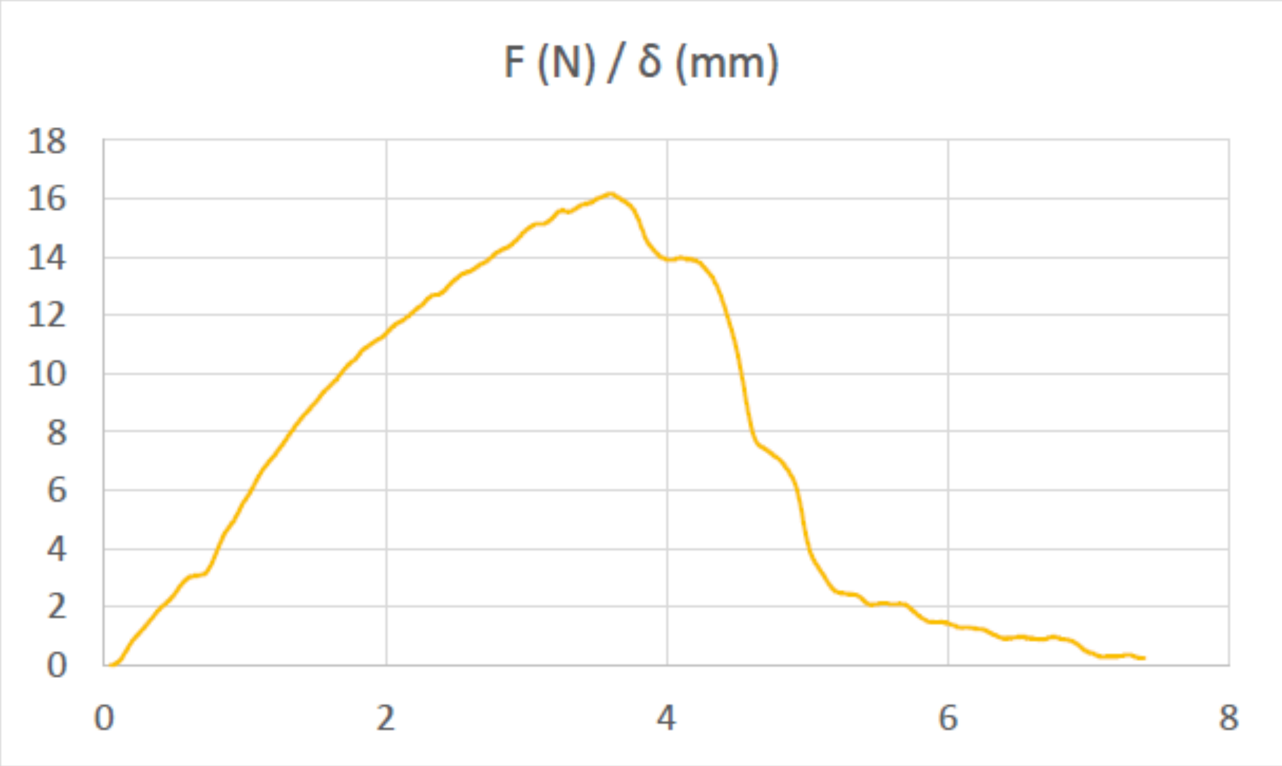

Fig 12. Typical diagram of wood specimen in bending test.

Discussion

We, as designers, humanize the material as opposed to the mycologists who just see the species of fungi and their mechanical properties it. We see more than that in this alive, DIY material. We see feelings, memories and responses arising from its looks, smell and texture, while we interact with it. We will not forget how the smell of mycelium made us feel the first time we stepped in the laboratory. That sweet smell brought to mind something completely different than fungi, something that reminds cocoa beans and chocolate, as well as the smell of bakeries early in the morning. With that being our first impression, we were more than ready to explore the nature of this unique material.

Something that seemed strange to us, that they were not as open to experimentations as we expected them to be. We found some substrates to be very interesting for the mycelium to grow, substrates that were not it the literature at the time and we wanted to test them and see how the material forms. We suggested some of the substrates to them and they condemned them right away, without even trying. That was not only discouraging to us, but it also restricted us, concerning the final results we could have. By the end of the cultivation process we managed to raise their interest on the material experience, hoping they would help us with the creation of the specimens for the user tests, but their priorities were still straight. Based on their theoretical knowledge, but also previous experiments, they could easily turn down any suggestion that would take them off schedule. The fact that we did not deal with both of our projects parts in the same level of severity, resulted in negative results on the material experience tests we wanted to conduct.

We have noticed that, in more than one occasion, the opinion and suggestions of the only female member of our team were not taken as seriously and was dismissed. This refers to the above, but also other technicalities we came across. We believe that this attitude was not deliberate but can be attributed to her lack of experience and young age, but also, subconsciously, since she was the only woman in a team of men.

This collaboration of design engineers and mycologists turned out to be fruitful in many ways and for both sides, despite the misunderstandings and restrictions we faced. The whole task had pretty high chances of failure from the beginning, since we were sailing in unknown waters. Working with a living material is anything but easy and anticipated. You can never know if you did everything right until the material shows you, and you can only guess what went wrong. The creation of DIY materials, and mostly living ones, is a process of trial and error, in which you have to record every step and any variable alteration, until you get what pleases you and what meets your requirements. Then, you will be able to recreate it. Despite the little time we had and the uncertain nature of our project, we managed to collect some positive results. If we used the GIY kit, we would still be in the dark, regarding the proper ways and methods to follow for such a DIY experimentation. We learned that when it comes to growing fungi everything must be taken under consideration, the substrate, the light, the temperature, the humidity and most important the sterilization. Finally, the two-pronged approach that was undertaken during this project provides a unique overview of the field but at the same time creates a problem. The entanglement of scientific, explicit and tacit knowledge as well as the plurality of viewpoints and the interdisciplinary character of the endeavour requires deep reflection and reflexivity to transform into useful and meaningful contributions for the community of scientist, makers and DIY aficionados.

Conclusions

The turn towards ecology and sustainable development is a very important step not only for our planet to prosper, but also for our own well-being. It is, therefore, necessary to approach design differently, through the nature of raw and final materials being used. The mushroom materials embody the concept of sustainability and promote circular economy. They have very good aspects and potential, but they also have limitations that concern their production and application fields. The literature suggests many unexplored fields and substrates to be used, as well as ways to tinker with the material in means of colouring, shaping, function etc. Living materials are an interesting and unique subject for experimentation. Combining large scale Biofabrication processes with DIY tinkering is an invaluable part of the process of defining and refining new materials that are conductive to the transition towards sustainability beyond an eco-modernist agenda.

The overall collaboration experience was satisfying but there are some parts of it that need to be reviewed. Firstly, both sides of the team, in this case the designers and mycologists, should clearly state their goals from the very beginning of the task. If the goals do not align, an optimum solution should be generated to serve everyone included, or the goals should be dealt with the same amount of severity, to avoid loss from the desired results. Therefore, a thorough plan should be composed and the goals must be clear. Moreover, when the scientific background and experience of the team members diverse, the reasons for the rejection of ideas should be clear and well explained to avoid misunderstandings. Mutual respect and interest are essential for a collaboration to be successful, and everyone should help anyone that needs help.

Acknowledgments

We would like to thank the team of mycologists for the knowledge they shared with us and their precious assistance in this endeavour. We are looking forward to extend this collaboration and take our common knowledge, as well as our experience with the material, one step further.

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Niki Boukouvala

Niki Boukouvala is a young Designer and a recent graduate of Department of Product and System Design Engineering, University of the Aegean, currently based in Athens, Greece. Her main focus lies in product engineering, service and graphic design, and she is also passionate about sustainable architecture and design, as well as research for new materials and technologies. She is excited about new ideas and innovative approaches to existing problems, while she experiments with new materials for crafting in the real world, as well as mastering the design techniques of the digital world.

Spyros Bofylatos

Dr. Spyros Bofylatos holds a doctorate in theory of Design from the Department of Products and System Design Engineering of the University of the Aegean. His research sprawls around design for sustainability, craft, service design and social innovation. His work is based on creating meaningful dialogue between the theoretical framework and the sociotechnical propositional artifacts that embody different research questions. At the very core of this process is the notion that we live in transitional times and fostering the discourse that leads to networks of artifacts and communities that embody alternative systems of values is necessary to move away from today's unsustainable society.

Nikolas Zacharopoulos

Nikolas Zacharopoulos is a Lecturer at the University of the Aegean. He teaches materials science and materials selection to design engineers. The focus of his research lies in modelling microstructural features of metals (dislocations, grain boundaries, cracks) and their interactions. He was a post-doctoral fellow at NCSR Demokritos, where he worked on dendrimers and coarse-grained potentials. He is a graduate of the National Technical University of Athens and holds a Ph.D. from the University of Michigan.

Sustainability Principles through Educational E-Textile Kit

Paula Veske, Department of Electronics and Information Systems, Ghent University, Belgium

Barbro Scholz, Stühmer|Scholz Design, Germany

Abstract

Innovations in smart textiles technology are on the rise with a promise to add value to the consumer's life (Goodman et al., 2018). However, these innovations and the high development speed involved also raised concerns about environmental issues related to these trends (van der Velden, Kuusk, & Köhler, 2015). Therefore, TTorch project was created to bring different fields like electronics and textile engineering together to create a kit for educational purposes and follow circular economy principles during the process. TTorch is a creative toy with a development kit for up to 10-year-old children, using e-textile principles. The product kit creates a bridge between engineering and design, by letting the user explore a personal light source and build surroundings to it. The goal of the project is to show how interdisciplinary fields can work together and with that creating different opportunities. This paper gives a short overview of e-textiles, research on e-waste, textile waste and e-textile waste management. Further on it will focus on the necessary collaboration between design, engineering and industry by emphasising difference between core team and network around the core team. The collaboration aims to create an ecological product kit for educational purposes following the concept of STEAM. Discussions will include how collaboration between team members with diverse backgrounds, and their surrounding network was necessary to identify the specific gap in the market and to evolve the idea from product to development kit.

Keywords

E-Textile; Education; Collaboration; Design; Sustainability

Different wearables and everyday electronics (like smartphones) push us towards connected living and have increased interest in smart textiles. The development of flexible electronic products has provided more ways for smart textiles to seamlessly integrate into everyday life (Goodman et al., 2018). Innovations have been so rapid that the focus of creating environmentally sustainable and, moreover, durable products, has been discarded. It is critical to start educating people on the topic early and to bring textiles closer to the science world. A study by Ercan and Bilen (2014) showed that primary school students are insufficiently taught about electronics waste awareness which plays an important part in smart textiles. Furthermore, the study states that the need for the environmental education of individuals and societies has emerged with the current increase in environmental problems. Especially in the e-waste field with great amounts of electronics shipped to third-world countries and then buried in landfills or burned. To achieve successful solutions, it is essential to have collaboration and to share knowledge between different fields of expertise. Thus, creating an interdisciplinary development kit for kids would create awareness for sustainability in several research areas, like textiles and electronics, early on.

The article will start with a short introduction to e-textiles, electronics and textile waste management and research on e-textile waste management. The overview gives fundamental knowledge about current research on the topic and context for the necessity of environmental sustainability education. Further on, the TTorch project will be introduced with a focus on the topic of environmental sustainability with e-textiles. The article will discuss creating a successful collaboration when the team members have different cultural backgrounds and are working in different countries. Moreover, how the core team size is kept small and how additional value comes from network collaboration across the entire field.

E-Textiles

E-textiles (electronic textiles) are part of a bigger field called smart textiles. Smart textiles are fabrics or apparel products that contain technologies which sense and react to the conditions of the environment they are exposed to, thus providing the wearer with increased functionality (Van Langenhove & Hertleer, 2004). The conditions or stimuli can be of mechanical, thermal, chemical, or of combination nature (Van Langenhove & Hertleer, 2004). E-textiles are smart textiles that have electronics incorporated in them by using different integration technologies, like crimping, laminating, soldering etc (Van Langenhove & Hertleer, 2004).

The global e-textiles (smart textiles) market is growing rapidly, rising from USD 795 Million in 2014 to a predicted $4.72 Billion by 2020 with a predicted growth of 33.58% between 2015 and 2020 (Goodman et al., 2018). There are many health and quality of life benefits of e-textiles in medical, healthcare, sports, and quality of life contexts, where they can, for example, facilitate health monitoring (Katashev et al., 2019). Moreover, Suunto Movesense Sports Bra with integrated textile electrodes for heart rate monitoring is available since early 2019 (Suunto). Additionally, Levi's Commuter Jacket made in collaboration with Google helps bike commuters make a safer and more convenient trip (Levi's&Google). The jacket has already been on the market for many years. Energy harvesting is also entering the smart textile world since it is possible to use the movement of a human body as an energy source (Hou et al., 2013; Hu & Zheng, 2019).

Innovations in smart textiles technology promise to add value to the consumer's life and satisfy the textile industry's demand for new market opportunities. However, these innovations and the high development speed involved have a counterpart as well: they raise concerns about environmental issues related to these trends. There is a knowledge gap to support the decisions. To fill the lack of environmental knowledge of these designers, their managers and clients as well. Since textile designers make numerous product development choices and influence the architecture of products based on the market and user insights. (Van der Velden et al., 2015)

Environmental Sustainability in E-Textiles

However, since the smart textile field is interdisciplinary and requires knowledge transfer from the textile, ICT and electronics fields, it is even more important to focus on environmental friendliness before products reach the mass-market. Since e-textiles contain both textiles and electronics, it is critical to have an overview of the state of waste management in both the electronics' and textile industries.

E-Waste and Textile Waste

Ilankoon et al. (2018) present in their work that the current status of electronics waste management estimates that about 44.7 million tonnes of e-waste was generated in 2016 and is expected to reach to 52.2 million tonnes in 2021 with an annual growth rate of 3-4%. Furthermore, they state that the EU formed the WEEE directive, Directive 2002/96/EC in February 2003, (EU, 2003) and it promoted reuse compared to recycling by also emphasizing that producers must take responsibility for the collection and treatment of their end-of-life equipment. It was reported that within the first few years since the implementation of the WEEE directive, about 67% of collected e-waste in Europe remained completely unaccounted for. Since the initial legislative framework did not achieve the desired goals, the European Commission revised the directive and the new WEEE Directive 2012/19/EU (EU, 2012) became effective in February 2014 (Ilankoon et al., 2018).

According to the Directive, the Member States are expected to make sure that from July 1, 2006, newly marketed EEE shall not contain any lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) in concentrations above the defined maximum concentration values (MCVs) for homogeneous materials (Wäger et al., 2012).

Meanwhile, in the EU alone, clothing and household textiles are the fourth most polluting products, from a lifecycle perspective (Beton et al., 2014). Globally, 3% of all greenhouse gas emissions are caused by the production and use of textiles (Nørup et al., 2018). In general, the consumption of textiles is rising, not only because of population growth but also because increased prosperity has led to countries such as China beginning to approach European and American levels in this regard (Beton et al., 2014). In Denmark and Sweden, the consumption of clothing and household textiles has increased, respectively, by 62% (2003–2008) and 40% (the period 2004–2014) (Nørup et al., 2018). Therefore, since the e-textile field combines two quite worrisome markets from an environmental point of view, the focus on getting people to think about creating environmentally sustainable e-textile products must be greater.

Both the electronics' and textile waste management fields are currently researchinghow to improve the situation. For example, Sahajwalla and Gaikwad (2018) write about an emergent alternate class of technology which can transform e-waste plastics into high-value products 'Microfactories'. Emerging Microfactory technologies are addressing the e-waste plastics problem by transforming them into value-added products such as Grenew briquettes for steel making, supercapacitors, silicon carbide, polymer composites and 3D printing filaments. Also, on the textile field, the Trash-2-Cash research project (Trash-2-Cash, 2015-2018) started with EU funding and with an the aim to create newly regenerated fibres from pre-consumer and post-consumer waste. The project included 18 partners spanning 10 countries including designers, design researchers, scientists, raw material suppliers and product manufacturers from across Europe. When the project ended in 2018 the outcomes were high-quality materials and product prototypes from waste, offering companies in various industries (fashion, interiors, automotive and other luxury goods) new eco-fibre options. However, the pace of change is still slow. E-textiles still haven't reached the mass-market and thus, all the mistakes with e-waste and excessive textile waste can still be avoided. Therefore, early education on e-waste and textile waste is critical.

TTorch Product kit

TTorch is a kit for children to learn with e-textiles about materials and technology and through the animal character about the animal's capabilities and its living environment. TTorch first kit lets children imagine who lives in deep seas. The main part is a character, octopus Ceffys (Fig 1 and Fig 2). Toy character is mostly ready-made, however, it will be visible how it is built. Supplementary add-ons, like e-textile quilt blanket, with different storylines, will be available that could be put together by the children. This creates and gives the opportunity to explore the characterand its functions and then develop the surroundings via blanket and story booklet. The booklet is being available as printed or in online form, to teach different facts about the character and its natural environment, including topics like pollution in the oceans. The kit brings together technology and the textile field from early on by focusing also on the environmental sustainability of e-textile products. The kits and products can be returned to the creators after their life-cycle by shipping them back for disassembly and reuse. This system supports the closed loop idea where the product life is circular.

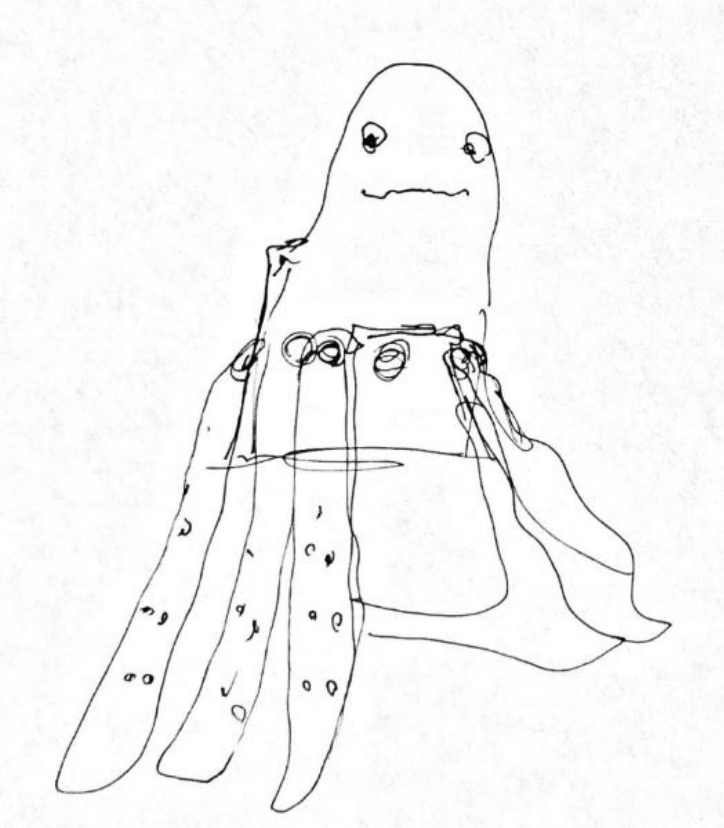

Fig 1. Early sketch of Ceffy the Octopus.

Fig 2. First prototypes for TTorch.

Context and Use

The aim of the kit is to reach as many users as possible. Therefore, the kit can be experimented with in workshops and/or at home. Workshops at events, schools, kindergartens and even at birthday parties could provide an opportunity to see what is possible and how the kit works before buying it. Depending on the age of the children, assistance from adults may be necessary. The connections between nature and technology become clearer through this hands-on approach and textiles make it easier for children to get started with these topics. It allows the use in interdisciplinary teaching methods. For example, preschools could use the kit in textile focused courses, technology courses or nature and biology courses.

As the parts of the kits are interchangeable, they will be useful in group learning and collaboration at an early stage: by sharing and exchanging parts or by building one big creature together.

The availability of information and a personal introduction to textiles and tech are essential for the success of the kit. Since visual media is an effective communication method, it is also necessary to create tutorial and inspirational videos explaining the different ways in which the kit can be used, how the electronics work in the textile and why they are used.

STEAM and Education

The kit contributes to the concept of STEAM (Science, Technology, Engineering, Arts and Maths), to motivate children to learn with a toy that they can even design themselves. Using nature as the central theme provides opportunities for education on multiple levels and subjects. Moreover, the flora motif creates a base that focuses on nature and sustainability.

Peppler (2013) mentioned in her paper that STEAM-powered tools and materials allow for open-ended exploration, a high degree of personal expression, and aesthetically compelling possibilities. Also, how emerging tools, materials, practices, and products at the intersection of the arts and the STEM disciplines could revolutionize computing education as well as have rippling impacts within each of these fields. She showcases that in their study, e-textiles bring together knitters, composers, dancers (as end users), biologists, and computer scientists. Thus e-textiles demonstrate how interdisciplinary the work can be.

Developing a STEAM educational product, interdisciplinary knowledge from all involved fields must to be gathered, as well as experts on pedagogy to assess the realistic usage and possible handling of the kit by children, focusing on their motoric skills for example.

The team’s backgrounds merge knowledge from all STEAM fields. Thus, it is possible to make an educational kit with artistic methods and designs together with basic engineering and electronics principles. Bringing in experience from smart textiles research, environmental sustainability principles can then be incorporated into the kit’s design. There are more examples of STEAM use in environmental sustainability education.

For example, in 2016 Nord Anglia Education announced the details of its new science, technology, engineering, arts and mathematics (STEAM) curriculum, developed in collaboration with one of the world’s most influential universities, the Massachusetts Institute of Technology (MIT). Students were challenged to solve a real-life problem facing their local community, e.g. they had to identify and describe an environmental problem in their city and its impact on the overall health of the city including air, food, water, energy, transportation and waste. The initial programme was launched in 13 schools in September 2016, and the project is still ongoing (Education, 2016).

Parts

Each kit consists of several parts which are prefabricated, so that the assembly of the product would be more enjoyable. Prefabrication also includes thermoplastic polyurethane (TPU), so that there would be less sewing required, resulting in more durable products in the end. Usage of TPU films enables the electronics to live longer in textiles, especially when it is necessary to wash them and (in general) make them more resistant to the influences of moisture or dirt. Later, electronics can be delaminated and the parts can be reused.

Moreover, different conductive materials and/or electrical conductors, like stainless steel snap buttons, are used for creating mechanical connections in the circuit. For example, the use of colour code snaps or conductive hook and loop strips for making the connections within circuits.

The components do not include printed circuit boards (PCB), in order for the product to be simpler and environmentally sustainable. Furthermore, by leaving out PCBs and designing only mechanical circuits, it creates more options to play around with the kit.

The goal of the TTorch is to be simple enough and easy to understand, that children could assemble it by themselves. Additionally, they would be able to focus on the playful part of it, rather than spending effort on simple connections and getting started.

Make of the Kit

One of the main goals was to create the kit in an environmentally sustainable way. Textile parts of the kit are made of fabric leftovers from a network of textile product manufacturers. Using leftovers also creates awareness of the materials and their origin. Since fabric scraps can include very different materials they allow for more creative freedom and assembly options. A digital print on some of the parts might be used to brand the parts, and to give the possibly different materials from the leftovers a more uniform look.

It is complicated to use electronics sustainably with the current state of the technology. Currently, one of the best options is to work towards a more sustainable design of everyday objects. An efficient design allows for reduced waste production by creating patterns with a low percentage of fabric loss. The layering system of the product by TPUs make parts reusable and/or recyclable by disassembling the layers under heat. The designing phase focuses on creating a valuable product that can be repaired instead of being utilized.

Moreover, the sourcing and production of TTorch will be planned regionally, which reduces emissions for transport and logistics. Establishing a local circle of product creation, provides an opportunity for closed loop production. Meaning, when products are not used anymore or need repair then users can return them. Closed loop provides the possibility of control over old products and makes a second-hand market available.

Collaboration

TTorch Team Collaboration

TTorch interdisciplinary two-member core team consists of experts in the fields of textile and product design and electronics know-how together with textile and garment production experience. The core team first member has industrial and textile design background with e-textile knowledge and creates different prototypes and product concepts in the field. Second member has expertise in textile and clothing engineering with experience in different production companies. The two perspectives create results from discussions, as problems can be evaluated from various sides. Questions that cannot be answered by the team members can be identified and external experts from surrounding network can be consulted.

It was essential to see how the skills are best divided between tasks. It was identified how to use the previous experiences of partners, like having an overview of realistic production processes while also bringing the newest information from the research field. Moreover, the collaboration complemented the project by transforming the idea from just a toy product to development kit that would educate on critical topics.

Since the team members are located in different countries, regular discussions are mostly held through online media, whereas a few physical meetings, to work together and form team thinking, are also held. The project contains both practical and theoretical tasks. All planning, outline discussions, and sharing of ideas could easily be done through email and files shared online.

In the first prototyping meeting it became clear how important it is to work together and be able to find solutions for the next steps and shape team integrity. Also, on the technical side, it was productive to work out small but crucial details to understand each other's perspectives and ways of working.

It was critical to meet and make the first prototypes together. While making and producing items together, it was easy to exchange thoughts on subsequent steps and explore the unique perspectives of different professional backgrounds. The different viewpoints created different designs, circuits and bonding technologies. For example, coding the female snaps to only plus side and male snaps to only minus side was avoided in the first prototyping phase. The engineering section could make the decision by creating the circuit ahead on paper and demnostrating that it would not correspond on the toy and on the blanket the same way. Discussions about proceedings and solutions gathered argumentations from both design and technical side, which lead to fast pace in decision making by the team speeding up efficiency in the process.

Collaboration with External Network

Authors have a network of experts from related fields. It was important to keep the core team small but include knowledge and experience from other fields. For example, including mentorship from business and marketing experts with several years of experience, also in research centers, adds vital expertise. Moreover, the build-up of electronic parts needs additional consulting, thus, low voltage systems and microelectronics experts were involved in source good electronics materials and ensuring technical accuracy from the beginning. A small core team was able to make decisions rapidly and move forward while receiving support from an external network, like project managing, illustration and story build-up for the toy etc. Thus, the first prototyping was already done one month after the project started and first feedback from children was received within the first 45 days.

Building up the educational aspect and logic of the kit experts on pedagogic research fields (like preschool education) are invited for discussion and feedback. Moreover, a group of parents gave feedback via questionnaire since they are also in the main end-user group. The feedback and questionnaire mainly accentuated the attractiveness of the tech product with a tactile appearance and wireless communication. Easy packing for different locations (like kindergarten and vacations) was equally crucial.

The background and knowledge from manufacturing makes collaborating with industry partners easier and provides opportunities for direct discussion with technical partners. Having this expertise in the core team makes it is possible to engineer realistic sustainable processes from the beginning. The different backgrounds from team members support having various industry partners both for supplying materials (like fabric leftovers or electronics) and setting up production later on in the project.

Communication with the Target Group and Collaborative Network

A big part of the project is the interaction and the electronics. The user group 1 includes children between the ages of 3-7. During the process, regular small tests were done with children, to get feedback for mainly two reasons: are the interaction and ideas interesting enough for children and are their motorical skills and awareness enough to understand every aspect of the toy. For example, Fig 3 and Fig 4 represent a test during prototyping phase. During and after the test it could be concluded that kids needed constant stimuli where the blanket could help.

User group 2 are the parents and other adults who are interested in the toy for their children. They are also involved in the development process to get feedback about the toy and to join the usability test with confidence, as the parents' moods have an impact on the childrens' moods (Häusser 2012). It is vital to explain the prototypes understandable way and on eye-level as e-textiles are not well known and it might be challenging for the parents to estimate the potential risks through electronics in the toy.

Fig 3. Small test between prototyping with children to see the first reactions.

Fig 4. Small test between prototyping with children outdoors.

Challenges of Collaboration

Pohl (2005) et al. study shows that researchers perceive transdisciplinarity not as an essential part of problem-driven research but just one additional demand on the part of programme management. It would be more significant to shift knowledge of specific disciplines in such a way that it is most useful and meaningful. Thus, creating the right philosophy and momentum within the team was necessary. For example, clarifying the contract, tasks and money distribution openly was a primary task.

Collaboration is done over distance, therefore, making and sharing schedules as early as possible was crucial. If problems (like insufficient time for completing a task) did occur, the other partner could take over, provide support or do both. Extra attention was needed and put into using a correct and personal communication language. The backgrounds, cultural contrast and the fact that first languages differ may affect how topics and ideas are perceived. Thus, sharing ideas over video or e-mail was critically checked to be clear enough and on schedule.

Discussions and Conclusion

The innovations in the e-textile field have been so rapid that the focus from environmental sustainability of the processes and products has been discarded. Although e-waste and textile waste management are investigated, the process is slow. It is essential to remind and teach environmental sustainability as early as possible. Thus, creating an interdisciplinary toy and development kit for kids with sustainable materials and techniques would create more awareness in different environments and networks.

One of the aims was also to show how collaboration creates and innovates. STEAM as a concept allows playful education on several layers at once without being too complex but suiting children's different perspectives and interests. The TTorch toy octopus is mostly ready-made, however, it will be clear how it is built. Supplementary add-ons (like an e-textile quilt blanket with different storylines) will be available that can be tested and put together by children. Providing the opportunity to explore the character and its electronic functions via a blanket and story booklet brings interdisciplinary fields closer together at an early age. Creating solutions, that can be experienced, are essential to creating memorable knowledge and validating ideas with further guidance to developments (Bas van Abel et al., 2012).

In the TTorch project, the knowledge and perspectives of different disciplines, like engineering and design, were combined and harmonised to discuss the materials, production technologies and sustainability of the product. Involving external partners only when necessary made partners more willing to give concise input without being fully involved in the project. It has been demonstrated how the network is collaborative and supporting partners are contacted only when necessary. Supporting the project as equal partners were parents, educators and the children themselves, so that the interaction and ideas behind prototypes would be adequate for children and according to their motor skills.

Collaboration has its logistic and social challenges; however, the collaboration made the project creation process versatile by elaborating the initial idea from one toy to a development kit with several parts, a story and a specific market gap. The potential of the project increased significantly which could be measured monetarily by having add-ons on the kits but also reaching and educating more children with different storylines.

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Paula Veske

Paula Veske is a textile engineer. She has experience working as a technologist in traditional clothing development and manufacturing companies. Additionally, in developing and creating smart textile products and production activities for manufacturing companies. Currently, she is conducting research at Ghent University on the integration of electronics in textiles. The research focuses on sustainability and efficiency of methods and materials.

Barbro Scholz

Barbro Scholz is an artist and textile designer. She has a background in design with a focus on electronic textiles and interaction, her interest is in the impact of designed objects especially textiles with their poetic tactile character. With that, Barbro shares her knowledge by teaching students in (e-)textile design. Additionally, she is one of the founders of Stühmer|Scholz Designbüro based in Hamburg where the core knowledge is in the field of textile technology and design development from idea to prototype.

An Interactive Playmat to Support Bonding between Parents and Young Children with Visual (and Intellectual) Disabilities

Paula Dekkers-Verbon, Bartiméus & Vrije Universiteit Amsterdam, The Netherlands

Marina Toeters, by-wire.net, The Netherlands

Marije Baars, Eindhoven University of Technology, The Netherlands

Emilia Barakova, Eindhoven University of Technology, The Netherlands

Paula Sterkenburg, Bartiméus & Vrije Universiteit Amsterdam, The Netherlands

Abstract

How can a caregiver contribute to secure attachment in a playful manner when the infant is blind or has visual (and intellectual) disabilities? This paper describes the design and development of an interactive playmat to contribute to this bonding process by stimulating sensitive mirroring behaviour of the parent. The motivation for developing the playmat is discussed, followed by an overview of the collaborative developmental process. An iterative co-creation process involving researchers from various disciplines, professional designers and focus groups was used; several test phases with target users took place. This paper describes the starting point from which the process was commenced and the following three iterations. The third iteration is worked out in full detail, including: sensor technology, technical drawing of the product, textile selection, electronics and software, as well as casing design and connection.

Playing with the interactive playmat goes as follows: parent and child are facing each other, sitting or lying down next to the mat. The young child with visual disabilities starts exploring the mat and presses deliberately or accidentally on one of the four coloured tiles, which enables a (previously set up) sound. The parent vocalises and copies the child's behaviour, which supports the cycles of communication between them. Together, parent and child explore the interactive playmat. The playmat not only makes sound, it is also stimulatory in the sense that it is made out of different textures, which promotes the curiosity of the child even more.

In the discussion, the product is reflected upon and the collaboration in the iterative collaborative process is reviewed. Both parties gained much knowledge and enjoyed working together. The planned field study is described: the interactive playmat will (in the upcoming months) be tested on twelve parent-infant dyads. The paper is concluded with the expected implementation of the interactive playmat.

Keywords

Multi-disciplinary Collaboration; Young Children with Visual Disabilities; Attachment; Smart Textile; Soft Technology.

The development of young children is related to a secure attachment relationship with their caregivers. When a child feels secure, his/her development will be positively influenced and the child can learn to regulate his/her emotions. This is the same for children with visual (and intellectual) disabilities. The parent functions as a secure base and safe haven for the child when (s)he mirrors and articulates the emotions of a child in a sensitive way (Dekker-van der Sande & Sterkenburg, 2016). The question that arises is: how can the caregiver contribute to secure attachment in a playful manner when the infant is blind or has visual disabilities?

The challenge was to develop a platform for interactive play that stimulates sensitive mirroring and thus secure attachment of the young child with his/her caregivers. During sensitive mirroring the parent is aware of the own 'inner world' of child, which differs from the parent's. The parent tries to understand this inner world of the child and react adequately (Dekker-van der Sande & Sterkenburg, 2016). However, mirroring of children with visual (and intellectual) disabilities can be a challenge. For the parents, the emotions and the behaviour of the child can be difficult to interpret. Parents of a baby with severe visual disabilities or a baby that is blind, have to learn to understand the body language and the hand gestures that their child uses to communicate (Loots, Devisé, & Sermijn, 2003). Furthermore, with children with an intellectual disability, the developmental age should be taken into account. Much repetition is needed for learning. The mirroring of the child should be done in a simple and concrete manner (Feniger-Schaal, Oppenheim, Koren-Karie, & Yirmiya, 2012). The aim of this study was therefore to develop a platform that supports parents in sensitive mirroring of the behaviour and emotions of young children with visual (and intellectual) disabilities.

The downside of the use of toys when playing with children with (visual) disabilities is that almost all toys promote individual play (Manojlovic, Boer, & Sterkenburg, 2016). Furthermore, professionals stated that "during therapy sessions it is difficult to find interactive, challenging and, at the same time, age-appropriate products that facilitate bonding" (Manojlovic et al., 2016, p. 6). Progress is being made: the VIPP-V (Platje et al., 2018) and the biofeedback system (Frederiks et al., 2015; 2019) both make use of technology to promote bonding and are tested for sensitivity and responsiveness of parents for young children and persons with visual and intellectual disabilities. However, at this moment, there is no specific intervention known that uses technical tools to help mirror emotions. Therefore, the research question of this paper is: how can we improve the interactive playmat (developed for a child with Down Syndrome by Manojlovic et al., 2016) to be able to support the bonding process (through mirroring) between young children with visual (and intellectual) disabilities (age six months up until three years) and their parents?

Overview of the Co-Creation Process

With the development of the interactive playmat, a Research Through Design approach was used (Toeters et al., 2013; Zimmerman et al., 2007; 2010). The main steps included: developing a concept and prototypes, several iterations of usability testing with the focus group (parents and their young children), followed by reflection and re-design.

The first meeting of Sterkenburg (one of the authors, psychologist at Bartiméus, a Dutch organisation providing care and advice for people with visual disabilities, and professor at the Vrije Universiteit in Amsterdam) with Manojlovic (then: graduate student in Product Design at the University of Southern Denmark) was on February 2nd 2015, where design guidelines were determined.

Manojlovic presented six concept ideas on March 4th, 2015 (Manojlovic, unpublished):

- Rotating Light Stick: parent and child turning the stick (each person on one end) will change the colour.
- The Drum Playground: copying each other's behaviours while drumming on a playmat.
- The Interactive Sock: interactive puppet socks on hands of both parent and child.

- Matching Suits: vibrating suits with touch patches.
- Interactive Cubes: magnetic matching cubes.
- Choreographic Carpet: interactive carpet that detects human movement.

The first iteration resulted in the Drum Playground and the Choreographic Carpet being further developed into the first prototype of the interactive playmat, that was tested during interaction of a child with Down Syndrome and her parents in 2016 (Manojlovic et al., 2016; see: 'Starting point'). The idea of an interactive playmat was tested on a focus group with different stakeholders in the care for young children with a visual impairment: a developmental and child psychologist, a physiotherapist specialized in child-care and a family therapist. Next, the second prototype was a game or toy for promoting bonding of the child with visual (and intellectual) disabilities and their parents. This prototype was a result of several activities. First, ideas from the focus group were gathered by sending out a short questionnaire to therapists and early-intervention workers at Bartiméus, with the aim to learn more about child-parent bonding of children with visual disabilities.

During the survey, the following questions were asked (in Dutch, this is a translation):

- What techniques do you recommend for parents to work on the bonding with their child with visual disabilities?
- To what extent do you think it is possible that bonding through playful interactive mirroring (copying each other's behaviour) is possible for children with an intellectual disability?
- What way of playful interactive mirroring would be most effective for children with visual disabilities? (Think of: parroting, copying movements, touch, etc.)

Inspired by the answers of the focus group, ideas for playful interactive mirroring games came to mind and were put to paper:

- Music playmat: parent and child make music together.
- Theme mat (seasons): for example creating an autumn sensation with different textures, sounds and smells.
- Sweater for a parent: stimulating touch by giving the child feedback by means of vibrations or sounds.
- Puzzle mat (doors): engaging the child in play by combining storying telling and puzzling, every piece containing a story, emotion or scent.
- Follow game: large playmat with parent and child locating sounds together.
- Step spring: connecting parent and child to each other via a vibrating, light-emitting step spring.
- Bouncing game: throwing and catching of a digital LED ball on a playmat.

Then, the focus group gave feedback on these ideas via an expert meeting. Next, the project group came up with a number of design requirements for the interactive playmat with the aim to encourage the parents in sensitive mirroring of a young child with visual (and intellectual) disabilities. For the third iteration, several sensory stimulating toys were reviewed. At this iteration, a prototype of the interactive playmat for young children with visual (and intellectual) disabilities was created and tested on one parent-child dyad. The parent was asked to give feedback on the interactive playmat. After the second iteration, Toeters (one of the authors and owner of by-wire.net, professional design and research studio for fashion technology) took over the challenge of further developing the interactive playmat.

With this interdisciplinary inquiry, a solid working relationship came to be between the designer (Toeters), the researchers in designing interactive systems (Baars and Barakova) and the scientific practitioners (Dekkers-Verbon and Sterkenburg). Multiple meetings were held and the scientific practitioners visited the design and research studio several times. Also, this paper was simultaneously written by the authors from all disciplines, with the use of digital document sharing.

Starting point

The first prototype of the interactive playmat, made from fabric, was based on positive and multimodal stimulation and it registered movement. The soft part of the platform contained sensors and actuators: one buzzer and two luminous rings (see Fig. 1). Parent and child took place opposite to each other and the game went as follows: the buzzer played a high-pitched melody to draw the parent's and child's attention so they would focus on the textile mat. After a two-second break, the two rings emitted light (Fig. 2). The idea was that parent and child with Down Syndrome reached out towards the lights, thereby making the same movement and thus playful mirroring would be stimulated (Manojlovic et al., 2016).

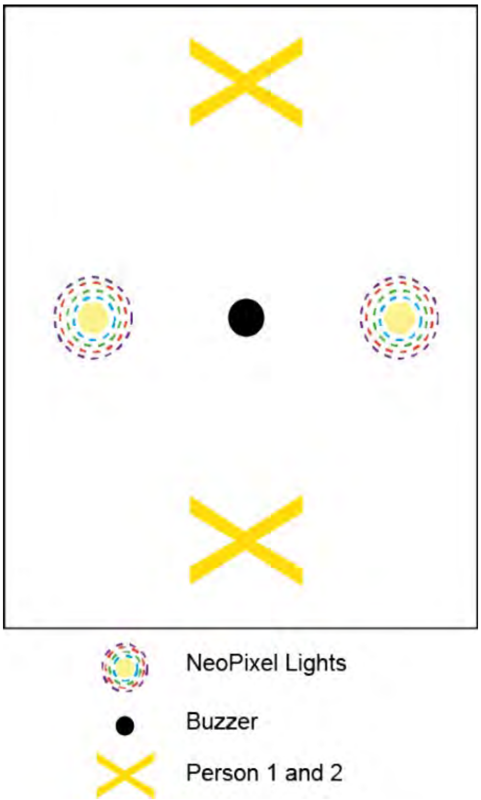

Fig 1 and 2. Interactive playmat developed by Manojlovic et al., 2016.

The prototype was tested by a family with a two-year-old girl with Down Syndrome. Her parents were enthusiastic about the use and possibilities of the playmat in terms of discovering and playing together with their child. The authors claimed "…a form of mirroring was indeed taking place in interaction" (Manojlovic et al., 2016, p. 5). However, there were also limitations to this prototype. It was conceived to be difficult for the child with visual disabilities to perceive the displayed lights. The advice was to continue developing the playmat in such a way that it turns out to be more suitable for children with visual disabilities. Furthermore, the authors concluded that it is important "to understand how professionals would experience such activities and environments, what would inspire them and what would be their concerns" and that the early-intervention workers specialized in visual and hearing disabilities should be kept involved in the follow-up on the research (Manojlovic et al., 2016, p. 7).

First Iteration

After the exploratory phase, Baars and Barakova designed a prototype of the interactive playmat for young children with visual (and intellectual) disabilities, with the size of a pillow. This first prototype consisted out of twelve touch-activated tiles, each with a unique texture (Fig. 3). Next, the first prototype was evaluated. Baars watched documentaries where children with visual disabilities interacted with their parents, with the purpose to learn more about the children's development and interactions. She also received feedback from three industrial design coaches who suggested using instrument chords so parent and child could compose a music melody together. Baars also gained input from different experts at Bartiméus: Sterkenburg and three early therapeutic counsellors gave advice. Baars then visited a therapeutic toddler group from Bartiméus where she observed the children and she spoke to the counsellors about the playmat. Besides stressing the importance of the mirroring movements that should be triggered by using the interactive playmat, the feedback of the focus group implied it would be "interesting if the parent was able to record their own sounds and link them to a square" (Baars, unpublished, p. 14). Also, the focus group highlighted the significance of engaging the remaining visual abilities of the child. Furthermore, the playmat was believed to be too small to stimulate the gross motor movement of the children and the tiles were difficult to activate for small children (much pressure was needed).

Fig. 3 and 4. Respectively first and second prototype (photos taken by Baars).

Second Iteration

With the focus group feedback, the next prototype was developed (Fig. 4). This prototype was a floor playmat to enable children to make larger movements and facilitate mirroring behaviour. The squares were changed into contrasting colours with clear borders. This was done with the idea that children that have remaining eyesight might be able to differentiate between the various patches on the playmat. For the second iteration, four coloured squares with very different feel were stitched on to white surface: purple wool, yellow fleece, ribbed blue and orange velvet. The activation of the tiles was simplified: they could now easily be activated by hands or feet. The sounds coming from the playmat were changed to piano chords that were emitted from a small speaker coupled to the interactive playmat.

Next, a usability study was performed during two test runs with a toddler with visual disabilities and her mother in their natural environment (their home). The mother and her child played vigorously with the mat and clearly enjoyed it. Mirroring behaviour was observed on multiple occasions (Baars, p. 21). Due to the external sound source, the child focussed outside of the mat multiple times (as to where the sound originated from). Afterwards, Baars conducted a semi-structured interview of the mother. The mother claimed that by using the playmat, they came up with new games that they otherwise would not have thought of. The mother felt that, although she thought a strong point of the playmat were its contrasting colours and different materials, the contrast of the colours should be increased even more. The interviewed mother said that she would prefer using the playmat together with the therapeutic counsellor, because the counsellor can explain the benefits of playing in this (mirroring) way. The mother proposed to give every square its own speaker so the sound comes from the tile that is pushed upon. Furthermore, the sounds were perceived to be too similar. Modularity in terms of sound would be welcome to ensure long-term use. Another wish was the use of sensors without the necessity to attach a computer. Last, the washing of the playmat was a problem due to the electronics wired inside the mat.

Third Iteration

Toeters took over the development of the interactive playmat. The recommendations coming from the observations and the interview were taken into account when developing the third prototype (Fig. 5 and 6). In this prototype, the speaker was embedded into the interactive playmat to prevent the child from focussing outside of the mat. With the purpose of increasing the contrast even more, the yellow square was switched to green. Furthermore, the sounds were changed to animal sounds and can be adjusted repeatedly. The total sensing and interactive system were integrated in the playmat, so it became a standalone product. The sensors are washable and integrated. In this third prototype, the sound box was made separate (see also Figure 12-15). Only the box needs to be removed before washing.


Fig. 5 and 6. Third prototype of the interactive playmat for young children with visual (and intellectual) disabilities.

Sensor Technology

In the third iteration two layers of Velostat were used, that sandwich a layer of fiberfill (Fig. 7). Velostat is a pressure-sensitive conductive material: squeezing it, will reduce its resistance. This change in resistance can be measured so that it becomes a flexible sensor of the pressure. Velostat is washable and can be used for large surfaces. The used sensors are square surfaces of 30x30 cm. Fiberfill is another synthetic material used for padding and insulation in garments and soft interior products such as carpets, cushions and duvets. When touching the playmat, this material makes sure that the changes in resistance increase. On two opposite corners (diagonal), a conductive wire is connected via zigzag stitches (Fig. 8).

Fig. 7. The layering of the sensor technology.

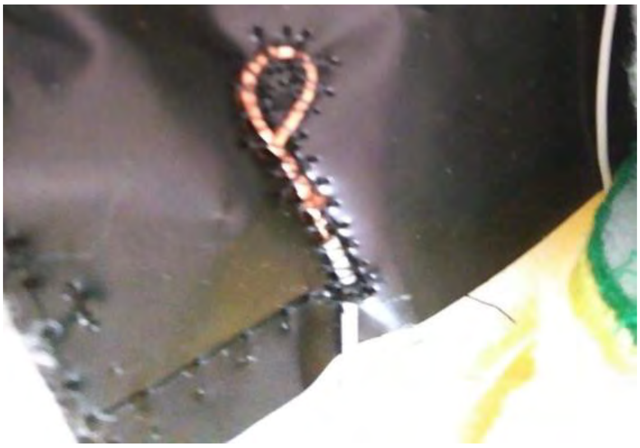

Fig. 8. Electric wire connected to Velostat.

Technical Drawing of the Product

The playmat is 120x120 cm and split into different blocks (Fig. 9). Four blocks include the sensor technology as described above. The seams are positioned to guide the conductive wires (displayed as yellow lines in the technical drawing).

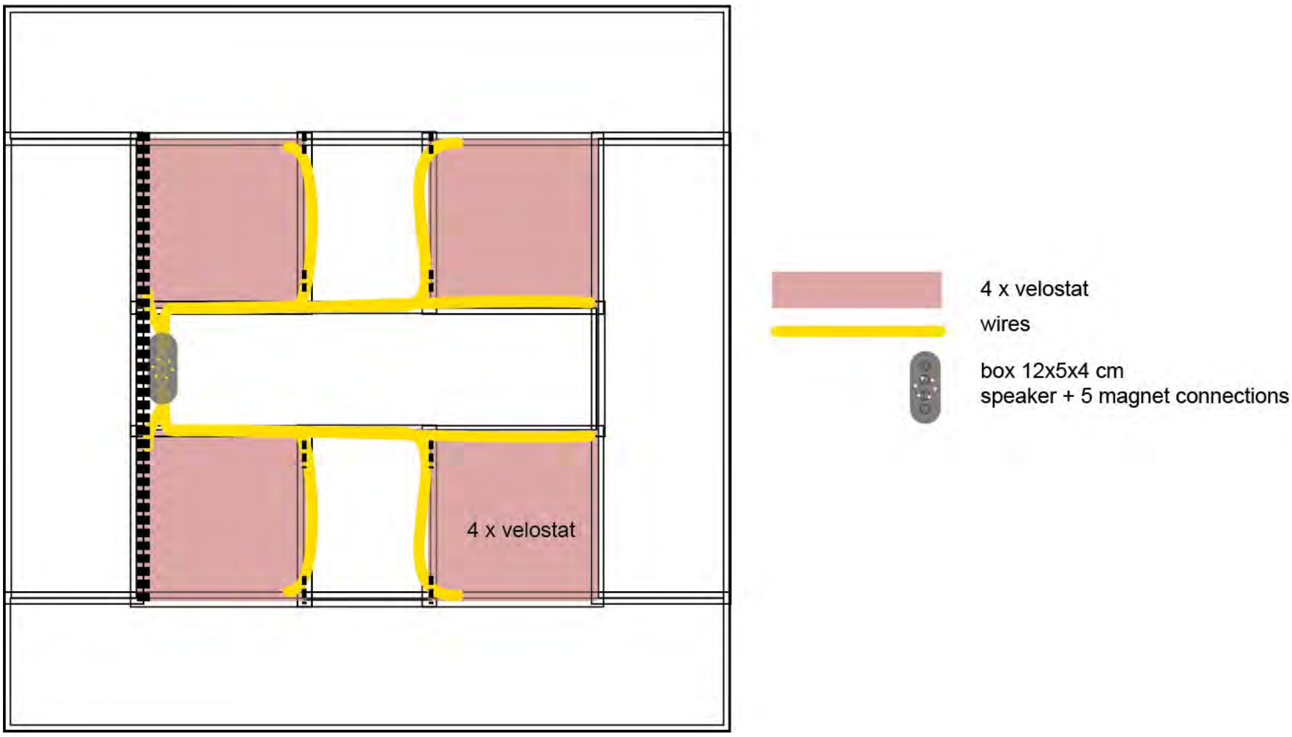

Fig. 9. Technical drawing of the positioning of the sensors (wires and Velostat) and actuators (sound box).

Textile Selection

The base of the playmat is yellow cotton (kau 07) and fibrefill over the full width. The fibrefill is the same as used as spacer in the pressure sensors. The four patches are sewn into it. The textiles were selected because of their high contrasting colours and for the contrasting tactile experience when touching them. The selected combination is: Hydrophilic Green (HYD-11), orange fabric with palettes, Velours Lycra in red (vel.01) and petrol blue fake fur (bont 26).

The contrast between the colours makes it easier for children with visual disabilities to discriminate the various parts of the playmat, which stimulates the exploration of the playmat. The texture differences create extra dimensions in terms of stimulating the senses of touch and sight of the young child. The participant in the pilot test (ten-month-old baby) was especially drawn to the orange glitter fabric and the blue fur like fabric.

Electronics

Within this third iteration, we especially iterated on the electronics part via a trial and error approach. Based on the second iteration, the following electronics were used: Arduino Uno R3, small speaker (SPKR3W4O) and an MP3 module named DFplayer-mini with a micro SD card. An MP3 module (actuator) was used to create different sound feedback when different tiles were being touched (sensory input) and was linked to the speaker and the board. This system can detect when different tiles are touched and responds with the desired sound signal. When more than one tile is being touched, the highest registered value overrules the other signals. The CapacitiveSensor.h library was used for this. With the micro SD card as input, it is easy to change the sounds uploaded to the module, corresponding to the liking of parents and child. The DFRobotDFPlayerMini.h library was used. For the current iteration, all components needed to be integrated in the mat itself, therefore it was necessary to downsize all the electronics and also integrate the power source and a switch in the system.

Firstly, the board was replaced with the Pro micro 3.3 Volt. This system had problems with the analog sensor readings - it worked well with a single sensor, but had problems with measuring the four sensors in parallel. Several other low voltage boards were tested, but installing the sensing and actuation software program was problematic.

The final choice was Arduino Nano, which is small in size and able to measure all four sensor readings. This board can be seen in Fig. 10-11. A trade-off in this board is that it needs 7 Volt power supply, while the total system is designed to work on 4.5 Volt. So, a 9 Volt battery had to be added and the total system plus the shape of the controller box needed to be adjusted to this change. With each adjustment, the controlling program also needs to be adjusted.

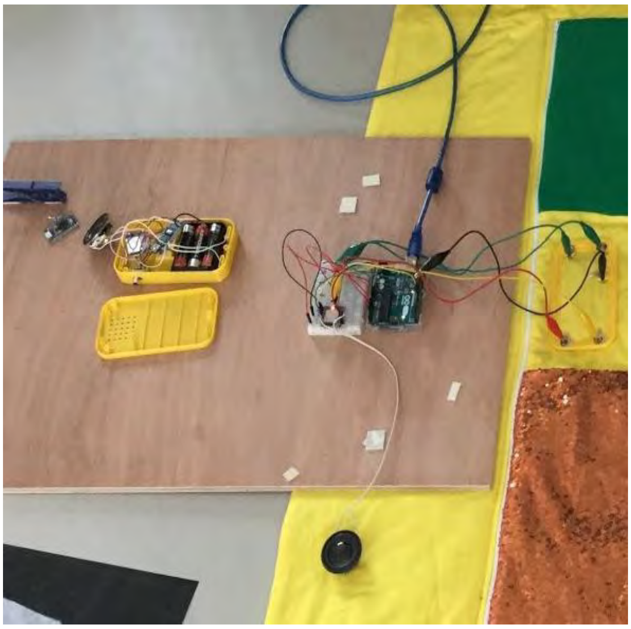

Fig. 10. Playmat connected to temporary board.

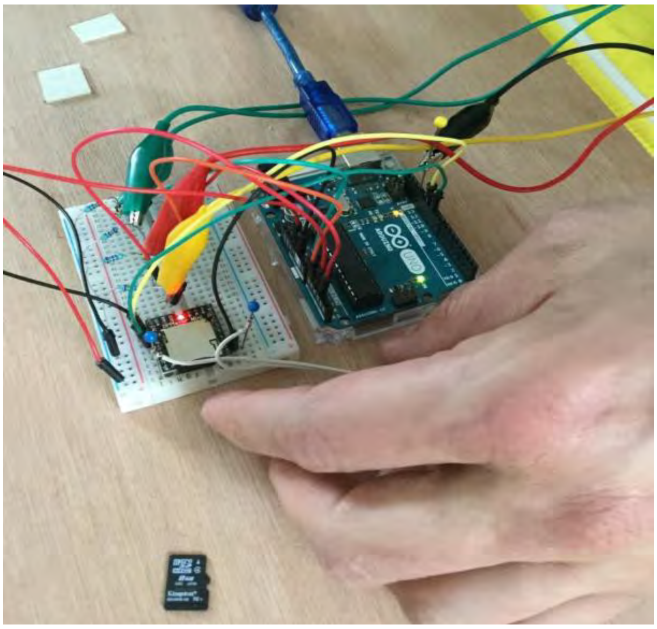

Fig. 11. Detail: changing the SD-card (temporary board in use).

Software

A finding during the programming process was that there is a problem with the Arduino UNO ADC that affects other boards as well. Multiple analogRead() performed on different pins with no delay will not give enough time for the ADC to “cool down” and measurements will be completely incorrect. The Arduino community came up with a solution for this problem: perform two analogRead() on the same pin, dump the first and keep the second. The digital to analog converter

(DAC) is done twice in sequence so that the first measurement resets the measurement and the second one does the actual measurement.

Here you can find how this is programmed for sensor two:

```
Blauw = analogRead(Sensor2);
 delay(50);
 Blauw = analogRead(Sensor2);
```

3D printed casing design

In parallel, while repeatedly adjusting the electronics, the casing had to be redesigned and reprinted (Fig. 12-15). Some functional aspects (such as size, sound transport and position of the switch) and aesthetical aspects (like rounded corners, height, colour and position of the magnet connections) were taken into account. This binary approach gave a nice fitting result to the total project. Our pilot tester (ten-months-old baby) found this piece very attractive and interesting.

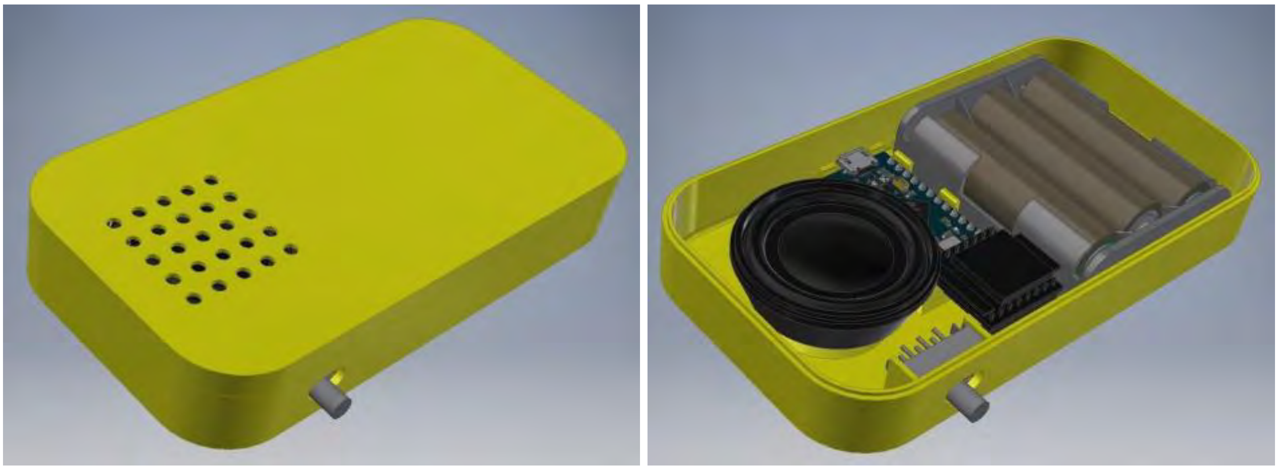

Fig. 12 and 13. 3D rendering of the casing design, closed and open.

Fig. 14 and 15. Actual print of the casing, with all electronics integrated.

Magnet connection

To increase the user experience, magnets were used: magnets guide the user (e.g. a parent or early-intervention worker) towards the correct positioning of the casing on the playmat. Magnets also make it easy to connect and disconnect the casing (for example for washing and charging).

Furthermore, magnets have long durability. In a vertical position, five magnets were integrated in the case. These magnets are connected to the motherboard in the case. Five metal rings were placed in a horizontal position on the mat (Fig. 16). These rings are connected to the sensors. The rings and magnets exactly fit together.

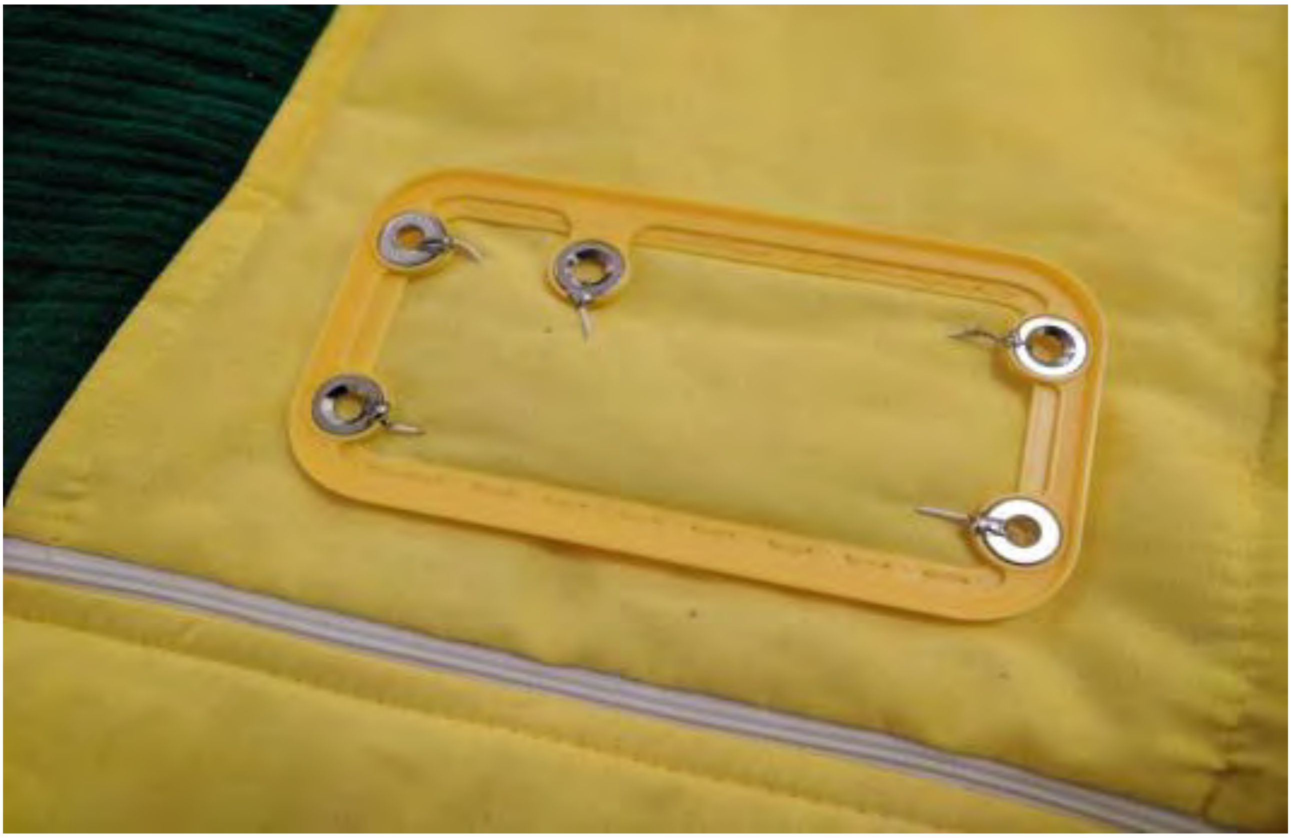

Fig. 16. Five magnetic connection points on the interactive playmat.

Discussion

Related Projects

The implementation of electronic textiles (e-textiles) is quickly advancing. Learning, discovering and sharing how to design e-textiles is nowadays incorporated in the education of industrial and fashion designers to be (Coleman et al., 2011). Examples of e-textiles are: a shirt that can take an electrocardiogram, a dress that can warm a painful back and a shirt that turns sunlight into electrical energy while wearing it (Toeters, 2016). With e-textile, the digital and physical world can be linked. For example by telling stories with augmented reality: digital story tale figures hidden in a pillowcase and blanket are made visible by an iPad to let bedtime stories come alive (‘Textales’) or QR-coded embroidery on a skirt is connected to a folklore tale (Kuusk et al., 2012; 2013; 2016).

The overall use of interactive technologies that promote social bonding and interaction is rapidly increasing (Barakova et al. 2013; Brok & Barakova, 2010; Frederiks et al., 2019). An example of social e-textile is a scarf designed to move on the rhythm of the elevated heartbeat to help a shy person become aware and express his/her feelings of excitement or arousal (Daems, Toeters & Feijs, 2015). Likewise, a sleeve “to let elderly in rehabilitation feel connected to their family at home and to give them more insight into the rehabilitation process” (designed by TU/e student Van der Voort, mentioned in Toeters & Brinks, 2012, p. 5). Moreover, innovative ideas in the form of e-textile are also being implemented in healthcare. For instance, an exercise glove that helps people with hand-arthritis (designed by Wagner and Schneider, mentioned in Toeters & Brinks, 2012, p. 4), a vibrating strap for people with Parkinson Disease (designed by Mangre, mentioned in Toeters & Brinks, 2012, p. 5) or Vibrating therapy integrated in a shirt to treat osteoporosis (Bhömer, Jeon

& Kuusk, 2013; Kuusk, 2016, p. 75-79). Also in the care for people with disabilities, e-textile is being used: for example, a bio-response system integrated in a sock so to measure stress levels of a person with severe disabilities, with the purpose to alert a carer even before changes in behaviour are visible (Sterkenburg et al., 2017).

The current study features an iterative research through design approach that aims at developing an interactive product that will improve the social well-being of a sensitive user group, namely infants with visual (and intellectual) disabilities. While interactive products designed for young children with developmental disabilities (Brok & Barakova, 2010; Huskens et al., 2015), or for adults with similar disabilities as in the current user group (Frederiks et al., 2019) were shown to be well accepted, little research is done on what kind of product is suitable for infants with visual disabilities. The pilot tests performed during the design iteration showed that the children were positively engaged and excited when interacting with the playmat. However, the performed tests included few participants and no test protocol was used. In addition, the developed system is a prototype and does not work flawlessly yet. Below we address the planned steps for further improvement of the interactive playmat and its usability testing.

Reflection on the Product

First, we plan to perform an observational study with four infants (without visual or intellectual disabilities). This user study will be done not only to fine-tune the setup of the future field study, but also to adjust the settings of the interactive playmat in terms of sound volume and sound timing.

Whilst testing the playmat, there are still some improvements to be made in terms of the textile pieces and the hardware fine-tuning. First, concerning the textile pieces: the replacement of the zipper so that children and parents cannot (accidentally) open it; and redesigning of the pattern parts for placing of the pressure sensors efficiently during production. Second, concerning hardware and software fine-tuning: the improvement of the energy efficiency; determining the size of the total box; usability improvement (for example easy replacement of the battery); and improving the reliability of all technological components.

Collaboration in an Iterative Process

In the context of the theme EKSIG 2019 *“Knowing Together – experiential knowledge and collaboration*”, we evaluated our collaboration between researchers from different disciplines. In this case, user centred design (ISO 13407:1999) and co-creation/participatory design (Ehn, 1988) were adopted. However, the traditional user-centered design methods and the tools that support them, assume that the design process is well scoped as a project: with a clear separation in terms of organization and expertise between users and the developers. Also, it assumes that the technology developer can plan and shape the product development process and can command the resources necessary for it.

These assumptions are not valid when developing solutions for highly specialized domains and when using non-conventional (also thus specialized) interaction platforms. In such cases, there is a need to pool diverse expertise and resources. While collaborating, all parties continuously learn from the other disciplines: perspectives change and spiralling growth upwards occurs when parties built on each other’s knowledge and expertise. To address these problems, we aim for processes where a variety of stakeholders can cooperate in what can be described as a *participatory organization*, i.e. free to contribute or not and without abiding by fixed deadlines (see Spinuzzi, 2005).

Due to the use of this multidisciplinary collaboration approach, this product became rich in functionality and developed as it is now. The user involvement during this iterative approach helped to fine-tune the product towards the target group. Having the expert knowledge of the target group, the developmental psychology expertise of how to motivate play, the design knowledge about interactive textile products and the electrical engineering expertise all on the same page and involved in the same process, brought us valuable results.

The behavioural scientific practitioners (Sterkenburg and Dekkers-Verbon) especially valued this involvement: psychologists and early-intervention workers were repeatedly involved and the design-researchers carried out observations of children with visual disabilities. The scientific practitioners appreciated the hospitable visits to the design studio and especially the patience the designers showed when explaining the technical parts of the interactive playmat. As Toeters quoted Vertooren in 2007: “For a successful collaboration you have to speak the same language.”

The designer Baars benefitted from working in close collaboration with Bartiméus: she was able to make use of their expertise. This resulted in an experiential design based on the knowledge available in the organisation, interpreted from a design perspective. Within this design perspective, different prototypes and iterations were made. At times, this needed to be translated back to the others disciplines involved: communication proved to be very important.

Reflecting together on the intermediate prototypes is essential in such a process. Every party brings their own expertise to the table, which makes reflection fruitful. In this case the designer Toeters learned much about the benefits of tactile diversity during the textile selection process, for example how different textures and colours should be, so that this specific target group would be triggered. She also learned about how to construct the pattern parts so that they would fit the later production processes, which makes the technology integration process easier.

The electrical engineer of by-wire.net experienced difficulties in reading stable sensor data and comparing this data with the data gathered one second ago in four parallel lines. Also, different breadboards acted differently on the exact same program of calculating, because of the variety of chips used on the different breadboards.

Although the authors believe the collaboration during this project was successful, there is always room for improvement. The physical distance between the various researchers was a challenge in the collaboration process. Working together on writing this paper required much planning and therefore time: a quick fine-tuning talk during lunch break was no option. In the process of writing the paper, the authors communicated via email, by phone and through remarks in the shared Google document. WhatsApp messenger was also used; however, a suggestion for future interdisciplinary collaboration is the use of Slack (a collaboration hub) in order to prevent a mix-up of private and professional communication channels. Furthermore, the authors made use of a shared Google document. However, it is preferred to use an independent cloud storage service like SURFdrive to be sure the data is secure and will not be shared with others without knowledge or permission (see also the Google Terms of Service). Unfortunately, using SURFdrive was no option for this research party, as in SURFdrive it is not possible to work simultaneously on the document.

Future Field Study

When the playmat is finished, further testing will be done to underwrite the effect on sensitive mirroring behaviour of parents of children with visual (and intellectual) disabilities. This will be done with a combined-series single-case design study involving twelve child-parent dyads from Bartiméus. Research questions will focus not only on whether parents show more mirroring behaviour, but also on whether the children seem to experience more joy while playing on the interactive playmat, than when they play on the ground or on their own playmat. The expectation is that the playmat will help parents show more mirroring behaviour because the playmat evokes such play. During the whole process of field study and implementation, it is crucial that the researchers actively ask the participating parents for feedback on the interactive playmat and that the researchers keep actively involving the focus group.

Implementation

While the scientific practitioners conduct the field study, the design team will produce twelve playmats. These playmats can then be used during the home guidance given by staff from Bartiméus for parents of young children with visual (and intellectual) disabilities. Also, the interactive playmats will be put into use in the therapeutic toddler group and in the living community of young children with visual (and intellectual) disabilities. If the field study turns out to be beneficial in terms of promoting sensitive mirroring behaviour in parents and/or joy in the children, first steps will be made to make the interactive playmat available for the free market. The playmat can then also be utilized by parents of young children with intellectual disabilities but without visual disabilities.

If in future the playmat can be hung on the wall, it can also be used by persons with a wheelchair and thus with reduced mobility, e.g. people with severe intellectual disabilities and/or the elderly. The playmat is a versatile object: sounds can easily be altered. It can for example be used by persons with (intellectual disabilities and) dementia. An example of an e-textile developed for people with dementia is Tactile Dialogues: a textile pillow that reacts to touch with personalized vibrations. It is used to trigger communication between persons with late-stage dementia and their relatives, by means of joint interaction and mirroring behaviours (Bhömer, 2016, p. 39-51; Schelle et al., 2015). The interactive playmat could be made suitable for persons with dementia by matching the programmed sounds to early memories that specific person has. For example using sea-related sounds such as seagulls and waves for a person who used to stay at the seaside when being a child. Stimulating a person to remember past days is called reminiscence. Reminiscence can improve the confidence of a person with dementia and provide valuable topics to talk about with that person (Maaskant & Schuurman, p. 25). Furthermore, reminiscence can help improve upon social-emotional parameters like depressive symptoms, self-acceptance, relationships with others, autonomy and environmental mastery (Gonzalez et al., 2015). Thus, although the playmat was developed for young children with a visual impairment, the use hereof in future can be implemented in a big range of care.

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Paula Dekkers-Verbon

Paula Dekkers-Verbon works as a scientific practitioner in the research group 'Social Relations and Attachment' for people with visual or visual-and-intellectual disabilities, a combined effort of Bartiméus (expert organisation for people with visual disabilities) and the Department of Clinical Child and Family Studies of the Faculty of Behavioural and Movement Sciences of the Vrije Universiteit Amsterdam in The Netherlands. With a background in clinical practice of medicine (as a medical intern) and in the care for people with intellectual disabilities (as a behavioural scientist), she now connects practice and research. Another project she works on is for example: stereotype and challenging behaviour of young children with a visual and intellectual disability. Her special interest lies in early childhood development, infant mental health and attachment.

Marina Toeters

Marina Toeters operates on the cutting edge of fashion technology and fashion design. Through her business by-wire.net, she stimulates collaboration between the fashion industry and technicians for a relevant fashion system and supportive garments for everyday use. The by-wire.net studio is dedicated to designing and prototyping innovative textile products and garments and advises, amongst others, Philips Research and Holst Centre on product development. As a teacher, coach and researcher, she works for multiple institutes like the fashion department at Utrecht School of Arts (HKU) and the Industrial Design faculty at the Eindhoven University of Technology (TU/e). In this project, she took the role of designer and coordinated the prototyping process of the hardware, software and textile pieces.

Marije Baars

Marije Baars is an Industrial Design Master student at the Eindhoven University of Technology. Currently graduating within the topic of dementia friendly communities. She is a social, user centered, participatory designer aiming for inclusion and empowerment. She believes design has the power to make an impact and drives long-term change. She works towards creating an inclusive society through social design and design thinking. She has experience with working with and designing for special needs groups, especially the elderly, since design is the perfect vehicle to illustrate the abilities people still have, instead of focusing on their disabilities.

Emilia Barakova

Emilia Barakova is affiliated with the Eindhoven University of Technology. She is the head of the Social Robotics Lab, leader of the Physical and Social Rehabilitation educational squad, and an editor of Personal and Ubiquitous Computing, International Journal of Social Robotics and Journal of Integrative Neuroscience. Barakova is an expert in the field of embodied social interaction with and through technology, social, cognitive and brain-inspired robotics, and designing technologies for individuals in social isolation and special needs groups. Several of her research projects focus on children with autism spectrum disorder (ASD), elderly with dementia, and embodying emotions and intelligence in robots. Barakova has organized three international conferences (2 ACM, 3 IEEE). She has worked for four years at RIKEN BSI in Japan, where she served as an intermediate director of the German-Japanese Research Lab.

Paula Sterkenburg

Prof. dr. Paula Sterkenburg has a chair by special appointment at the Department of Clinical Child and Family Studies of the Faculty of Behavioural and Movement Sciences and the Amsterdam Public Health (APH) research centre of the Vrije Universiteit Amsterdam, in The Netherlands, on 'Persons with a visual or visual-and-intellectual disability, social relations and ICT' (start 2019). The chair is affiliated to her work as licensed psychologist/therapist at Bartiméus Department of Psychotherapy in Doorn. The theme of her PhD study (2008) was 'Integrative Therapy for Attachment and Behaviour'. She received the Award of the Dutch Association of Healthcare Providers for People with Disabilities (*VGN Gehandicaptenzorgprijs 2007*) for the way in which she succeeded in building bridges between research and practice. She also received awards for her work: from the University of Groningen (2012) and the NutsOhra Fund and Vilans Centre (2013). For these awards, she ended in the top three nominees: the VU EMGO+ Societal Impact Award (2015); within collaborating in a team from Stichting Nieuwzorg (2015), Vrije Universiteit Amsterdam and Bartiméus by ONVZ Care-provider; *VGN Gehandicaptenzorgprijs 2016*. Furthermore, she is author and co-author of books and publishes articles on persons with ID, social relations and ICT.

Magic Lining: Crafting Multidisciplinary Experiential Knowledge by Changing Wearer's Body-Perception through Vibrotactile Clothing

Kristi Kuusk, Design Research Group, Estonian Academy of Arts, Estonia

Ana Tajadura-Jiménez, DEI Interactive Systems Group, Carlos III University of Madrid, Spain

Aleksander Väljamäe, Human Computer Interaction Group, Tallinn University, Estonia

Abstract

Our complex and rapidly changing world presents us with profound societal challenges, but also offers tremendous opportunities for new technology to respond to those challenges. Several recent EU initiatives have enabled participants from a diverse array of disciplines to engage in common spaces for developing solutions to existing challenges and to imagine possible futures. This includes collaborations between the arts and sciences, fields which have traditionally contributed very different forms of knowledge, methodology, results and measures of success. They also speak very different languages.

Magic Lining is a collaborative project involving participants from the fields of e-textile design, neuroscience and human-computer interaction (HCI). *Magic Lining* combines the findings of their respective disciplines to develop a 'vibrotactile' garment utilising soft, interactive materials and is designed to alter the wearer's perception of their own body. Here we explain the process of designing the first prototype garment—a dress that produces in its wearer the sensation that their body is made of some of other material (stone, air, etc.) and in turn elicits various perceptual and emotional responses (feeling strong, feeling calm, etc.). We reflect on the collaborative process, highlighting the multidisciplinary team's experience in finding a common space and language for sharing cognitive and experiential knowledge. We share our insights into the various outcomes of the collaboration, giving also our views on the benefits and on potential improvements for this kind of process.

Keywords

Multidisciplinary Collaboration; E-Textiles; Body-Perception; Embodiment; Multisensory Perception.

Today we are experiencing a period of profound socio-ecological change. Multidisciplinary engagement in research is essential if we are to overcome the challenges posed by this change. The tools for such collaboration are in continual development. A number of European Commission initiatives under the umbrella of 'STARTS' (Science, Technology and the Arts) are seeking to foster and explore the potential for common spaces in which arts and sciences can co-create. As part of this initiative, the *Magic Lining* project focuses on the experiential knowledge, opportunities and difficulties arising from a multidisciplinary space that merges the expertise of fashion and textile design and technology (known as e-textile), human-computer interaction (HCI) and cognitive neuroscience. In order to understand this space, we entered into a collaborative process (as recommended by Ingold, 2013) to create knowledge, build environments and transform lives through making. The project aims to create fashionable clothing that focuses on making people feel good about their bodies instead of the usual focus on having their bodies look good for others. To this end, we merged fields in order to ground e-textile development in recent developments in the fields of cognitive neuroscience and HCI, thereby showing the potential for changing personal body-perception through the use of technologies that provide multisensory bodily feedback. In this article, we share our motivations and the background to this experimental project, noting also the potential for this multidisciplinary collaboration to feedback into our respective disciplines. We describe our reasoning and the knowledge shared within our team throughout the life of the project.

Background and Related Work in Fashion, E-Textiles, and HCI

Fashion affects many aspects of our lives and plays an important role in shaping consumer culture (Sassatelli, 2007). It connects symbolic and aesthetic expressions with the cultural meanings that objects carry (Pan, Roedl, Blevis and Thomas, 2015). Clothing in fashion attempts to balance two contradictory aims: it focuses on our attractions while protecting our modesty (Kawamura, 2004). It is a symbolic product; and its meaning is determined by time (Kaiser, 1996). However, the biosocial aspects of fashion have been largely overlooked, and this is especially apparent when we consider the plenitude of studies in fashion aesthetics (van Busch, 2018).

Our goal with *Magic Lining* is to create fashionable clothing that considers this overlooked biosocial element, by focusing on making people feel good about their bodies for themselves instead of having their bodies look good for others. To this end we combine the fields of e-textile development, cognitive neuroscience and HCI.

E-textiles, as materials connecting textile softness with electronic properties (Hertenberger *et al*., 2014), are obviously a promising material for interactive clothing. They allow technology to become almost imperceptible in close proximity to the body, and to weave or knit components into the textile structure itself. In this way, clothing can begin to play a role in supporting the body in ways that are beyond the vision current fashion trends. For example, the knitted cardigan *Vibe-ing* (M Bhömer, Jeon and Kuusk, 2013) offers vibration therapy for rehabilitation through vibrating elements integrated into the pockets, which are constructed using a standard knitting machine. This sort of e-textile invites the use of touch to enhance stimulation, whereas *Vigour* (ten Bhömer, Tomico and Hummels, 2013) enables geriatric patients, their family and physiotherapists to gain insight into exercise and the progress of rehabilitation by monitoring the movement of the upper body. *MVO* sustainable and supportive garments for hospitals (Toeters, 2016) are aimed at nurses and caregivers themselves, helping them to maintain healthy postures and working environments: the garments include a posture sensor, a gas sensor and a supportive under layer. The neuro-rehabilitation concept *Mollii* (2019), a close-fitting suit that is already successfully on the market, provides rehabilitation electrotherapy programmed for the particular needs of the individual. The suit reduces unwanted reflexive movements and muscular stiffness in people with spasticity or other forms of motor disability, thereby enabling the wearer to improve their posture and enhancing their range of motion and functional ability. Fitness wearables (Adidas, 2018; OMsignal, 2018; Owlet, 2018; Sensoria, 2018) and monitoring devices (Zoll, 2017) are also increasingly becoming an integral part of our everyday clothing.

While audio-visual cues have tended to dominate feedback and communication strategies, tactile or haptic cues represent a good complimentary channel and in some cases provide a necessary alternative (for example, in space and underwater environments): ‘Tactons’, or ‘tactile icons’, are structured, abstract messages that can be used to communicate non-visually (Brewster and Brown, 2004); and new forms of interface that exploit ultrahaptics have opened up the development of tactile surfaces by offering mid-air haptic feedback development (Shakeri *et al*., 2018; Ultrahaptics, 2018; Obrist *et al*., 2015). Tactile sensations can be delivered by electric stimulation, which has already been used in the rehabilitation of movement disabilities (Inerventions, 2019). *Teslasuit* (2018), is a bodysuit that utilises fine-tuned location-specific electric stimulation of the skin to deliver haptic feedback directly to the entire body. *Hardlight VR suit* (2017) follows the same whole-body concept, but instead using a force feedback approach. *Versatile Extra-Sensory Transducer* (Eagleman *et al*., 2017) can take in diverse types of real-time data—from sound waves to help the deaf, to flight status, even stock market trends—and translate this data into dynamic patterns of vibration in its motors (Keller, 2018).

Fig 1. Magic Lining concept photos representing sensory-feedback, integrated in the inner layer of the garment, changing the perceived "material" of the body.

These technologies have already begun to enter the market, but the potential of the experiences they can deliver is still largely unexplored. While the prototypes and products mentioned thus far focus on developing the technologies and materials they use, there is also a need for understanding the psychological effects of these tactile sensations on the wearer. What potential is there for giving the wearer the feeling that they are made of some different material? Will they feel fitter? More relaxed? Happier? Our interest is the peculiar link that smart textiles may be able to form between our bodily sensations and cognition. Specifically, *Magic Lining* (Figure 1), aims to find meaningful, affordable solutions in the space between neuroscience research on body-perception, HCI and body-centred smart textile applications.

Neuroscience and the Use of Sensory Feedback to Alter Body-Perception

Neuroscientific research has shown that the way people perceive their body appearance or their physical capabilities is not something fixed. These body-perceptions change continuously in response to sensory signals relating to one's body (Botvinick *et al*., 1998). Research has shown that these body-perceptions impact on the way people interact with their environment, as each individual must continually keep track of the configuration, size and shape of their various body parts when performing actions (Maravita and Iriki, 2004). Moreover, body-perceptions are basic in forming our self-identity (Longo *et al*., 2008) and are tightly linked to self-esteem (Carney *et al*., 2010) and social interaction.

Recent studies in this area have shown the potential of using bodily, sensory feedback (or manipulating body signals) to alter body-perception (Tajadura-Jiménez et.al., 2015; Botvinick et.al., 1998; Azañón *et al*., 2016; Haggard *et al*., 2007; Maravita and Iriki, 2004; Tsakiris, 2010; Tajadura-Jiménez *et al*., 2017; Vignemont *et al*., 2005; Tajadura-Jiménez *et al*., 2012; Longo *et al*., 2008; Tajadura-Jiménez *et al*., 2018; Maister *et al*., 2015). For example, presenting discrepant visual and tactile cues, or visual and proprioceptive cues about the body can lead to a change in one's body-perception, such as the perception that one's arm is longer than it actually is and corresponding errors in physical coordination (Kilteni *et al*., 2012; Vignemont *et al*., 2005). More recently, research has also shown that aural feedback can be used to alter body-perception. So, for example, one may also get the perception of having a longer or a stronger arm, if, when tapping one's hand on a surface the sounds produced are heard from a farther distance or louder than expected; and this will also influence one's subsequent arm movements and even one's emotional state (Tajadura-Jiménez *et al*., 2012; Tajadura-Jiménez *et al*., 2015; Tajadura-Jiménez, 2016).

Beyond these effects on body-perception, other works have shown that similar sensory feedback alterations can be used to alter the perceived material one's body is made of. If, for example, when an object hits one's hand it sounds like it is hitting marble rather than flesh, one's hand may feel stiff and heavy as though made from that material (Senna *et al*., 2014). Other studies have shown that shifting the frequency spectrum of the sounds made when rubbing one's hands together may make one's skin feel smoother or dryer (Jousmäki & Hari, 1998). Another study suggested that one's body may feel as if "robotized" or made of mechanic components, if, when moving one's limbs one receives vibrotactile feedback and sound from recordings of real robot articulations (Kurihara *et al*., 2013). Our project was inspired by all of these findings.

Crafting Common Space for Sharing Experiential Knowledge

Our team of three brings together expertise from each of our respective fields: e-textile design, cognitive neuroscience and HCI. This meant facing not only the challenge of learning about our respective fields, but also coming to terms with our different ways of working, acquiring and sharing knowledge. Our team consists of individuals with unique experiences, skills and motivations. We now introduce each actor of the study and their involvement in the project.

Kristi Kuusk, an e-textile designer, has the role of *artist* in our project. Kristi has a BSc in Information Technology and MA in Fashion Design, and her PhD thesis is entitled "Crafting Sustainable Smart Textile Services" (Kuusk, 2016). Her goal is to apply theoretical and scientific content in a new way, combining this with her passion for developing alternative sustainable futures for textile and fashion, and proposed to design a garment that would provide its wearer with a variety of sensations.

A multidisciplinary researcher in the fields of HCI and Cognitive neuroscience, Ana Tajadura-Jiménez has the role of *neuroscientist* in our project and is the principal investigator of the *Magic Shoes* project. Her research focuses on the use of sensory feedback for altering body perception and its applications for health. Her goal is to inform the design of novel body-centred and wearable technologies to support people's emotional and physical health needs and to effect behavioural change.

Aleksander Väljamäe an *HCI researcher*, is also a partner in the *Magic Shoes* project. He is focused on contributing to concepts and expertise in physiological computing. Among his research interests are somatic practices and soma-based design in relation to the work of actors and dancers. Specifically, creating an IT communications loop between body and mind for health and well-being, whereby vibrations provide information about the cognitive and emotional states of the user.

For all three members of our team, 'craft', as a way of thinking through material (Nimkulrat, 2012), was implicit in our practices in the *Magic Lining* project. We believe that this craft attitude has been essential in enabling us to share our experiential knowledge and engage with one another's disciplines. The team respects the "enduring, basic human impulse, the desire to do a job well for its own sake" (Sennett, 2008, p. 9), and we challenge one another to strive toward it continuously. We believe that by alternating between cognitive and sensory inputs throughout the collaboration we have been freed from our typical roles (as artist and scientists) and that this allowed each of us to contribute our distinct experiences, knowledge and skills.

Developing *Magic Lining*—A Collaborative Process

To obtain first-hand experience of the potential of soft vibrotactile materials, our team proposed to develop a dress capable of changing the wearer's perception of their own body. We followed an iterative design process, producing three prototypes and two user studies on the effects of various textile vibration patterns on body-perception (spatial haptic metaphors). This led to the production of a fully functioning prototype garment (Figure 2).

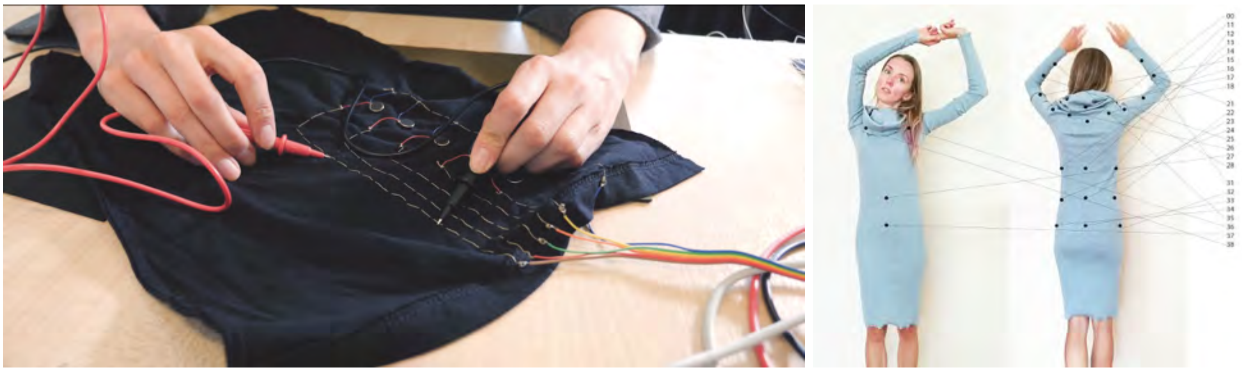

Fig 2. Left: first prototype of *Magic Lining*, allowing the user to experience a series of vibration motors delivering sensation patterns to the body through textile. Right: The vibration motor positioning on the final prototype. For a video describing the project and process: https://vimeo.com/289294125

The team members were each based in different countries, so communication was mainly via e-mail and Skype calls. In addition to these virtual meetings, we met for a workshop in Tallinn University, Estonia and for two residencies in Carlos III University of Madrid, Spain.

To kick-off the *Magic Lining* project, each team member presented their research at the World Usability Day event organized in Tallinn University. The scientists, Ana and Alexander, also visited Kristi's studio in order to get a better understanding of her work as an e-textile designer. During that meeting, Ana explained her work in neuroscience and proposed several keywords to provide focus for the project: "self-esteem", "body appearance", "physical strength", "body flexibility" and "body agility". This meeting coincided with a two-day workshop, which brought together around 20 people of multidisciplinary backgrounds and with a common interest in the project area. The group engage in an ideation process, to discuss the keywords and the ways in which they might guide the process of technological design. This sparked the first proposals for beginning the practical collaborative work.

Five weeks later, the first two-week residency at Carlos III University of Madrid took place. During this residency the team brainstormed ideas for a first prototype garment. Our team proposed to place small vibrating motors in the inner part of a fabric sleeve. These motors would connect to an Arduino microcontroller board, enabling them to be programmed with various patterns to stimulate the wearer's skin. The team discussed the possible mappings of vibrating patterns to sensations: which pattern could help convey the sensation of being stronger, or more flexible, or build self-esteem? How would these sensations be varied by the integration of the motors into different kinds of fabrics? Could a smoother fabric help the wearer to feel sensations and emotions associated with a soft embrace? Could a harsh, coarse surface trigger sensations associated with aggression, which would in turn make one feel more powerful or strong? A large part of the residency period was dedicated to addressing ideas relating to questions like these, and to introducing each team member to relevant work in one another's respective disciplines. Through these discussions, new ideas and practical considerations came into play, and in this way a common space for sharing experiential knowledge began to take shape.

The first vibrotactile prototype consisted of five vibration motors placed in a line (Figure 2, left) and allowed the team to explore the basic idea and the sensations the vibrating movement could potentially create. As we aimed to create more sophisticated patterns of vibration, we then proceeded by developing this into a sleeve that could transmit the vibrations across larger areas, creating sensations around the arm or on the back. We also wanted to explore the possibility of having the pattern of vibrations move gradually about the body. To achieve this, our next step was to create a 3 x 7 matrix of vibrotactile material.

Fig 3. The second prototype of *Magic Lining* allows the user to sense vibration movements from one end to another, inside out and outside in, on the back and around the arm.

After solving several technical issues in programming the second prototype (Figure 3) and connecting the electronics, the team began looking deeper into vibration patterns and behaviours. The team studied papers in experimental neuroscience to understand how sensitivity to tactile stimuli differs across various body parts (e.g. Nolan, 1982), how vibrations have already been used on the body (e.g. Amemiya 2013 and 2016), and what kind of vibration patterns have been used (e.g. Deroy *et al*., 2016; Harris, *et al*. 2017). They also looked at the spacing between each motor and the duration of vibrations. We do not elaborate on those insights here, and they are covered elsewhere (Tajadura-Jiménez *et al*., in preparation).

Having first experienced the second prototype for themselves, applying it to different body parts and with vibrations passing in various directions and movements, the team began preparing a wider user study to test systematically the effects of the different vibration movements and locations on people's body perceptions. According to the initial tests on team members, the conditions with the greatest potential were: a wave moving from the fingers to the upper arm; a wave from the upper arm to the fingers; a wave moving vertically from the centre of the back towards the upper and lower back; a wave moving vertically from the upper and lower back towards the centre of the back; a wave moving horizontally from the centre of the back towards the sides of the back; and a wave moving horizontally from the sides of the back towards the centre of the back.

For the user study, the team changed the look and feel of the initial prototype to something more robust and comfortable, and with the vibration motors hidden from view. In order to quantify user responses, we developed a questionnaire based on previous cognitive neuroscience and psychology papers and on HCI papers (e.g. Tajadura-Jiménez *et al*, 2015; Longo *et al*, 2018; Stroyer *et al*., 2007). The questionnaire asked participants to report the bodily sensations they experience immediately before the test session and then the experience of each vibration pattern on their body. It also asked whether they felt quicker/slower, heavier/lighter, stiffer/more flexible, harder/softer, and so on. In this way, we created a starting point for understanding whether the vibrations could affect the way people feel about their environment or their own body composition (e.g. wood, water, rocks etc.).

To allow us to programme a wider range of patterns and with more detail, our third prototype resembled a spider's web (Figure 4), with 38 vibration motors placed in lines that cross at the centre.

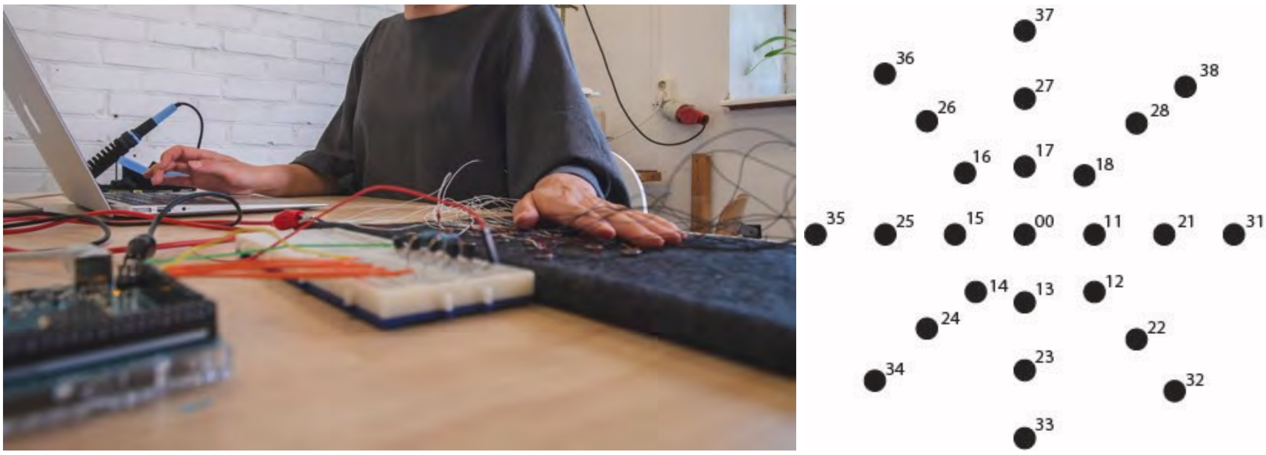

Fig 4. The third prototype of *Magic Lining* allows the user to sense vibration movements under his/her hand. The aim is to create body sensations that relate to materials.

During the second two-weeks residency, which took place in the seventh month of the project, the *Magic Lining* team explored further ideas about sensations, movement, vibration and textile materials. Once the "spider's web" electronic circuit was set up, the team created patterns that allowed us to check all the motors individually and in groups. We then started to explore with patterns that moved with different strengths, speeds and directions.

To create the patterns, one of our external collaborators developed a "pattern generator"—a software programme that allowed us to set the sequence and duration of each individual vibration motor, thereby generating code for the Arduino controller. This allowed us to freely experiment with many more patterns and intensities, which we again tried first on our own bodies.

After trying various patterns and analysing the results from the previous user tests, we identified some interesting directions for our project. We decided to focus on simulating the touch of three, very different, materials and then set to work developing a series of vibration patterns, intensities and different material surfaces that would simulate as closely as possible our idea of how a cloud, water and concrete should feel (see Figure 5). We began by thinking about how best to characterise these three phenomena and between the three of us came up with a list of keywords that would define the sensations we were aiming for. For example, "cloud" made us think of these keywords: air, calm, cuddle, cosy, comfortable, gas, warm, temporary, soft, white, light (i.e. weight), sun, flexible, fluffy, slow, light (i.e. colour), round, and loose. Parallel to this process, we sought the most appropriate material surfaces in which to embed the vibration motors. We looked at around 40 sample materials of varying characteristics and evaluated their influence on the sensations produced by the vibration movements. Again tested each material sample for themselves, this time with each of the three patterns, and selected the two samples that seemed the most extreme in relation to each other. Material sample 1 was a soft, fluffy, white unwoven polyester of the type normally found inside warm jackets, and sample 2 was a black, structured, woven waffle polyester that could be used for light jackets, skirts or trousers.

To enable the user to experience all three different vibration patterns on the new prototype, we added three, soft-touch, user selection/interface surfaces.

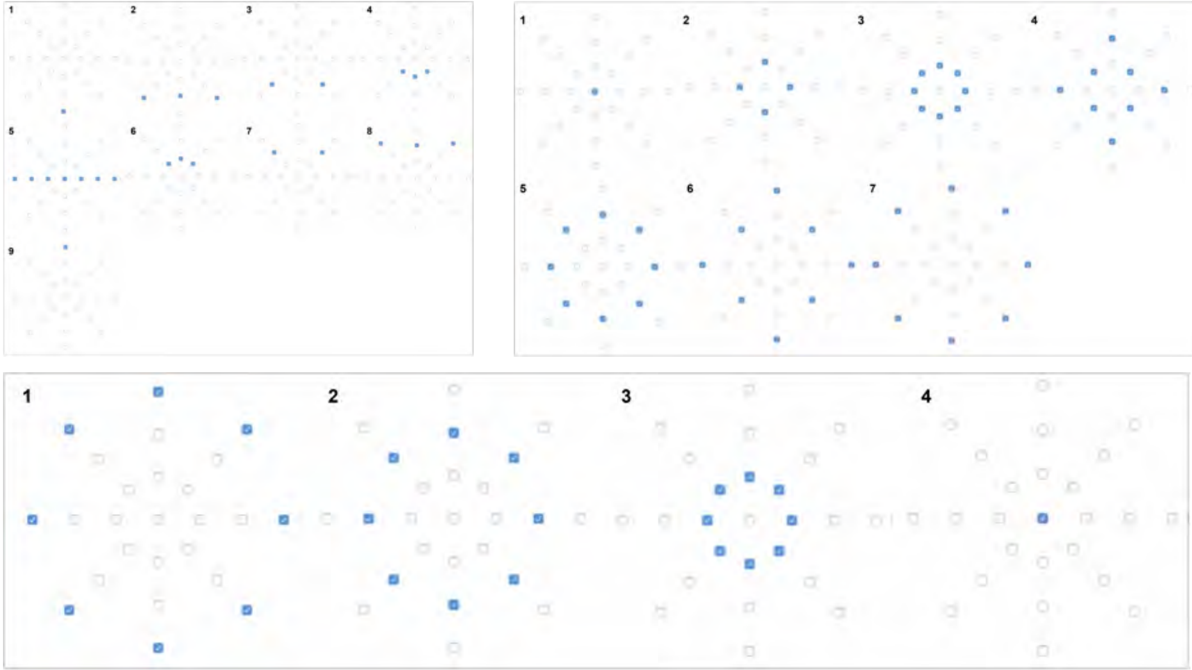

Fig 5. Vibration patterns used to simulate the feelings of water (upper left), air (upper right) and rocks (bottom).

Having got the prototype to a reliable functioning state, we started to experiment with adding sound and movement to enhance the vibration patterns. Drawing from *the Magic Shoes* project, we paired patterns with suitable sound files, which could be triggered by the wearer's hand touching different surfaces. We looked at whether sound enhances the experience of touch, again relating this to each of the various vibration patterns and fabrics.

Before deciding on the final cut and look of the *Magic Lining* garment, we presented the prototype at public events at the Pompidou in Paris and at the International Conference on Movement and Computing in Genoa (Kuusk *et al*., 2018). We produced a second, duplicate prototype (made from a different textile) to enable as many visitors as possible an opportunity to try a *Magic Lining* garment, and asked them each to complete a short questionnaire about the experience. The visitors were able to try all three vibration patterns with two different surface materials. The feedback from these events informed our decisions about the final prototype.

***Magic Lining*: altering body perception through e-textiles**

Our final wearable prototype is a dress with 38 integrated vibration motors. The motors are distributed along the body and guided via an Arduino controller. The placement of the vibration motors follows the spider's web structure of the third prototype and the logic that it would be possible to experience movements over both arms as well as around the body (Figure 6 right). Since the vibration is placed on the outer side of the arms, it can give the sensation of embracing the wearer and move around her.

The cut and material of the dress was selected based on the following criteria. For the vibrations to be felt as intended, the garment needs to be tight and close to the body. At the same time, the dress has to be flexible to allow the wearer to move freely. Jersey tubular dress with tight sleeves allows both.

This prototype invites the wearer to experience three very different materials: strong, fast, rhythmic vibration resembles a cold, rough surface, such as rocks; smooth, moving, medium vibration reminds the wearer of a flowing stream of water; and soft, distributed, slow vibration allows the user to forget him/herself in a soothing sensation of air or cloud.

Fig 6. The inside layer of the final prototype of *Magic Lining* allows the user to feel as if she/he is made of three different materials: air, water, rocks. A professional dancer is shown experiencing the prototype in these photographs.

We invited an acting professional dancer to experience the sensations the dress evoked in her (Figure 6). She expressed clear sensations of feeling calmer or more nervous when the vibration patterns were switched. This was reflected in her way of speaking, the tonality of her voice, speed of movement and body language. She described mental images of composers and pieces of music that specific vibration patterns brought to mind.

We continue to develop the project and to explore this idea in new directions, including: the use of multisensory stimulation (where vibrotactile feedback is paired with other sensory feedback such as sound, light or smell); a closed-loop bio- or neuro- feedback system; and social interaction settings. We would now like to provide some insight into our experience of this multidisciplinary shared project, and to discuss its possible implications for future collaborations of this kind.

Discussion

Departing a little from Tim Ingold's claim that *"It is the artisan's desire to see what the matter can do, by contrast to the scientist's desire to know what it is"* (Ingold, 2013, p.31), we instead discovered both "artisans" and "scientists" in all of our team members. It is our willingness to let go of the authority of our respective areas of expertise, our established methods, and to reach out into the unknown, that has enabled us each to listen and learn from each one another's experiences. Over the course of the project, the e-textile designer had the opportunity to conduct formal user studies, while the neuroscientist could reflect upon the tactility of various materials. All three of us sewed, soldered and programmed. We continued as experts in our fields, but conducted this work using unfamiliar methods and tools.

As art, the goal of the project was to create through our garment a sensation of air, water or some other perceived substance, flowing through the wearer's body. With the structure and knowledge provided by the scientific participants, the concept developed into something far from a fashion statement and gained real insight into people's body perception. Through user studies, as artists we learned to seek test our ideas and intuitions. The additional technologies we began to look at during the project (e.g. the use of sound) opened further avenues for future exploration.

As science, the goal was to open up a space for designing multisensory wearable interfaces that act on bodily sensations and emotional experiences, by practical experimental application and reflecting on existing research, in order to find alternative directions, concepts and methods for further research. From the scientific point of view, the artist brought a new, alternative approach to the work, and three new lines of future research unfolded during the collaboration: (i) a new way of thinking about materials (e.g. a cloud, rocks) as sensations relating to the definition of body perceptions (e.g. being light or heavy); (ii) the potential for the interaction between vibrotactile patterns and textile surface to induce various bodily sensations; and (iii) new ways of changing one's body perception from within a garment—i.e. a form of stimulation that is both invisible and entirely intimate to the user.

The project produced a series of prototypes that enable the public to experience bodily sensations that suggest the material substance of a cloud, of water, or of rocks, thereby affecting the wearer's perception of their own body. The sensory-feedback technology developed from those prototypes is integrated into the inner part of the final prototype haptic dress, *Magic Lining*.

The work has benefited and inspired both our artistic and scientific partners. We have presented the project, its process and results, internationally: World Usability Day at Tallinn University (one art/design presentation, two science presentations, and a two-day workshop); Vertigo Residencies day at Centre Pompidou (presentation and demonstration); International Conference on Movement and Computing (demonstration and scientific paper); and the textile futures seminar at Tallinn Design Festival (presentation). Further, interest from commercial industry.

It is because all three team members shared all of the project tasks—generating ideas, prototyping, conducting user studies, analysis, experimenting with and experiencing the prototype technology, planning, reflecting, writing, etc.—that we were able to contribute our specific knowledge and experience most effectively. Although some tasks may have been performed more quickly had we allocated them exclusively to an 'expert' team member, we learned by working together—seeing directly the results of one another's work, but also submerging ourselves fully into every aspect of the process with the guidance of someone for whom this was a daily practice. We believe that this shared approach has led to insights we would not have gained otherwise. It required that we all step away from the comfort of our own discipline and accept the challenge of viewing a task from each other's discipline and perspective. In this way, we each took the opportunity to experience with fresh eyes the work and concepts that had already been central to our own work for some years. As Sennett (2008, p. 220) points out: *"Though much can be lost in moving from one language to another, meanings can also be found in translation."*

The following insights, ways of exchanging ideas and co-creating, emerged from our experience of developing *Magic Lining* as a multidisciplinary team. We experienced a shift in perspectives, "thinking out of the box", and cross-pollination between our areas of expertise. Following the approaches and methods of scientific practice gave structure to the artistic practice and, conversely, the artistic approach enabled moments of creative "chaos" to inspire the scientific practice. All three participants appreciated the common co-creative space and have seen its benefits for their daily work. We had to allow a generous period for getting for know each other, to gain a mutual understanding and find a common language. We achieved this through taking the time to present our ideas to one another, through creative drawing sessions, and by exploring materials. We kept a daily log of activities, including notes and photographs, that helped us to maintain our focus and continue to progress the project.

Our collaborative work showed that the use of vibrotactile patterns could induce various haptic metaphors in the wearer. In other words, e-textiles enable one to "wear" different sensations. However, it is important to bear in mind that since the vibrations delivered via textile are still relatively novel, there may be a "surprise" factor at play and wearers may eventually become habituated toward the experience—a phenomenon that is common with tactile actuators (both mechanical and electrical). The effects of long-term usage of this wearable technology need to be studied. Nonetheless, given the specificity of somatosensory stimuli and their role in fight-flight type reflexes, the use of haptic metaphors as tactile icons or “tactons” could be very effective. We are hopeful that the field of somaesthetic research and applications relating to designing for various bodily experiences, such as *Soma Carpet*, (Shusterman, 2008; Höök *et al*., 2016), will benefit from our work. As identified by *Teslasuit*, the personalisation of patterns is probably key to the success of such haptic clothing.

Every project is a new invention, utilising the knowledge gained from previous work, but always solving new challenges in new ways (see also Satomi and Perner-Wilson, 2007), and we discovered throughout the process that e-textile development could be very precisely tailored for a specific purpose and user—everything from the physical garment to the placement of the vibration motor arrays and pattern programming.

Our work *on Magic* Lining has made us wonder about the fashion of the future. Could it become something that is essentially experienced by the individual user rather than seen by others? What would the future catwalk be like? Instead of wearing the latest cuts and patterns of famous fashion designers, could we be wearing designer-emotions, downloaded directly to our second skin?

Acknowledgments

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Kristi Kuusk

Kristi Kuusk is a designer-researcher working on the direction of crafting sustainable smart textile services. She is looking for new ways for textiles and fashion to be more sustainable through the implementation of technology. In 2016 Kristi presented her PhD project on craft and sustainability qualities in smart textile services at the Eindhoven University of Technology in Designing Quality in Interaction research group. The related collaborative design work has been presented in various international exhibitions, shows and conferences. Her PhD work related to Augmented Reality on textiles was granted a patent in 2018 and commercialized by an industrial partner. Today Kristi works as an Associate Professor and researcher in the textile futures direction at the Estonian Academy of Arts. In 2017 her project "Magic Lining" was awarded by the jury of VERTIGO to collaborate with ICT R&D projects with the goal of producing original artworks featuring innovative use-cases of the developed technologies. In 2018 her explorative children clothing brand Spellbound was selected by the jury of WORTH as one of the winning projects for transnational creative collaboration. In 2019 Brooklyn fashion + Design Accelerator nominated Kristi as one of the 23 women leading the world of fashion technology.

Ana Tajadura-Jiménez

Ana Tajadura-Jiménez is an associate professor at the DEI Interactive Systems Lab at Universidad Carlos III de Madrid and honorary research associate at the University College London Interaction Centre (UCLIC). She graduated in Telecommunications Engineering from Universidad Politécnica de Madrid in 2002 and obtained an MSc degree in Digital Communications and Systems (2003) and a PhD degree in Applied Acoustics (2008), both at Chalmers University of Technology, Sweden. She was a post-doctoral researcher at the Lab of Action and Body at Royal Holloway, University of London (2009-2012) and an ESRC Future Research Leader at University College London, leading the project "The Hearing Body" (2012-2015). Since 2016 Ana is a Ramón y Cajal research fellow in Spain conducting research on multisensory body perception, wearable and self-care technologies at the intersection between the fields of human-computer interaction and neuroscience. She is currently Principal Investigator of the MagicShoes project, which aims to inform the design of technology to make people feel better about their bodies and sustain active lifestyles. This project has taken her to be part of the H2020 STARTS Arts-Science collaboration initiative. Her research has lead to over 100 peer-reviewed publications in international journals and conferences, and 4 book chapters.

Aleksander Väljamäe

Aleksander Väljamäe received his PhD in applied acoustics at Chalmers University of Technology, Gothenburg, Sweden, in 2007. He has been doing research in Sweden, Spain, Japan, Austria and Russia. During this time he has being active in a number of EU projects: POEMS, PRESENCCIA, BrainAble, TOBI, Future BNCI, CONTRAST, GALA, BrainHack; and acted as an external expert for EC. Since 2016 he is an associate professor in physiological computing at Human-Computer-Interaction group, Tallinn University, Estonia. His current psychophysiology research concerns how audiovisual media influence humans on perceptual, cognitive and emotional levels, with particular stress on health/well-being and new applications (Brain-Computer Interfaces, neurocinema, neurotheatre). He also actively participates in art and science projects, e.g., his technical directing of the “Multimodal Brain Orchestra” performance in 2009, Prague or directing neurotheatre performance "Demultiplexia" in 2017, Brussels. He authored over 30 journal articles and book chapters.

Sharing Heritage Restoration Expertise: The UNESCO Creative Cities Network as Opportunity of Creative Development for Kuldīga, Latvia

Pilar Fernández, Brandenburg University of Technology Cottbus-Senftenberg, Germany

Kristina Rovnenko, Brandenburg University of Technology Cottbus-Senftenberg, Germany

Abstract

Kuldīga's old town preserves its built environment thanks to the continuous restoration of its historic buildings. Such commission has required the application of a specific knowledge experientially transferred among generations. Ensuring the existence and transmission of this expertise to new apprentices, major participation of local citizens by diversifying the preservation activities and finding stable economic sources presents difficulties. The on-site observation of the city's built heritage, the access to inventories and the review of the main activities implemented by the Restoration Centre have been key to understanding these deficiencies and rethinking the development of Kuldīga through its creative potential. An important finding is that the expertise derived from a repeated reproduction of artisanal techniques on the field of restoration, can be a unifying factor in the development of Kuldīga, and that the flexible nature of the experiential creative practices allows for greater experimentation towards unexplored areas. In the light of the current actions successfully undertaken by the UNESCO Creative Cities Network's participant members, the eventual incorporation of Kuldīga to this network may enable collaboration and visibility at the international level, and linking its craft expertise to areas such as creative tourism, innovation through research and first-hand education activities.

Keywords

Heritage; Restoration; Experiential Knowledge; Kuldīga; UNESCO Creative Cities

The present paper explores the case of Kuldīga's old town as a noteworthy example in preservation matters and on the potential of its craft expertise associated to restoration practices as an opportunity of associative development for the city, as part of the solution to the present challenges.

Kuldīga, a city located on the arrays of the Venta river in Latvia, retains an untouched town scenery which displays a series of traditional techniques developed through centuries on the building's roofs, doors, windows, furniture and small-medium scale objects; an aspect that has shaped its character giving it a unique degree of authenticity preserved over the last 300 years. Recrafting buildings with artisanal accents has been one of the paramount tasks undertaken by the city authorities during recent years, a work that has required a very specific know-how in treating the wood and developing intellectual and manual processes in order to keep the uniqueness of the site.

Its preservation has been mainly materialized thanks to the work conducted by the Kuldīga Restoration Centre, the institution that has carried out various restoration actions and awareness raising programmes targeting the old town's residents. However, despite the truth that the implementation of these activities has brought advancements in conservation issues, education and participation of local population in understanding the cultural value of the city's built heritage; is still necessary to expand collaborative alliances towards new audiences and ensuring the economic resources to give continuity to the preservation's practices.

Therefore, this paper aims to develop a deeper understanding of the artistry expertise required to conduct restoration works in many built examples of Kuldīga, and to explore the associativity with similar crafts cities in order to use the creative potential of these processes as a collaborative means of advance for the city's creative sector. Additionally, to review and propose coherent partnership as part of the solution to current problems faced by the Restoration Centre.

The Experiential Knowledge in Context of Built Heritage

Several experts have developed numerous approaches to the meaning of the term "experiential knowledge" over time. Although these definitions derive from authors involved in distinct disciplines, there has been consensus in affirming that knowledge of this kind emerges mainly from "things recalled from experiences, things tacitly or implicitly learned or acquired" (Storkerson, 2009), and that given the relationship between individual and experience, not always can be accurately communicated to others.

Another significant aspect in its definition is its intuitive nature, specifically since most times "[…] we arrive at knowing in such a way that consciousness is informed of what is known without witnessing or knowing how it was arrived at" (Storkerson, 2009), being a feature that does not allow to classify it as formal knowledge. In consequence, a great resistance has been demonstrated in linking experiential knowledge with research in many disciplines.

However, despite these characteristics seeming to be at odds with the rigorous methods generally applied in the research area, "[...] many researchers in art and design and related fields perceive experiential knowledge or tacit knowledge as an integral part of their practice" (Niedderer and Reilly, 2010), which links the experiential knowledge to the creative sector and suggests a degree of complementarity.

An example of the relationship between experiential knowledge and creativity are the artisanal processes applied in the generation of uncommon products, accepting as principle that "craftsmanship involves the skilled working with the hands to create something of use for a purpose where the skills require training and usually continuous practice" (Klamer, 2012). On this aspect, Sennett (Sennett, 2018) stresses the importance of training to develop a skill, due to "[…] the more people train and practice in developing a skill, the more practical minded they will become, focusing on the possible and the particular" (p. 46), highlighting the practical sense of any craft.

According to Duffy (2011) in the context of built heritage, the meaning of artisanship "[…] can be extended to the remaking of things" (p. 234). This fact demands directing the attention on the same piece or building several times, particularly considering that "[…] the notion of craft becomes paramount in any discussion of character, particularly in the context of pre-industrial building types" (p. 233).

Nowadays, the practice of re-crafting and restoring the built heritage is indeed a very common exercise, especially in sites of abundant historic urban value such as picturesque areas, architectural ensembles with focus on crafts or historic towns, among others; places that require retaining specific physical attributes and relevant historical layers as part of their seal of authenticity. This is the case of the city of Kuldīga, Latvia.

The Kuldīga's old town presents more than 400 wooden living houses built between the 17th – 19th centuries and developed in a modest geometry erected in accordance to epochal materials and technologies. Most of these dwellings, where local residents have been living for generations, are also the product of a particular artisanal skill acquired by repetition over time, a fact that was fundamental in achieving an incomparable built environment. This expertise is distinguishable on the roofs, facades, doors, windows, ornaments and even furniture, characteristics that gave a formal unity to the town and endowing it with a unique value.

Latvian Heritage: The Case of the Old Town of Kuldīga

Kuldīga was the former centre of Cours, Bandava, until the formation of a new settlement around the 9th century, and invaded by the Germans years later. It was mentioned for the very first time in official documents in 1242, and from 1596 to1616 served as the capital of the Duchy of Courland (Municipality of Kuldīga n.d.). The urban fabric includes buildings of various centuries harmoniously blended in the wind-streets of the town. Due to a charming atmosphere of the past and the Venta River, Kuldiga is often called the "North Venice" (Jākobsone, 2010)**.**

Over time, the inhabitants of the city have developed a very strong sense of belonging towards the values of Kuldīga's old town, constituted by a unique cultural landscape where it is possible to observe tangible remains of previous peoples' actions, particularly, the exceptional artisan handwork. This important work facilitated obtaining the European Heritage Label in 2008, because of the preservation of its singularity.

Jākobsone (2010) has also specified that result of applied local surveys have shown the relevance of continuing with the implementation of education activities to renovate and improve the cultural heritage environment, following the core principles, techniques, methods and materials demanded by the historical building preservation field.

Kuldīga and its Unique Environment of Wooden Buildings and Craftworks

Until the present day, the urban-planning structure of Kuldīga has preserved features of an ancient town with a large number of long-standing buildings, art objects and unique products of local artisans.

Following to Jākobsone (2010) the urban and architectural characteristics of Kuldīga underwent several changes over the centuries. The old site plans and pictures of the city show that initially the vast majority of structures were wooden. One of the main constructional features of the buildings was double-pitched roofs made of straw and shingle. Later, fire safety considerations came to the fore due to an increase in site development density, and as an intention to reduce the possibility of fires, tile roof construction was started, a circumstance that has given the city a distinctive atmosphere to this day.

In the 19th century, single-story wooden houses remained the dominant type of dwellings, whereas, in contrast, one-and-a-half story buildings and two-story ones were less common. Afterwards two- and three-story masonry houses came into ascendance, creating a clear outline of the perimeter of the streets (pp. 41-50).

The Tentative List report submitted in 2011 indicated that the singularity of this area in comparison to other areas of the world, such as the Scandinavian states, is the result of "[…] its authentic town environment of the 13th century, as well as the character of cultural landscape from first half of the 20th century". The report also defined the old town of Kuldīga as a mixture of "[…] wooden building manners of the North-Eastern costal (sic) regions of the Baltic Sea, but also masonry building manners, details and authenticity in general, that is not preserved in equal value of concentration, compactness and harmony elsewhere" (Latvian National Commission for UNESCO 2011).

Buildings, architectural elements, and small-medium scale objects like furniture produced during the 17th-18th-19th centuries conform Kuldīga's wood heritage. In relation to Kuldīga historic centre's architectural values, Jākobsone (2010) has established that some of them have been recognized as not alterable in order to preserve the original image of the city; for instance, the medieval town planning's configuration, small streets and backyards, the red clay tile roof landscape and the details of civil buildings and churches. These details are based on carpentry such as doors and ventilation panes above them, woodcuts, windows, jagged ledges; and hammered work in vanes and gates (p. 19).

Fig 1. Photo collage showing different examples of Kuldīga's wooden heritage made by the authors. (Photos: Kuldīga: Architecture and Urbanism, 2013).

From Buildings to Small-Medium Scale Objects

As already mentioned above, Kuldīga has a great number of wooden structures and elements. This collection is represented by buildings, entrance doors, transom windows, pieces of furniture and small-medium scale items. For instance, the St. Catherine's Lutheran Church, built in the 17th century, is the oldest monument of sacred architecture in the town. Wooden structural elements of the building and a collection of objects such as an organ, an iconostasis and a pulpit are of particular importance. Additionally, elements of dwellings are no less valuable. Ornamentation of transom windows, which was created individually for each house, serves as a proof of local artisans' craftsmanship. Therefore, many of the buildings belong to the group of objects with a national significance; some of them represent examples of properly implemented restoration; others testify mastery of Kuldīga's artisans.

For a better understanding of wooden built heritage stock, it has been divided into two large groups according to its main function and use: religious buildings and civil ones.

Ecclesiastic buildings always stand out among other structures in cities for the reason of their spiritual significance as well as a unique architectural appearance peculiar only to this type of structures. Jākobsone (2010) states that churches of Kuldīga, represented by a diverse range of styles, are considered jewels of built heritage. Not only the buildings themselves, but also artful items in the interiors testify to the skills of local inhabitants and active community involvement (p. 234).

Residential houses represent the most common types of buildings in the town. Recent research provides evident data on the origin of wooden architectural elements relatively well preserved over the centuries. Gained through the study, knowledge of artisans' talent and applied techniques contributes a proper restoration of the buildings in order to preserve the atmosphere of an ancient town, especially in its historical centre.

A list of properties and objects, which fully displays the scale and sizes of the Kuldīga's wooden heritage repertory, is attached below (see Table.1):

Buildings	Building Ornaments	Furniture	Objects
There is a great number of wooden buildings being symbols of different eras in the town. Their value is determined by the presence of authentic structural elements and materials, as well as properly implemented restoration work reflecting features of the former settings. Some constructional details and junctions represent unique methods developed by artisans of that time (Jākobsone, 2010).	Many entrance doors and windows of ecclesiastical and residential buildings in Kuldīga are decorated with different ornaments mostly following geometrical and scrollwork patterns. Some facades are decorated with casings, and wooden frames of windows have artistic fittings in the corners. Transom windows with muntins often have their own decor created by craftsmen of local workshops.	Wood furniture of the ecclesiastical buildings is of particular artistic value demonstrating harmonious composition of the elements, detailed carving and peculiarity of forms. Some items are made and restored by renowned carpenters.	Sculptures, located in the churches of Kuldīga, are great examples of applied art made by skilled professionals. Some of them stand separately; others are parts of the interior elements. In both ways, elaborate ornamentation and proportions of the forms catch visitors' interest.
1 storey wooden residential building Address: 1905. gada iela 12 Date: 19th century Significance: National significance	**Entrance door A** Address: 1905. gada iela 14 Date: No date (n.d.)	**Holy Trinity Roman Catholic Church:** *1. Central altar;* *2. Pulpit;* *3. Organ loft;* *4. Confessional booth;* *5. Chest of drawers;* *6. Chest for baptismal font.* Address: Raiņa iela 6A Date: 17th – 18th century	**Holy Trinity Roman Catholic Church:** *1. Easter Christ.* Address: Raiņa iela 6A Date: 17th – 18th century
1.5 storey wooden commercial and office building (old town hall) Address: Baznīcas iela 5 Date: 19th century Significance: National significance. Status: Restored	**Entrance door B** Address: Baznīcas iela 1 Date: No date (n.d.)	**St. Anne's Lutheran Church:** *1. Altar;* *2. Pulpit.* Address: Dzirnavu iela (Mills Street) 12 Date: 19th – 20th century	**St. Catherine's Lutheran Church:** *1. Figure supporting the pulpit.* Address: Baznīcas iela 31/33 Date: 17th – 19th century
1 storey wooden residential building Address: Baznicas iela 7 Date: 19th – 20th century Significance: Regional and/or Local	**Transom window A** Address: Baznicas iela 7 Date: 19th – 20th century	**St. Catherine's Lutheran Church:** *1. Altar;* *2. Pulpit;* *3. Organ.* Address: Baznīcas iela 31/33 Date: 17th – 19th century	

2 storey wooden residential building (Duke's pharmacy, now a dwelling house) Address: Baznīcas iela 10 Date: Early 18th century Significance: National significance Status: Restored	**Entrance door C** **Transom window B** Address: Baznīcas iela 17 Date: 18th – 19th century	**The Orthodox Church of Intercession of Our Most Holy Lady:** *1. Iconostasis* Address: Smilšu iela 14 Date: 19th century	
1 storey mixed construction residential building Address: Baznīcas iela 17 Date: 18th -19th century Status: Restored	**Entrance door D** Address: Kalna iela 13 Date: Late 18th century	**Chest-like wardrobe** Address: Baznīcas iela 17 Date: 18th -19th century	
1 storey masonry and wood commercial and residential building Address: Jelgavas iela 1 Date: 19th century Significance: National significance	**Entrance door E** Address: Skolas iela (School Street) 2 Date: 19th – 20th century		
1 storey wooden residential building Address: Kalna iela 13 Date: Late 18th century Significance: National significance	**Entrance door F** Address: Skrundas iela 12 Date: 19th century		
1 storey wooden residential building with a wind porch Address: Kalna iela 14 Date: 19th century Significance: National significance	**Transom windows C** Address: Smilšu iela 23 Date: 19th century		
1 storey wooden residential building Address: Kalna iela 15 Date: Late 18th century Significance: National significance	**Entrance door G** Address: Corner of Pasta iela - Jelgavas iela Date: 19th century		

1 storey wooden residential building Address: Liepājas iela 17 Date: 19th century Significance: National significance	**Transom windows D** Address: Ventspils iela 37 Date: 19th century		
1 storey wooden kiosks (Dairy and Tourism Pavilion) Address: Pils iela 4a Date: 20th century Significance: Regional and/or Local			
2 storey mixed material residential building (villa) – Museum Address: Pils iela 5 Date: Late 19th century Significance: Regional and/or Local			

Table 1 List of Kuldīga's wooden heritage repertory made by the authors. (Source: Kuldīga: Architecture and Urbanism, 2013).

The Kuldīga Restoration Centre as Vector of Preservation

In Kuldīga one of the most active organizations in conserving the artisanal and architectural features of the city's built heritage has been the Restoration Centre, the institution that has stimulated the association between different stakeholders and the community by implementing various initiatives. As recognition of this labor, "the Kuldīga Restoration Centre has been awarded the European Union cultural heritage award 'Europa Nostra' for researchers and restorers work with residents in furthering understanding of cultural heritage issues" (Krastiņš, 2013), a distinction that not only highlights its practical vocation but also its socializing role.

International Restoration Workshops

The International restoration workshops consist of a sequence of practical sessions organized and implemented mostly by the Kuldīga Restoration Centre aiming at professionals from the creative field concerned.

The strategic goals of these international meetings are improving the wooden houses' condition by applying practical works and offering seminars to spread the awareness of preservation of wooden architecture and traditional crafts techniques internationally. In addition, these workshops are a didactic attempt oriented particularly to young professionals, offering them educational classes where the knowledge is shared emphasizing the importance of traditional crafts in the progression of the tourism industry and the relevance of undertaking sustainable development maintaining the authenticity of cultural assets for future generations.

Fig 2. International summer workshop of restoration in Kuldīga, 2010 and 2017 respectively. (Photos: Ilze Zarina, Head of Kuldīga Restoration Centre)

Preservation Activities Complex of Kuldīga Old Town

Conforming to information provided by the Head of the Kuldīga Restoration Centre, since 2008 the centre has been performing the project "Preservation activities complex of Kuldīga old town". The project, which aims to improve the attitude of the community in understanding the values of Kuldīga's built heritage, and "to preserve traditional and rare craft skills and knowledge that are in danger and disappearing [...]" (Kuldiga Restoration Centre, 2018) has brought several benefits. For instance, the institution has notably broadened its network beyond the region to other countries such as Estonia, Finland, Sweden, Norway and Denmark, having as common operational objectives "[…] the conservation of the authenticity of the historical sites, to ensure appropriate maintenance of the sites and to exchange the knowledge about heritage sites preservation" (Kuldiga Restoration Centre, 2018).

Furthermore, the initiative has been a successful example of bringing together different actors involved in protected heritage, such as "craftsman, experts on historical buildings, architects, municipality specialists and owners of the historical houses" (Kuldiga Restoration Centre, 2018), and in reaching multiple advancements in restoring the built heritage of the city by sharing international experiences between regions of similar profiles. These advancements have been possible thanks to the implementation of particular activities that are part of the project, such as the "Cultural heritage laboratories" and the "Regular maintenance of windows" programme, among others.

In the case of the Cultural heritage laboratories, the main goal has been focused on educating to Kuldīga's citizens in the appreciation of the significance of local cultural attributes. Since 2008, the institution has organized eight laboratories oriented to instruct residents through the guidance of local and international experts in restoration subjects.

The practical approach to the restoration topic has attracted the participation of citizens in different activities, such as painting the facades of buildings, practical preservation of wooden details, restoration of roofs, maintenance of windows, isolation of historic buildings and the examination of historical layers from different time periods present in old buildings, among others (Kuldiga Restoration Centre, 2018). Some of these laboratories have also addressed issues related to common climatic features, such as saving energy in old houses, by providing several alternatives to be applied by the same residents in their own houses and opening discussions on certain problems to be solved at the municipal level given its complexity.

For its part, the Regular maintenance of windows programme was created as an endeavor to motivate the participation of Kuldīga's residents in applying restoration works to their own properties, bringing them closer to simple but effective techniques. This commitment was formalized through the signature of several contracts between the participant families and the municipality to ensure at the same time economic coverage of the "(…) costs of materials for windows preservation and consultations of the specialists" (Kuldiga Restoration Centre, 2018).

Fig 3. Example of window's restoration work conducted by the Kuldīga Restoration Centre in Baznicas iela 7, Kuldīga, 2018 (Photos: Pilar Fernández)

Through the findings, it was revealed that in different family groups committed to carrying out practical work on their houses, the youngest ones (for example: grandchildren) collaborated with the more adults and experts of the group, gaining early knowledge about traditional materials and methods. This fact represents an auspicious situation not only for the work itself, but also in transmitting valuable knowledge and non-formal training within local families, contributing to reinforce social-cultural aspects such as regional identity and sense of belonging in Kuldīga.

Problems and Challenges

The activities implemented by the Kuldīga Restoration Centre between the years 2008–2012 have been funded through different sources. Some of them coming from the Kuldīga Distric Council, the Latvian State Culture Capital Foundation (SCCF), the Nordic Council of Ministers (KKNORD) through its NordPlus Adult Educational programme, and country members of the project's network such as Norway, Denmark and Finland (Kuldiga Restoration Centre, 2018).

However, the support has been mainly obtained on a competitive basis. This situation has meant laborious work for the Kuldīga Restoration Centre, since every year it has to apply to different funding calls, generating uncertainty among the organizers, particularly considering that "[…] results of the granted applications always are announced rather late" (Kuldiga Restoration Centre 2018). The lack of economic guarantee not only has demanded a busy schedule, but also has put at risk its continuity, a circumstance that has instigated the Kuldīga Restoration Center to be in a permanent search for new financial alternatives.

In this sense, the centre's team is aware that it needs to enlarge their cooperation to other countries and other groups, such as NGOs from social fields, and to set new education guidelines oriented to different audiences and to improving the understanding of Kuldiga's heritage. The institution has also concluded after several years of work with the community, that the introduction of new activities is urgent in order to attract to all those citizens who have not yet participated in the preservation of the city's old town.

The UCCN as an Opportunity of Collaborative Development for Kuldīga

The UCCN is a project established in 2004 "to promote cooperation with and among cities that have identified creativity as a strategic factor for sustainable urban development" (UNESCO 2013). The network formally designates cities in several creative categories, connecting local actors into an international web, and puts an emphasis on specific areas for the development of creative economy of cities (OECD, 2014). It covers seven fields: Crafts and Folk Art, Design, Film, Gastronomy, Literature, Media Arts and Music (UNESCO, 2013).

Nowadays, the 180 cities from 72 countries "which currently make up this network work together towards a common objective: placing creativity and cultural industries at the heart of their development plans at the local level and cooperating actively at the international level" ("About us I Creative Cities Network", n.d., para.1).

According to the UCCN's mission statement (2013), the organization aims to achieve the following objectives:

- strengthen international cooperation between cities that have recognized creativity as a strategic factor of their sustainable development;
- stimulate and enhance initiatives led by member cities to make creativity an essential component of urban development, notably through partnerships involving the public and private sectors and civil society.
- strengthen the creation, production, distribution and dissemination of cultural activities, goods and services;
- develop hubs of creativity and innovation and broaden opportunities for creators and professionals in the cultural sector;
- improve access to and participation in cultural life as well as the enjoyment of cultural goods and services, notably for marginalized or vulnerable groups and individuals;
- fully integrate culture and creativity into local development strategies and plans.

The Crafts and Folk Art Category and its Compatibility to the City's Profile

At present, there are 38 cities designated under the "Crafts and Folk Art" category. By means of nomination for this creative field, Kuldīga acknowledges the human talent in traditional craftwork.

The wooden architecture of the city developed through centuries, giving evidence to and accumulating a rare "know-how", an aspect that has played an important role in the city's construction and has reinforced local identity. Accordingly, various events and measures have been undertaken at local and national scale by the city authorities to preserve these particular features, such as the improvement of regulations on building activity, academically oriented research, restoration and renovation of buildings, and the elaboration and publication of graphic and educative materials, supported by different institutions and municipal departments.

Until now, the efforts in preserving the Kuldīga's building architecture and its craftworks have been mainly materialized thanks to the Kuldīga Restoration Centre. The institution has achieved important progress in this matter, and has increased local participation. Additionally, recognizing that the mastery in crafts is present in daily life, citizens have received the Restoration Centre' assistance in restoring the appearance of each dwelling by re-crafting elements such as doors, windows, shutters, etc. This practice has undoubtedly enhanced the creative field of traditional craft and the transference of related expertise within the region.

Joining the UCCN's network will provide opportunities to Kuldīga for reaching sustainable urban development though the Crafts and Folk Art field as the main strategy, and will benefit from it in the long term in facing the current problems and challenges derived from the preservation of wooden architecture and craftworks. Cooperation with UCCN will help advance Kuldīga in raising the visibility of its heritage at the international scale, and will direct attention to cultural assets via different platforms.

Partnership within the UCCN with Focus on Creative Tourism, Education and Research

Creative Tourism

In 2006 the UCCN accepted a definition of creative tourism given by the Organisation for Economic Co-operation and Development (OECD): "Creative tourism is travel directed towards an engaged and authentic experience, with participative learning in the arts, heritage, or special character of a place. It provides a connection with those who reside in this place and create this living culture" (OECD, 2014). Many cities have already taken advantage of their nominations in order to improve their tourism industry and to develop specific city brands. For example, Santa Fe recognized for "City of Crafts and Folk Arts and City of Design" has already evolved a creative tourism program, and the "Literature label of Edinburgh city is expected to generate almost EUR 5 million a year in total economic benefit" (OECD, 2014, pp. 82-83).

In view of these examples, a city that can effectively cooperate with Kuldīga is Gabrovo, Bulgaria. According to UNESCO, Gabrovo has developed an Ethnographic Open-Air Museum (ETAR) and possesses the largest number of craft centers among the whole country (2013). Its craft field consists of woodcarving and wool weaving, works that are annually displayed at the International Craft Fair, where artisans from all over the world visit Gabrovo to demonstrate and share their skills on traditional techniques. This being a good example for Kuldīga in improving practices in the craft field.

Gabrovo can act as reference in rethinking Kuldīga's old town as an open-air museum due to its uniqueness. By designing a craft-route as a concrete option to guide tourists through the exploration of rare examples of the restoration of buildings and unique objects. The OECD (2014) affirms that this type of tourism industry is different to traditional models due to its skill-based approach, and prioritizes active participation in cultural occasions rather than a passive approach of learning by visiting museums and attending events only as a spectator. A change from cultural tourism towards creativity occurred in the 1990s and was put successfully into practice by many countries based on the creative features of particular cities, such as music, crafts, etc. (pp. 51-53).

The same report (OECD, 2014) also emphasizes that the main objectives of this perspective are to reach and expand new groups of visitors and to advance growth of the creative sector. Therefore, the anticipated positive effects include making the city more appealing place for craftsmen, tourists and local residents; engaging new specialists; design a better image of the city; improvement of "soft infrastructure" such as small-scale businesses and creative platforms; knowledge exchange due to new cooperation and partnership; raising the city's visibility and attractiveness (pp. 62-63).

Innovation through Research

In the field of innovation and research, the suggested partner is Carrara, Italy, designated as a member of the UCCN in 2017 for its white marble. According to the description given by UNESCO (Carrara, Creative Cities Network, n.d.; UNESCO Creative Cities Programme for sustainable development 2018), the city is an active member of the network, carrying out initiatives within the craft field on sustainable development of creative economies, and preserving local identity by hosting international meetings and events.

One of the most important events organized by Carrara is The International Fair Carrara Marmotec, an initiative that explores and highlights the use of modern technologies (UNESCO Creative Cities Programme for sustainable development 2018), exploration that can contribute to Kuldīga's International restoration workshops by sharing and applying new approaches to the processing of wooden materials.

Highlighting the fact that the Kuldīga Restoration Centre already has experience in carrying out technical initiatives; researchers, academics and students could be a new audience to attract, due to research in a wide range of topics and interests, from theoretical and conceptual issues to innovative use of specific equipment or new tools in the preservation of built heritage. The practical exploration can also bring into light product novelties, such as the accurate reproduction of damaged or lost wooden pieces, the creation of new parts of architectural elements based on original patterns, material innovation applicable to windows, doors and roofs to save energy, etc. In this context, experts can share new advancements as a matter of discussion in international meetings, and original results may be displayed in exhibitions and fairs, a circumstance that even can bring economic profits to local developers.

Education and Training

Barcelos, Portugal, is the suggested partner in this area. The city, widely recognized as the "city of artisans", has permanently organized and performed the Craftsmanship and Ceramics Exhibition to promote traditional craft. The main purpose of implementing this initiative aims to involve new generations in a creative craft field, a situation that can be useful for Kuldīga as a strategy to attract young professionals who are willing to learn a particular creative expertise to the region.

The city has brought into action educational programmes to transfer traditional craft knowledge. As "part of its Strategic Plan for Urban Sustainable Development, Barcelos is renovating a series of important historic buildings and sites in the medieval city centre in order to provide additional spaces for the creation and promotion of culture within the area" (UNESCO Creative Cities Programme for sustainable development 2018). Such efforts seem to be a compatible characteristic when considering the main projects and initiatives conducted by the Kuldīga Restoration Centre during recent years, and the number of properties with particular cultural significance that can be converted into educational centres. Formal and reconditioned infrastructure can help in providing better conditions to professionalize the transference of experiential knowledge in small regions.

A final aspect to be considered is the relevance of mobility. Barcelos cooperates with cities from the Global South to foster interchange and creative development (UNESCO Creative Cities programme for sustainable development 2018), facilitating intercultural exchanges. This is a possibility for Kuldīga in sharing best practices in the preservation of old towns.

Conclusions

The case discussed concludes affinity and complementarity between experiential knowledge and the craft processes applied in the restoration of built heritage. This fact is given by the distinctive character of the Kuldīga wooden heritage created by artisans owning valuable knowledge and experience acquired through time, and by its practical and participatory preservation perspective.

The preservation system led and implemented by the Kuldīga Restoration Centre is based on two empirical factors. The first one is the deep understanding that the experiential approach plays an essential role in the sustainable and correct maintenance of architectural heritage. The second one is the relevance assigned to the development of a practical educational component focused on the skills of artisans since the hand-working abilities cannot be gained by using only theoretical knowledge.

The Kuldīga experience demonstrates that transferring knowledge of this kind to the community and interchanging experiences request of innovative methods. Hence, it is possible to assert that the versatility of this expertise has ample potential to experiment with new possibilities beyond the region, contributing to the development of the city through its creative profile.

Concerning the current challenges in terms of preservation, the need for associativity is imminent. Kuldīga's profile reflects auspicious compatibility to the UCCN objectives, aimed chiefly to the integration of creativity into local development plans by implementing cultural initiatives and sharing good practices. With this regard, the original values observed on the wooden buildings repertory of the city proves a particular closeness, as distinctive regional heritage, to the "Crafts and Folk Art" category established by the UCCN.

The examination of the activities implemented by the member cities of such category has shown that the alliance with similar pairs benefits a collaborative development. Being a member of the network will help Kuldīga by providing new opportunities for experimentation based on available expertise. The proposed lines of action to be explored by joining the network are three: creative tourism, innovation through research and education and training.

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Pilar Fernández

Pilar Fernández graduated as an Architect in 2011 from the University of Magallanes (UMAG), Magallanes and Chilean Antarctic Region, Chile. Since 2014, Fernández has been an academic at the Department of Architecture at the University of Magallanes. She is currently obtaining a Master's degree in Heritage Conservation and Site Management at the Brandenburg University of Technology, Germany, funded by the University of Magallanes and by the Ministry of Culture of Chile (2018-2019). As an academic, she focuses on teaching Theory and History of Architecture, a position that involves discussing several historical aspects that have stimulated her reflection on the notion of heritage and its relevance for societies. However, during the last years, Fernández has developed a particular interest in the historic urban heritage management mechanisms and the effectiveness of preservation policies at national and regional levels. Previous works presented at conferences have addressed issues such as the built heritage derived from institutional actions and the impact of state decisions on the preservation of the built heritage's integrity in Punta Arenas, Chile.

Kristina Rovnenko

Kristina Rovnenko is a student at the Brandenburg University of Technology Cottbus-Senftenberg, pursuing a Master of Arts in Heritage Conservation and Site Management. Rovnenko graduated from the Kuban State University, Russian Federation, in the field of Architecture. Current studies and participation in heritage-related projects increased her interest in the topic of architectural preservation and the role of community involvement for its proper implementation. Her past position as a teaching assistant at the Department of Urban Planning and Architectural Design at the German University of Technology in Oman was a great platform for the development of issues concerned and knowledge exchange, working not only theoretically, but also practically with the local residents.

BeWeDō® Kenkyukai: Small moves can set big ideas in motion

Mark Bradford, Massey University, College of Creative Arts, School of Design Nga Pae Māhutonga, Wellington, New Zealand.

Abstract

At the core of the 'BeWeDō® Kenkyukai' (research seminar) are movement practices inspired by the Japanese martial art of Aikidō, however, participants do not learn Aikidō. The 'BeWeDō® framework' instead adapts one specific Aikidō movement exercise to transform the possibilities of conversation between people *with* movement.

Over the past two years, I have been applying a new mode of embodied practice called the 'BeWeDō® framework' within the ideation process. BeWeDō is a dynamic new way of transforming conversations – with movement. The approach utilises physical movement engaging the body-mind-environment inspired by the Japanese martial art of Aikidō, to enable people to 'start, share, shape,' and transform conversations.

This ethnography combined autoethnography, visual ethnography, participant observation, concept mapping, and 12 surveys completed during fieldwork. The research findings indicated that during BeWeDō: (1) physical movement and touch amplify connection and trust; (2) moving enriches conversation; and, (3) everyone has a creative voice. BeWeDō® is a psychologically safe approach, which offers relational leadership understandings in co- creation, as a process for structuring practices to transfer and replicate tacit knowledge accumulated in embodied ideation.

Keywords

Design Research; Embodied Ideation; Co-creation; Psychological Safety; BeWeDō

At the core of the 'BeWeDō® Kenkyukai' (research seminar) are movement practices inspired by the Japanese martial art of Aikidō (Ueshiba, 1984), however, participants do not learn Aikidō. Instead, the 'BeWeDō® framework' (Bradford, 2015) adapts one specific Aikidō movement exercise to transform the possibilities of conversation between participants *with* movement. A BeWeDō® Kenkyukai is the opposite of sitting around a table or being trapped passively listening to a presentation. The approach utilises dynamic physical movement engaging the *body-mind-environment* (Howes, 2005), to enable participants to 'start, share, shape,' and transform conversations.

The Art of Aikidō: The Know-How is *in* the Action

Aikidō was developed by Morihei Ueshiba (1984) by adapting and blending ancient Japanese martial arts such as Jujitsu, Karate and sword fighting with breathing and meditation studies. For Ueshiba, contemporary society needed techniques of harmony rather than competition. He believed that the purpose of Aikidō was to teach people a courageous and creative way of life, and carefully chose processes of interaction which advanced non- violence as a higher path.

Aikidō's strengths are centered on relationships, collaboration and conflict resolution – incorporating the freedom to make adaptations, improvise and *make things up*. In an Aikidō dōjō (a practice space for studying a dō or 'way' described by Mitsugi Saotome Shihan (1989) as a ‘university of life’) Aikidō practitioners engage in movement practices as a collective, which provides opportunities for learning, transformation and creative insights. In Aikidō this process is conveyed by the Japanese word *keiko* which means to train, practice, learn, and engage (Lowry, 1995). Essentially keiko is a learning path – a process that cannot be practiced conceptually and requires Aikidō practitioners to engage co-operatively in order to sense individually what experiential knowledge gained and shared through practice could mean (Gleason, 1994; Pettman, 1992). The know-how is *in* the action.

However, Aikidō involves more than just learning a set of techniques. For Saotome Shihan (as cited in Levine, 2013) “when someone grabs your wrist, it does not signify the beginning of an attack; it means the beginning of a conversation” (p. 152). Aikidō proactively embodies a mindset which can transfer into constructive action beyond the Aikidō dōjō (a place for training) (Saotome, 1993; Strozzi-Heckler, 2007) from an expansive societal standpoint. This ‘way’ (or path) of being in the world is guided by the Aikidō philosophy of *aiki* (M. Ueshiba, 2010). Aiki is a philosophy which involves being more ourselves, sensing how we move through the world, and how we interact with others. Aikidō as a creative practice is an emerging event which involves constantly reassessing one’s situation and priorities by blending with, and maintaining control of, relational interactions to generate collaborative strategies from a variety of positions. An Aiki approach involves self-awareness, effective body movements, calmness and a sense of cooperativeness: a respectful process of co- existing – ‘knowing together’ – and co-creating with others. Developing the ability to engage effectively with a range of people is an essential aiki principle which can be used in collective contexts such as co-creation (Sanders & Stappers, 2008). The approach involves a participatory mindset embracing openness and partnership. For Sanders and Simons (2009), co-creation is a specific collaborative event at any stage in a design process where ideas, experiences, and expertise are exchanged with the intent of creating something that is not known in advance.

Arts-Based Approaches to Experiential Knowledge and Collaboration

In addition to Aikidō, other arts-based approaches involve experiential creative engagement to generate opportunities for knowledge exchange.

In their case study on the Brazilian dance and martial art of *Capoeira*, Stephens and Delemont (2006) identified how *Trovao’s* (a full participant) use embodied strategies to create good axé (energy) in order to empower their movements in combination with the arts rhythms, singing, and clapping. This is very similar to how the contemporary art of Japanese drumming *Taiko* (Powell, 2004) embodies ki (energy) to unify player and drum, player and ensemble, mind and body. The repetitive action involved in drumming blurs boundaries between the drum, space, and the person, as well as providing the drummer an *expanded experience of the self in relation to* the ensemble.

The moving body, argue Loke and Robertson (2010), is a visual medium because it is seen by others, and can convey and represent ideas, as well as generate a change of mind (Wieschiolek, 2003). Radley (1995) highlights how *dancers* use the stage, props and other performers bodies as part of the construction of an imaginary space. This is an expressive way of being, where the body-subject sketches and communicates the elusory through embodied gestures. For ballet choreographer Balanchine (as cited in Wainwright, Williams, & Turner, 2006) this involves working with their ideas on real bodies – a relationship based on seeing how dancers can stretch, jump and turn together collaboratively, to generate ideas.

In their book *The Dance of Leadership* (2006) Denhardt and Denhardt also maintain that dancers, like leaders, move their bodies through time and space to articulate ideas. Embodiment is expressive, and how we act and interrelate with others through movement itself is a way of knowing which carries meaning that is also instantly *felt*. Sklar (2000) describes dancing as *training in movement*, where “our bodies become laboratories for experimentation with kinetic details” (p. 72). Through performance (Roberts, 2008) dancers co-create with other dancers by diverse means via body movements – gesture, touch, sound, smell – socially constructed by culture. Rather than a passive surface, the *entire body remembers in the action*.

In a study on *musicians*, Bathurst and Cain (2013) found that musicians are also well aware of each other – an emotional embodiment articulated through gestures by the *performative, moving body*. They describe how a musical trio invite an audience into a *co-creative space* in order to respond to the music: "a gestural art that invites open exchange, dialogue and co- creativity" (p. 374). Through music, the body collaborates with sound, turning both instrument and performer (Robert DeChaine, 2002) as well as *communicating across bodies, thoughts, and places*. This correlates with Ladkin's (2008) descriptions of the master musician Bobby McFerrin:

> *McFerrin never spoke to us. He communicated through gestures, vocal inflections, and the way he used his body. His body language was inclusive, there was an openness and a lack of guardedness in the way he loped around the stage. (p. 33)*

The process of communication is also key in *improvisation* (Crossan, 1998). Developing an ability to improvise is useful in the performing arts of dance, music, martial arts, and comedy, through to other non-art contexts such as engineering and personal relationships. It is an ongoing relational negotiation which *opens up possibilities* (Lemons, 2005) and makes spontaneous connections where no connections existed before and values the ability to "make it up as we go along" and "to think on one's feet" during collaboration in *moment-to- moment* practices (Sawyer & DeZutter, 2009) with the aim of stretching co-creatively (Barrett, 1998). Indeed, Jazz musician Stan Getz considered improvisation a language – a way of conversing with unanticipated ideas – dedicated to a process of *rethinking* (Weick, 1998). This view is supported by Newton (2004) who writes that reflective practice in jazz improvisation, allows each player in the group to develop their ability to hear new knowledge, and translate this into their part in a *collective performance*.

I argue that more flexible forms of arts-based participatory practices are required for embodied ideation – approaches that blend broader understandings of collective creativity with specific relational knowledge for design(ing) action. More specifically, my interdisciplinary research (Bradford, 2015) explored the connections between the Japanese martial art of Aikido, leadership development, and creative modes of practice. In order to focus upon dynamic embodiment and relational social processes, rather than individual abilities in embodied ideation, we require new tools, methods, and practices to transfer and replicate tacit knowledge accumulated in collaborative practice.

Over the past two years, I have been applying a new mode of embodied practice called the BeWeDō® framework (Bradford, 2015) (Fig. 1) within the ideation process. BeWeDō is a dynamic new way of transforming conversations – with movement. The approach utilises physical movement engaging the body-mind-environment (Howes, 2005) inspired by the Japanese martial art of Aikidō, to enable people to 'start, share, shape,' and transform conversations.

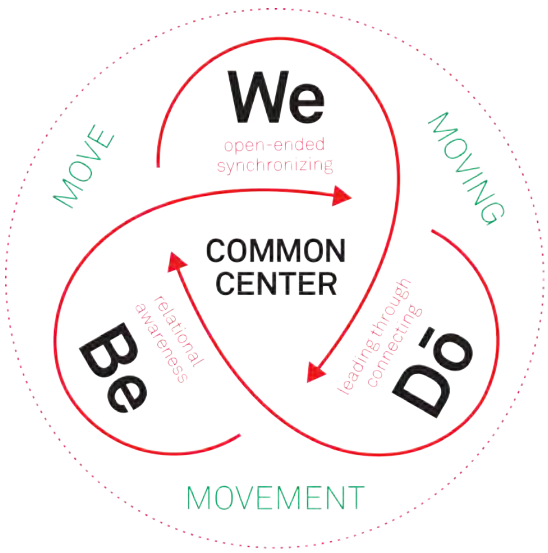

Fig 1. The BeWeDō® Framework.

BeWeDō: Transforming Conversations – With Movement

The BeWeDō® Framework structures co-creative possibilities for embodied ideation in the following ways (adapted from Bradford & Leberman, 2019, p. 73) (Table 1):

Be	A personal space involving relational awareness. The concept is about taking a step forward physically – to move – to create space for dialogue and co-creative exchange on a more personal level: an optimistic body-practice asking, 'where could this lead?'
We	A relational space embracing open-ended synchronizing. Essentially, an attitude for acting in ways – moving together – which influence co-creative practice as a dynamically interwoven activity.
Dō	A situational space – leading through connecting – a way of leading your life: co-creative movement enabling 'what could be?'
Common centre	Is the interconnected nexus: 'one center point' bringing people together. Embracing being in the moment – within an intersection of moving bodies – and dynamically interfacing in collective creativity through combinations of relational practices.

Table 1. The BeWeDō® Framework.

The BeWeDō® framework adapts one specific Aikidō movement exercise – tai no henko – where people work in pairs by connecting with each other by the wrist in order to move their bodies (communicating in both the physical and mental sense with the movement of their partner) to more desirable positions by turning 180 degrees. When you offer your hand and your partner touches your wrist using tai no henko, it provides a compelling multi-sensory experience on how to dynamically connect and co-create possibilities with movement. For one participant, "it's not the move itself that's important, it's the moving. It's the fact that you have moved, and your perspective has changed" (personal communication, October 1, 2014). For Ingold (2000), "*we know as we go*, from place to place" (p. 229).

> *Physically moving an idea around the room with your partner puts you into a different mindset than having a chat over a cup of coffee or sitting at your desk having a conversation. BeWeDō allows the conversations to go and happen in a different way..., Your comment is going to take the discussion somewhere.*
>
> *(personal communication, July 17, 2014)*

CASE STUDY: BeWeDō® Kenkyukai (Research Seminar)

The BeWeDō® Kenkyukai (Table 2) utilises the BeWeDō® Framework to offer people a psychologically safe (Edmondson & Lei, 2014) motion-led embodied knowing (Fig. 2) which offers relational leadership (Uhl-Bien & Ospina, 2012) understandings in co-creation (Sanders & Stappers, 2008) as a process for structuring embodied ideation. The BeWeDō® Kenkyukai starts with a clear challenge to the group guided by two research questions (these are curated prior to the BeWeDō® Kenkyukai*). Over two sessions people perform the three phases of tai no henko – kihon, ki no nagare, and reppo – and talk simultaneously to generate opportunities for knowledge exchange.

	Group: People form a circle and the facilitator provides a brief event introduction.
Be	**Phase 1: Tai no henko kihon** (body shift) People learn tai no henko kihon in pairs and *move* to create space to 'start' a conversation guided by Question 1*. Kihon is used by the listener to lead the process of asking the speaker a question. This could range from a simple question to clarify details about the challenge, through to questions that *move* the conversation i.e., 'can you tell me more"?
We	**Phase 2: Tai no henko ki no nagare** (energy flow) People learn tai no henko ki no nagare in pairs and begin *moving* together to 'share' perspectives guided by Question 1*. Ki no nagare is used by the speaker to ask a question to clarify details about the challenge, understand a person's perspective, or disagree with a person i.e., 'have you thought about it this way"?
Dō	**Phase 3: Tai no henko reppo** (changing direction) People learn tai no henko reppo in pairs and generate co- creative movement which 'shapes' relationships through the exchange of perspectives in response to Question 2*. Reppo is used when either the listener or speaker has an idea or response to the challenge – 'here's another way to think about it' – to enable *movement* to a new position or place i.e., "here's another way to think about it."
Common centre	**Phases 1-3: Tai no henko kihon, ki no nagare & reppo** Used in combination as part of the BeWeDō approach, kihon, ki no nagare, and reppo involves people *moving together* in dynamic relationships: a cumulative motion-led embodied knowing that offers new relational leadership understandings and orientations for transforming co-creation conversations.
	Group discussion: People form a circle and reflect on their experience.

Table 2: The BeWeDō® Kenkyukai (research seminar).

- No experience in martial arts necessary.
- The atmosphere will be relaxed.

BeWeDō® Kenkyukai: Small Moves Can Set Big Ideas in Motion!

As an ethnographic researcher, my knowledge is grounded within the interplay between practical, personal, and participatory field experiences. My aim was to understand how collective experiential knowledge is accumulated and communicated in and through collaboration, and how it is embodied in the outputs and may be traced back to the origin of the practice. The research employed all my senses to create, perform, and represent knowledge as part of the process of reflecting critically on the BeWeDō® Kenkyukai experience to identify patterns as a form of ethnographic reliability (Fetterman, 2010).

Over the past two years, I have led 45 BeWeDō® Kenkyukai (in both educational and professional settings) with almost 300 people in Slovenia, England, USA and New Zealand refining the BeWeDō® framework. This ethnography (Berger, 2015; Creswell, 2009; Fetterman, 2010) combined autoethnography (Bass Jenks, 2002; Ellis, 2004; Ellis, Adams, & Bochner, 2010; Hayano, 1979), visual ethnography (Pedgley, 2007; Pink, 2013), participant observation (Greenwood & Levin, 2005; Lincoln & Guba, 1985; Sklar, 2000), concept mapping, and 12 surveys completed during fieldwork.

This article syntheses the ideas, patterns and relationships between patterns that emerged from the fieldwork and 12 surveys (personal communications, between September 27, 2017– April 4, 2018). The research findings indicated that during BeWeDō: (1) physical movement and touch amplify connection and trust; (2) moving enriches conversation; and, (3) everyone has a creative voice.

Physical movement and touch amplify connection and trust

According to one respondent, BeWeDō movements made discussions "much more gentle, in a funny kind of way. I was thinking I was going to spending the whole time thinking what question was I going to ask next, but actually because you've got that connection I was finding I was spending the time just connecting and listening and it didn't matter if there was a bit of a pause in the conversation because the question almost flowed naturally from that point." For Slepian and Ambady (2012), "bodily movement can influence cognitive processing, with fluid movement leading to fluid thinking" (p. 628). Another respondent felt that "taking time to respond to the conversation physically before verbally [….] gives a space in time to accept and give respect." A number of respondents referred to how BeWeDō puts everyone on an 'equal footing' and the approach "levels out status [….] you're all learning the move." As Ingold (2011) reminds us: "we are our movements; therefore the knowledge we have of ourselves is inseparable from the sense we have of our movements" (p. 10). Furthermore, "BeWeDō is such a good leveller, because ... because we didn't introduce, I'm a manager, I'm a senior lecturer, I'm an administration you know … all of that's gone. Nobody knew what I did so suddenly it didn't enter in the equation. That's a rarity." One respondent observed with hierarchy removed, and a level playing field established,

> *you had confidence in your own instincts more, because trust was formed. If you accepted their hand around your wrist and vice versa then a 'test' was passed, you could get down to the nitty gritty much sooner. [Everything was] stripped away, no bullshit, get on with the job and have a laugh to boot!*

Respondents also noted that "it was useful to have another way to ideate without the use of whiteboards and post-its," …. "moving while brainstorming, connecting through light non- intrusive touch and eye contact all aide in making communication more effective." 'Simple' touch – hand-to-hand – can have a communicative function (Morrison, Löken, & Olausson, 2010), as well as help create bonds between people (Gallace & Spence, 2010). Other respondents felt: "you could be more open to sharing thoughts ideas. This sped up the process of engagement and ideation markedly," and BeWeDō's "capacity to foster the quick development of sharing of ideas/thoughts on an equitable basis could offer a more constructive approach to leading through/in teams." One respondent reflected how the approach "forces you to talk to people in the room which you may not otherwise for reasons as being shy, or they do not want to approach you. We were there for a common good." It was encouraging to hear how 'touch' increased feelings of trust, support, empathy for participants: "The ability for verbal expression, plus the supportive sense of touch is a great facilitator"; "the touch aspect does take away barriers of ego," and "it's much more intimate thinking with touch. Taking away sense of awkwardness/breaking down the awkward barriers much faster than the usual method of meet n' greets." In other words, BeWeDō enabled trust and co-operation between participants. For another respondent, it is about "connection and empathy - truly listening and engaging with each other as we solved the problem, which led to better quality of discussion and ideas." BeWeDō created connection:

> *you felt like you needed to maintain eye contact with this person because there was a physical connection going on … it's PHYSICALLY brought us closer together and physically means that our 'bubbles' have shrunk and I think because you have that presence and you've got that eye contact, I think it means that you're much more present in the conversation which leads to a better deeper conversation.*

Moving enriches conversation

Combining movement and conversation was seen as "more fun and interactive than just giving feedback on someone's idea," …. "moving around in the space was really helpful to the thinking process. It made it feel more like an active thinking process instead of passive sitting down." One respondent stated: "It's actually quite interesting now knowing the move goes with the change in conversation makes you more intentional ... I thought the moves really enriched the way you thought about the conversation. Am I moving the conversation, or are you moving it? Are you telling me you have a different idea?" BeWeDō emphasises collective initiative, and argues that individuals are constituted by relationality (Bradbury & Lichenstein, 2000), their relations (Cunliffe & Eriksen, 2011; Palus, Horth, Selvin, & Pulley, 2003; Uhl-Bien, 2006; Uhl-Bien & Ospina, 2012), and a 'dynamic' embedded in social interactions. A number of respondents felt that BeWeDō movement practices meant they"talked to a range of people in an active way," and that the approach "promoted listening as a form of observation, as well as a fine tuning of one's own sharing (talking)" …. "our conversations did not drift elsewhere.

What resonated for one respondent was "the notion of bringing a stylised pattern of movement and productive conversation together ... to use physical stance and relationship to invite another kind of exchange." The BeWeDō movement practices were "useful in terms of actually changing your perspective … and even just re-orientating you to a person helps rather than you simply TALKING AT somebody," …. "it helps make it more of a 'human' interaction, and less about exchanging information, or achieving a specific purpose [...] It's a reminder that you're actually in a *different* sort of interaction" (Fig. 2).

> *I really enjoyed the experience of moving while discussing, and the change in mindset this created for us. It made questions feel more collaborative than confrontational … a more <u>human</u> way!*

Fig 2. ThinkPlace BeWeDō® Kenkyukai, 2018.

Everyone has a creative voice

For a number of respondents, the experience of moving while discussing changed their mindset: “It made questions feel more collaborative than confrontational,” …. “BeWeDō takes people away from the ‘normal’ it encourages thinking about a problem in a different way. The changing perspectives aspect was particularly useful as it makes it easier for the other person to challenge your ideas in a constructive and non-threatening way,” …. “the rapid transition from discomfort (the unfamiliar...) to a more comfortable semi-intimacy that allowed an opening up of collaborative space.” One respondent felt that BeWeDō was useful because “you’ll always get someone who’s incredibly shy, lacking in confidence, but by the end of the hour and half session they would have engaged in some way. They would have said something, expressed something, that in most circumstances with a strange person they wouldn’t.”

In essence, “it created a new, novel construct for bilateral discourse. It also seemed do away with social norms and contrivances that shape conversation – in other words, how one behaves with a new person, student, older, younger, gender, etc.” …. “It didn't feel like it was a hierarchical thing but more we were really consciously taking turns to share ideas and listen to one another.” BeWeDō provides a psychologically safe (Edmondson & Lei, 2014) environment which enabled divergent thinking, creativity, interpersonal risk taking, as well as motivated engagement and performance. Importantly, respondents identified that during BeWeDō, “we were able to talk to people one on one, which created opportunities for everyone to have a voice” …. “a safe-space to formulate and share ideas” …. “a safe space to unpack controversial issues and to share potential solutions.” BeWeDō embraces a co- operative view of creativity (Pope, 2005): a shared, ongoing process of exchange; action *beyond the self* and in relation to other people; recognition of differences and an openness to disagreement; direct collaboration; and participation towards *co-becoming*. According to one respondent, “BeWeDō helped open up a *new conversational space* – a safe way to share personal ideas.”

Conclusion

In conclusion, the research indicated that during BeWeDō: firstly, physical movement and touch amplify connection and trust: thinking while moving combined with ‘simple’ touch using BeWeDō, enhances the flow of ideas which facilitates trust and prosocial behavior; secondly, moving enriches conversation: the BeWeDō® Framework is a relational leadership approach founded on the idea that individuals are constituted by social processes; and, thirdly, everyone has a creative voice: BeWeDō offered a psychologically safe environment where people feel they can take interpersonal risks. During BeWeDō, small moves can set big ideas in motion!

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Mark Bradford

Dr Mark Bradford is a designer and academic at Massey University, College of Creative Arts, School of Design Nga Pae Māhutonga in Wellington, New Zealand. Mark has a PhD in Business from Massey Business School. His interdisciplinary research investigates how design(ing) action is increasingly enacted relationally between people. Through his PhD research process, and inspired by the Japanese martial art of Aikidō, he designed the 'BeWeDō® framework.' BeWeDō is a unique way of enabling people to start, share, shape, and transform conversations – *with* movement (people utilise physical movement techniques and talk simultaneously to share perspectives and generate creative opportunities): no egos, no Post-its, no more bystanders.

Knowing Together in Correspondence: The Meal as a Stage for Bildung

Daniel Östergren, Örebro University, School of Hospitality, Culinary Arts and Meal Science, Grythyttan, Sweden

Inger M. Jonsson, Örebro University, School of Hospitality, Culinary Arts and Meal Science, Grythyttan, Sweden

Abstract

In a meal, there is a special sort of correspondence between diverse functions of knowledge taking place, a correspondence which also connects participants of the meal to a wider societal context. The interdisciplinary academic discipline of Culinary Arts and Meal Science (CAMS) at Örebro University can be described as thematically demarcated, with the meal as its main theme, justifying a broad scientific approach. In this article we shed light on how the philosophy of science of CAMS has developed during the discipline's first three decades of existence.

Starting out from a point of view of three separate *forms* of knowledge: science, artistic endeavor and practical skills, we see a development towards a point of view of three corresponding *functions* of knowledge: episteme, techne and phronesis. In this paper, we argue that an interdisciplinary discipline calls for such a *correspondent*, or functional, point of view. Our thesis is that such an approach points towards a greater methodological focus, which is also beneficial for highlighting how the outcome of CAMS is about knowing together in correspondence with the wider societal context. We illustrate how these functions are active by presenting a model. The analysis is based on examples from the academic activities of CAMS during the last three decades.

We conclude that CAMS has the potential to be particularly strong as a social force in educating *competence and skills* and *judgments and approach*. The latter, also known as phronesis or bildung, encompasses important ethical, sustainable and conscious dimensions. These are competences that are particularly significant in order to meet the challenges of today's and tomorrow's society. Therefore, we argue for the social importance of meal research for societal *knowing together*, and for the meal as an operative *stage for bildung*.

Keywords

Culinary Arts; Gastronomy; Interdisciplinary; Methodology; Education

For wine tasters, approaching a wine is a correspondence with the wine. It is as much about exploring the wine as it is about letting the wine explore us; we search for color, flavor and texture in the wine, and the wine responds by searching for affections, memories and experiences in us. Wine knowledge is a kind of knowledge that is participated in, gained through our correspondence with the liquid, a sort of knowledge explored through activity. There is a certain amount of skill needed for the practical part of a wine tasting: wine tasters need to know how to open, decant and pour the wine, how to hold and swirl the glass, how to swill the liquid around in the mouth, and how to spit the wine out properly. However, there is also a certain amount of artistry needed: how are the color, the texture and the flavors composed? In which ways are we moved by the wine? How do we approach the wine haptically? Furthermore, wine tasters also need theoretical principles in order to find structured explanations and direct their attention scientifically. And last but not least, a professional wine taster also reflects: what can we learn from this tasting and how can we use this knowledge? Wine tasting is one of many phenomena which are explored in the interdisciplinary Culinary Arts and Meal Science (CAMS). In this article we outline a philosophical basis for such explorations.

This article presents overarching ideas which encompass both the research and the education of the discipline of CAMS. These ideas are not limited to either a researcher's or an educator's perspective, but present a common framework for these two to rely on. This paper is to be seen as a philosophical departure point from which further research can be made, e.g. in the form of case studies of educational practices. An overarching aim of the larger project which this article is part of, is to highlight the importance of the concept of bildung in interdisciplinarity. Bildung is to be understood as practical wisdom or phronesis (c.f. Aristotle, 384-322 BC/1988; Gadamer, 1960; Flyvbjerg, 2001, Gustavsson, 2004; Tyson, 2018). The aim of this particular paper is to highlight the relevance of Aristotelian ethics, with emphasis on phronesis, when understanding how an interdisciplinary approach connects the academy to the needs of society and the restaurant industry.

Interdisciplinarity and Correspondence in Culinary Arts and Meal Science

Culinary Arts and Meal Science (CAMS) at Örebro University is an academic discipline where research has been carried out in close connection with professionals since 2002. In a meal, a special sort of correspondence is going on between diverse functions of knowledge, a correspondence which also connects the participants of the meal to a wider societal context. Correspondence is a concept defined by Ingold (2017) as an idea of looking at the world as if it was built from relations, where the correspondence is the very dialogue going on within the relations. This ontology is opposed to the positivistic idea of a world built by separable static constituents. Furthermore, in the modern societal context we live in, ethical, sustainable and conscious dimensions are becoming increasingly significant, and these are dimensions to which CAMS offers an important approach (Gustafsson, Öström & Annett, 2009; Magnusson Sporre, Jonsson & Pipping Ekström, 2015). We argue that Ingold's (2017) idea of correspondence shows a way towards such an approach in CAMS.

The research area of CAMS can be seen as thematically demarcated, with the meal as its theme, a thematicality which justifies a broad scientific approach (Gustafsson, 2002). However, initially, during the first decades of the discipline, it was characterized by multidisciplinarity, where researchers from different disciplinary areas co-operated by drawing on each other's research to develop their respective disciplines. These early years were characterized by quite a fragmented and therefore somewhat static and tentative approach. In this paper we argue that this approach might correspond to a philosophy of science based on three separate forms of knowledge: science, artistic endeavor and practical skills, which was frequently referred to in the discipline during this time. However, as the research carried out in CAMS over time has matured, it has evolved from its former multidisciplinary patchwork into a more seamless interdisciplinarity (Gustafsson et al., 2009). Interdisciplinarity has benefits over multidisciplinarity in the sense that it makes it possible to bridge different perspectives and approach questions from a more holistic point of view (Swedish National Agency for Higher Education, 2007; Frickel, Albert & Prainsack, 2016). In this paper we argue that such interdisciplinarity also calls for a less separated and more correspondent (see Ingold, 2017) point of view in the philosophy of science of CAMS. Our thesis is that such a point of view can lead to a greater methodological focus, which also highlights how a central outcome of an academic discipline is about knowing together in correspondence with the wider societal context.

Research in CAMS can be said to include sensory science, i.e. a more natural scientific approach, as well as culinary arts, i.e. a more human scientific approach (Örebro University, 2018). An example of recent sensory scientific research in CAMS is the article "Sommelier Training – Dialogue Seminars and Repertory Grid Method in Combination as a Pedagogical Tool", which is about developing methods for the sensory training of sommeliers (Herdenstam, Nilsen, Öström &

Harrington, 2018), and an example of research within the area of culinary arts is: “The time-space of craftsmanship”, about methods for articulation of tacit knowledge in crafts (Eriksson, Seiler, Jarefjäll & Almevik, 2019). However, as can be seen in these examples, the division between sensory science and culinary arts is not distinct, and the areas of sensory science and culinary arts are often combined or enriched by each other through interdisciplinary correspondence. Furthermore, CAMS is related to the field of hospitality research in the sense that it puts a strong emphasis both on the human side of the meal experience and on the material components of a meal, i.e. both on staff and guests as well as on food and beverages. CAMS is also related to hospitality research in the way that it emphasizes sensations of an experience even in terms beyond the financial profitability (cf. Santich, 2007; Mitchell & Scott, 2013).

The educational staff of the undergraduate education in CAMS at Örebro University benefit from the competences of both professionals, such as chefs and sommeliers, and researchers. Many of the researchers in CAMS also have extensive experience from working in the restaurant industry. Among many examples from the research staff are: *the theoretical wine taster,* a senior lecturer with more than 20 years of experience working as a professional wine taster and a purchasing manager of beverages; *the sensory creative chef*, a sensory laboratory researcher who has worked as a professional chef and has competed in the Culinary World Cup and the Culinary Olympics; and *the action-researching designer in the dining room*, a PhD student with more than 20 years of experience working as a professional designer of meal events. Thus, the team of researchers in CAMS creates scientific research that is united by the meal, and to some extent, the research often takes an insider’s perspective. This provides a fertile soil for growing research questions from themes and actual cases, approached by the researchers’ theoretical arguments in correspondence with extensive practical or creative experience from the industry.

Knowledge as a Form: The Static Mindset of the Early Years of CAMS

In 1992, the Swedish parliament assigned Örebro University to establish a permanent university education for restaurants. It was pointed out that what made this education unique was how it managed to:

> pay attention to the aesthetical dimension of the restaurant business in both theory and praxis
>
> (Swedish Parliament 1991/92: UbU14).

It was also stated that:

> such a university education clearly has potential for the Swedish restaurant industry’s ability to attract visitors to our country (Swedish Parliament 1991/92: UbU14).

The continuing development of the undergraduate education in establishing a postgraduate education in 2002, a decade later, can be traced back to two important changes: One was that the discipline of Domestic Science (at Uppsala, Gothenburg and Umeå Universities) developed in a more natural scientific direction and thus left most of the practical-aesthetical parts of the disciplinary area unattended. This gave room for the new research topic of CAMS to be established. The other important change was a turn in Swedish meal habits at this time, when more people started eating out and the eating habits of Swedish people thereby became more experience-oriented (Jonsson, 2015) and developed into a more democratic phenomena available not only to the well situated but to the whole population (Jonsson & Pipping Ekström 2009). This development indicated a need for a new research topic where knowledge was also written about meals outside the home. The background of CAMS is therefore twofold: it was established as a unification of Gastronomy and Domestic Science. A characteristic of CAMS is, in other words, that it has emerged from the need to academize the meal phenomenon, i.e. the discipline is rooted in a need for meal research. The origin of the discipline thus came from the thematic demarcation made by restaurant professionals and society around the meal phenomenon, rather than from a theoretically derived demarcation within the academy. Therefore, a close connection has been kept to the restaurant industry and to society, and we can argue that the knowledge present in CAMS has to a large extent been kept in the same natural shape that knowledge takes in professional practice and in everyday lives. Knowing together with the industry and society can therefore be seen as a foundational aspect of knowledge formation in CAMS.

The first professor in CAMS, Inga-Britt Gustafsson (2004), located CAMS as a multidisciplinary discipline in which three forms of knowledge were integrated. According to Mitchell and Scott (2013), following Gustafsson (2004), CAMS is:

> a multidisciplinary area comprising an intersection of food science, artistic endeavor and practical skills (Mitchell & Scott, 2013, s. 249).

Further, they also point to:

> the importance of wider social and cultural understanding of food and its production (Mitchell & Scott, 2013, s. 249).

From this point of view, it is suggested that in order to reach scientifically founded conclusions, CAMS requires not only science, but also collaboration with artistic and practical forms of knowledge. Why? One argument for this is that a meal includes both material and human dimensions: that CAMS studies the correspondence that arise between food and man. Alongside interdisciplinary science, CAMS needs artistic endeavor and practical skills because they highlight that very *intersection* which Mitchell & Scott (2013) mention, and ensures that CAMS does not become too focused on either the human dimension or on food in itself.

However, there are also important limitations to a division into scientific, artistic and practical dimensions, especially when it comes to methodological or didactical discussions where all three are often coactive and inseparable. In order to overcome this problem, Molander (1996) argued for a more action-oriented perspective on knowledge in university disciplines with practically oriented elements, and Gustavsson (2004) contributed by highlighting the practical skills and practical wisdom as other important dimensions. Based on the perspectives of Skjervheim (1957), Gadamer (1960), Flyvbjerg (2001) and Bohlin (2018) we find the division in scientific, artistic and practical being very much of a positivist division, which separates in pieces rather than highlights the unity and interaction within the discipline. Such a threefold division of knowledge, partly rooted in Critique of Judgment by Immanuel Kant (1790/2003), separates knowledge into fragments. Fragmentation opposes such a unity and ongoing action within knowledge which is an important aspect of interdisciplinarity (cf. Perullo, 2018; Ingold, 2017; Gustafsson et al., 2009; Swedish National Agency for Higher Education, 2007). We might then lose important parts of what has been pointed out as:

> the very nature of the culinary arts, as an applied science and a creative endeavor (Mitchell & Scott, 2013, s. 246).

Fragmentation in separate scientific, artistic and practical dimensions might also be counterproductive to the collaborative knowing together with the industry and society, a collaboration which is another form of unity that should be highlighted as a characteristic of CAMS (see “the importance of wider social and cultural understanding of food and its production”, Mitchell & Scott, 2013, s. 249).

Knowledge as a Function: A Methodological Turn in the Recent Years of CAMS

Before Kant (1790/2003), the common view of artistry also contained, to a greater extent, the practice of creating art integrated within the concept of artistry. Kant taught us to separate the subjective interest from art by setting up demarcations for artistry and practice, in order to create, to some degree, a universality in art. But then, as a consequence, the concepts were also separated from each other. This led to a shift in the view of artistry from quite a practical to a more theoretical point of view, i.e. from what was mostly an insider’s action-based perspective into what is mostly an outsider’s positivistic perspective (Gadamer, 1960; Bowie, 2003).

During the early 2000s, around the time when postgraduate education was established in CAMS, Bernt Gustavsson (2004), professor in Education and Democracy, raised the issue of the pedagogical-didactic perspective in CAMS. In order to be able to discuss this issue, he suggested to establish a philosophical point of view based on Aristotle's ethics (384-322 BC/1988), a point of view which better highlighted the knowledge-forming activities of the discipline. Half a decade later, the professor in CAMS Inga-Britt Gustafsson et al. (2009) also stated:

> At a fundamental level, it is this three-dimensional view of knowledge derived from Aristotle which has been adopted as the philosophical framework for the academic discipline of Culinary Arts and Meal Science (Gustafsson et al., 2009, p. 274).

Likely, this suggested shift was also about establishing a greater awareness of the inner correspondence between the theoretical and practical competences among the educational staff and researchers in CAMS, as discussed above (see also Molander, 1996; Ingold, 2013).

Notably this can also be seen as a step back towards a non-positivistic pre-Kantian point of view on knowledge, where knowledge once again put a stronger emphasis on the *people* who experience it. Gustavsson (2004) concluded:

> a good education educates knowing, skillful and wise people (Gustavsson, 2004, p. 52).

An important aspect of the uniqueness of CAMS as an academic discipline is how the lived insider's perspective on knowledge can be combined with the theoretical outsider's perspective, whereby CAMS is not limited to studies *of* meals from the outside, but also conducts studies-in-action. In CAMS there are both craftsmen and theorists, and as we have seen, these roles are often unified in the sense that they can be held by the same person.

Thereby CAMS grasps both sides of Ingold's (2013) dictum that a craftsman *thinks through making* while a theorist *makes through thinking*. This unification could also be explained akin to how Bengtsson (1998), Ingold (2013), Sjömar (2017) and Perullo (2018) phrase it with terminology often found in practice-led and design-led research: studies *in, with* and *through* [the meal as a lens]. From this point of view, CAMS has similarities to practice-led research and, for example, to the discipline of Craft Science at Gothenburg University, a theoretically related discipline but with another thematic demarcation that is instead focused on craft.

Hermeneutician Hans-Georg Gadamer (1960), also proposed an increased focus on the experience as a perspective, by arguing that a model of knowledge based on its functional aspects is useful in order to grasp the *interpretation* of knowledge. Such a model had already been introduced by Aristotle (384-322 BC/1988) in his *Nicomachean Ethics*: divided in episteme, techne and phronesis, functions which are equivalent to theoretical knowledge, practical skill and practical wisdom (Gustavsson, 2001; 2002; 2004). These Aristotelian functions of knowledge are useful in the quest of holism in the interpreter's, [i.e. people's], act of putting a theory into context (Gadamer, 1960). Aristotelian *knowledge as a function* shows knowledge not only as a lifeless form, but in its living function it also captures relations to knowledge, because it has the advantage of having a more obvious methodological dimension (Gadamer, 1978).

If we return to the first example of this article: For a wine taster, the Aristotelian perspective could refer to how it is not sufficient to know a lot (i.e. episteme) about how to taste wine. The wine taster must also believe in it as a meaningful approach (i.e. something leading to phronesis) in order to be able to engage in the action and to become skillful using the method (i.e. techne).

Results: A Model of Interdisciplinary Correspondence

In this paper we argue for the relevance of Aristotelian *knowledge as a function* in understanding how CAMS links the needs of society with the needs of the restaurant industry, and shed light on how they are reaching knowledge together. An important written argument for why this is a fruitful point of view can be found in the Qualifications Ordinance, Appendix 2 to the Higher Education Ordinance (Swedish Government 1993:100). There, we find that the learning outcomes for all forms of Swedish university degrees are presented in a structure designed with these same Aristotelian functions of knowledge in mind. In the Qualifications Ordinance, which is based on the qualifications framework of the Bologna Process, episteme is translated into *knowledge and understanding*, techne into *competence and skills*, and phronesis into *judgement and approach*.

Aristotelian knowledge as a function can thus be said to point out three areas of general competence to be achieved by higher education: episteme, techne and phronesis. Several Swedish universities have also chosen to apply this structure in the learning outcomes of their internal education plans and syllabuses, including Örebro University.

For a long time, higher education in the Western tradition has to a large extent focused on the function Aristotle called episteme (Bohlin, 2018). Work carried out with the aim of learning episteme is to be called theoretical *studies*. Gustavsson (2004; 2012) and Bengtsson (1998) try to position the other two Aristotelian functions in relation to this, in order to highlight their importance. Techne is the knowledge that is achieved in technical expertise, i.e. skills in handling (Gustavsson, 2012). We therefore define work carried out with the aim of learning techne as *training*. Phronesis is described as the ability to act sensibly and to apply knowledge critically (Gustavsson, 2012). If we start from Gadamer's (1960) interpretation of phronesis, the function of knowledge that "includes the application of experiential universals to the particular object of investigation" (Gadamer, 1960, p. 4), we can draw close parallels between phronesis and *bildung* (Segolsson, 2011; Gustavsson, 2012; Tyson, 2018). In this paper we therefore define a work carried out with the aim of learning phronesis as *bildung*. Segolsson (2011) emphasizes that phronesian bildung has a special importance in the way it binds forms of knowledge together. We believe that when Mitchell and Scott (2013, p. 249) point out that CAMS is "comprising an intersection of food science, artistic endeavor and practical skills", the mentioned *intersection* is such a binding per se, carried out by the Aristotelian functions of knowledge.

Gustafsson et al. (2009) pointed out that there is a correspondence between what we in this article refer to as forms of knowledge (food science, artistic endeavor and practical skills) and functions of knowledge (episteme, techne and phronesis), but without detailed explanations on how this works. We argue that this correspondence takes place in that very *intersection* which Mitchell and Scott (2013) mention between the forms of knowledge, and that it is *carried out* by the functions of knowledge according to Figure 1:

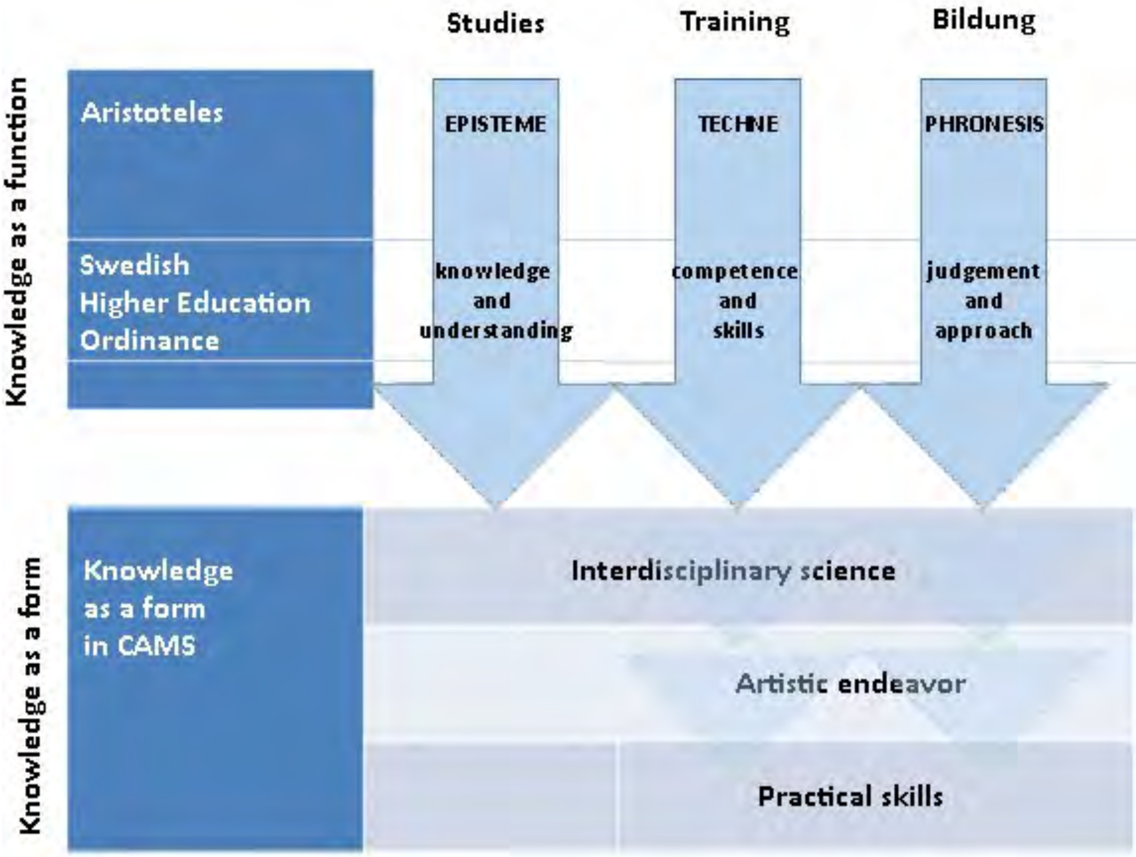

Fig 1. The correspondence between knowledge as a form and knowledge as a function in CAMS.

In CAMS, as we can see in Figure 1, all three Aristotelian *functions of knowledge,* implemented from the Higher Education Ordinance (Swedish Government 1993:100), are always connected to science. This is no difference compared to other academic subjects. However, due to its interdisciplinary scientific basis, CAMS also complements the scientific work with two additional forms of knowledge (artistic endeavor and practical skills), in order to study the meal from a holistic perspective (see Gustafsson, 2002 and Mitchell & Scott, 2013) What a researcher of e.g. wine tasting does, is to trust the skill he knows by heart as a guide towards the scientific development of, for example, methods for sensory training of sommeliers. When practice-led researchers study their practice, it is as a kind of knowledge- in-action. From a phenomenological philosopher's point of view this can be described as putting the practical skills *in brackets* (see *epoché* as defined by Edmond Husserl, 1913/2012) and engaging in theoretical reflection with practical skills as the lens (see also Ingold, 2013).

On the other hand, as shown in Figure 1, there is one application that is normally not studied in CAMS: episteme is normally not applied equally directly on artistic endeavor and practical skills. This has once again to do with the fact that the artistic endeavor and practical skills are performed in applied form, they mainly belong to the knowledge-in-action (see Ingold, 2013). From the point of view of Craft Research, Sjömar (2017) presents a precise argument for this:

> An example of this is the relationship between Art and Art History. It is hardly controversial to say that Art and Art History have few other things in common than the fact that the latter studies what the former have done. Art History is science *about* art, not science *in* art. One possible explanation for the focus on *about* instead of *in* is that art historians rarely have their own experience of artistic work (Sjömar, 2017, p. 101).

The experience of meals from an insider's perspective is central in CAMS, derived either from ongoing or previous experiences of e.g. cooking, serving, organizing or eating meals. Therefore, based on Sjömar's (2017) argument, CAMS is more to be described as a science *in* meals rather than a science about meals.

Discussion: Benefits of a Methodological Turn in CAMS

Normally, science is looked upon theoretically, with a focus on the point of view of its aims and conclusions. However, another possible perspective is to depart from the scientific practice of CAMS, i.e. the work carried out through the use of scientific methods. There, in the scientific methods, is where we argue that science is enriched by artistic endeavor and practical skills. It is in methods that researchers can be guided by skills and artistry towards scientific development, as illustrated in Figure 1.

Gadamer's (1960; 1978) hermeneutics points towards such a methodological turn, and allows for several forms of knowledge to be used in parallel in the same model (Keffel, 2004; Nilsson, 2009), and this makes Gadamer's hermeneutics promising for CAMS. The point is, as we have argued here and explained in Figure 1, that from a hermeneutical view, the threefold Aristotelian functions of knowledge are not directly translatable to the static forms of knowledge but rather to the *intersection between the forms,* with a special emphasis on the word intersection as it was mentioned by Mitchell and Scott (2013). If we accept that point of view, it follows that not solely interdisciplinary science but also artistic endeavor and practical skills can be grasped by techne and phronesis. This is exactly what is taking place in CAMS, and this, in turn, makes a broader scientific approach in terms of techne and phronesis possible. This is a strength compared to many other disciplines, which is one of the benefits of CAMS's interdisciplinarity.

Originally, at the time of Aristotle, when science was basically limited to mathematics, episteme was the principle of all science, while techne and phronesis were tied to knowledge that Aristotle did not view as science: craft and morality. However, this no longer applies. Gadamer (1960) and Nilsson (2009) both discuss how the fact that science was broadened to accept empirical studies as well as human and social sciences led to some aspects of techne and phronesis also being incorporated with science. However, what is interesting is that techne and phronesis are not limited to only being active in science. It is important to note that even though techne and phronesis nowadays can be active in science, techne and phronesis can still be active in, for example, artistic endeavor and practical skills *as well* (Bengtsson, 1998; Nilsson, 2009). A methodological strength in CAMS is thus the way artistic endeavor and practical skills also highlight other aspects of techne and phronesis which science alone cannot.

Discussion: Where are we Heading in CAMS, and how are we Knowing Together?

We want to point out the fact that the scientific way of managing knowledge for a long time has focused on the idea of *forms of knowledge,* and we therefore encourage more discussions also with regards to *functions of knowledge*. In this paper we have argued that CAMS is not limited to studying only the artistic endeavor and practical skills from the outside, but it is also open to treating them as aspects of a researcher's lived experience, something that is within the studies-in-action, functionally active in the shape of technian training and phronesian bildung. As we have seen, many researchers in CAMS have a background in the restaurant or food and beverage industries and can therefore use their artistry and skills to find perspectives on acting and reasoning scientifically (see also Ingold, 2013). Artistry and skills are thus not to be seen as simple sources of scientific facts, but rather as valuable *sources of scientific activity*.

Thus, we find that instead of the Kantian point of view on knowledge criticized above, a phenomenological-hermeneutical tradition (Hegel, 1807; Heidegger 1927; Gadamer, 1960; Gurwitsch, 1964), is more useful in explaining these philosophical positions in CAMS. The advantage of choosing this approach for CAMS is that it is more *functional* than *formal*, and draws attention to the unity in the functionality of knowledge rather than the difference between its forms. Such unity is also more compatible with the idea of an interdisciplinary thematicality in the subject demarcation of CAMS as we indicated above.

Our point is that it is this *thematicality,* i.e. the principle of being demarcated by the meal as a theme, which leads CAMS to a methodological focus, which in turn leads towards stronger emphasis on phronesis. While one could argue that most scientific branches are demarcated by their methodology –Physics and Biology, for example, study the same physical world but use different approaches in their methods– this principle of demarcation is not applicable to CAMS. In thematically demarcated disciplines such as CAMS, the demarcation is instead in the physical world, i.e. in the meal as a common theme. Therefore, as an important result of the fact that methodology is not part of this demarcation, CAMS is free to navigate in the whole spectra of methods and thus more free to focus on development of knowledge from a methodological point of view. While, for example, physicists have their way of studying and sociologist have theirs, the interdisciplinary CAMS has no such *way* predetermined, and is therefore open to studying the ways *waywise.*

If we are to define a philosophical platform on which the whole discipline of CAMS can be built, it must therefore, as Hegel (1807), emphasizes: bridge the classic dichotomy between worldly and human. And in order to emphasize the importance of the insider's perspective alongside the outsider's in CAMS, we need a model which is not limited to illustrating the formal *building materials* of knowledge [science, practice and artistry], but which is also based on the functional *building technology* [episteme, techne and phronesis]. Figure 1 is therefore not to be viewed primarily as a model of the knowledge constituents of CAMS, but rather as a model which shows how the knowledge works in action and function.

Figure 1 is divided into *forms of knowledge* and *functions of knowledge*, not in order to illustrate a separation, but rather to illustrate the union between them. The distinction between forms and functions is only made to shed light on the central point of our thesis: the correspondence and connectedness between them (see also Gustavsson, 2001; Gustafsson et al., 2009; Ingold, 2013; 2017). Thus, episteme has a connection with science, but they are not synonymous. Thus techne has a connection with practical skills, but they are not synonymous. Rather, we should see it in the same way as when science is *connected with* episteme, or when science is *connected with* techne, or when practical skill is *connected with* techne, the connection is also essentially dependent on phronesis. It is about what Gadamer (1960), and in other words also Ingold (2018), showed us:

> the application of experiential universals to the particular object of investigation (Gadamer, 1960/2006, p. 4).

Conclusions

For CAMS we find it useful to be aware of the correspondences shown in the model in Figure 1, in order to ensure that no significant parts of the discipline's thematic field of knowledge are missed when updating and improving the education or when setting up strategies for research. Furthermore, we claim that the functionality in the model can also be applied to the collaborations and correspondence which CAMS is to represent to the restaurant industry and to society. We therefore argue that this is also a model of the correspondence between academia and society: because CAMS's role in collaboration with society and industry is to spread the very same functions of *knowledge and understanding* (i.e. episteme), *competence and skills* (i.e. techne), and *judgement and approach* (i.e. phronesis).

Furthermore, this model is presumably not unique for CAMS as an academic discipline, and might therefore be equally useful in other interdisciplinary academic fields.

We therefore conclude that CAMS, enriched by both artistic endeavor and practical skills, is particularly strong as a social force by spreading *competence and skills* and not least *judgments and approach*. Phronetical skills, also known as bildung (Segolsson, 2011; Gustavsson, 2012; Tyson, 2018), add important ethical, sustainable and conscious dimensions to CAMS (Gustafsson et al., 2009), notably important competences for an academic education in order to meet the challenges of today's and future's society (Magnusson Sporre, et al., 2015). Bildung implemented in higher education can also bring attention to gender perspectives, social class perspectives and ethnic differences, and thereby give a broader societal understanding (Mark, 2009). It is about knowledge formation from a point of view which also emphasizes correspondence, i.e. the issue of how to attend to and engage in questions (Ingold, 2018). The approach to meal research that we argued for in this paper is a lens through which these issues are made more accessible. Therefore we finally want to highlight the social importance of meal research for societal *knowing together*, and the fact that the meals we all eat every day are also to be regarded as an operative *stage for bildung*.

Further research is suggested on educational practices centered on bildung within the interdisciplinary education in CAMS. Possible bildung-related research topics are: a) case studies of educational development from the point of view of how interdisciplinary research is implemented in interdisciplinary education, b) case studies on bildung-oriented educational practices in interdisciplinary education, c) longitudinal studies from the student's point of view on how they see their educational development and their development of correspondence with industry and society. This research can benefit from working with narrative methods, since such methods have proved useful for studying phronesis and bildung (Flyvbjerg, 2001; Tyson, 2016). The narrative stream of consciousness can be a strong method for making the links between sensory experiences and their correlated societal and environmental context more approachable to research.

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When Art meets Science: Conditions for Experiential Knowledge Exchange in Interdisciplinary Research on New Materials

Camilla Groth, University of Gothenburg, Sweden & University of South-Eastern Norway, Norway.

Margherita Pevere, Aalto University, School of Arts, Design and Architecture, Department of Art, Finland.

Pirjo Kääriäinen, Aalto University, School of Arts, Design and Architecture and School of Chemical Engineering, Finland.

Kirsi Niinimäki, Aalto University, School of Arts, Design and Architecture, Department of design, Finland.

Abstract

Interdisciplinary research across art and science offers the potential to open up new areas of knowledge previously hidden in-between disciplines. At the same time, differences in disciplines' theoretical frameworks, verification methods and expectations can cause discrepancies, which can be fruitful but may also require further navigation efforts. In this paper, we discuss the potentials and challenges of combining scientific and artistic research in interdisciplinary projects studying new materials. We interviewed 11 researchers working in different projects that combined scientific and artistic research in Finland and Germany, in order to investigate how they deal with different epistemological approaches and the limitations and possibilities that they brought up the interviews. In this paper, we focus on experiential knowledge sharing between the researchers in their research of organic materials. Our findings show that the prerequisites for experiential knowledge transfer need to be built consciously, over a long period of time by engaging in hands-on practices and cognitive activities that surpass the personal comfort zone of all members, and the common goals and research questions need to be motivating for all involved. Although academic research funding agents encourage interdisciplinary research, funding alone is not sufficient to motivate people to work and truly learn together. Even when motivation and common goals are found, the short longevity of funding might drive researchers to multitask, which in turn may damage the ideal conditions for transformational learning and knowing together. Thus, in addition to recruiting enabling professionals who have t-shaped experience of two or more disciplines, we suggest that conscious education in a new discipline could create a new generation of thinkers and makers who feel comfortable in the possibly unsettling zone between the disciplinary borders of arts and sciences.

Keywords

Art; Science; Research; Interdisciplinary collaboration; Knowledge transfer

As the architect John Zeisel says: people collaborate when they want to do more than they can do alone (1981/2006, 47). However, over the last decade, the research landscape has changed rapidly as a result of globalisation and emerging complex phenomena such as digitalisation, environmental crises and social awakenings. General research policies guide researchers towards actively solving material, societal and global challenges through problem-oriented, solution-focused and collaborative research strategies (Lamy, 2017; OECD). In such research efforts, collaboration over disciplinary borders is inevitable, as the issues are multifaceted, complex and involve several networks and relationships between multiple actors as well as deep domain-specific knowledge.

Moreover, creative fields are being encouraged to transgress from the disciplinary border; for example, the Arts and Humanities Research Council (AHRC) advocates collaborative projects between science, arts and humanities, claiming significant potential in such collaboration while also pointing out the limitations of using scientific approaches in isolation to tackle societal challenges, for example. Similarly, many European funding agents have formulated special research programmes around the subject, such as Horizon 2020, the OECD, the Academy of Finland, Volkswagen Stiftung, Robert Bosch Stiftung, and the Kone Foundation.

It is thus recognised that interdisciplinary research is acutely needed to solve complex societal and environmental problems that cannot be solved within a single discipline. Discussions on the possible challenges and benefits of fundamentally different epistemologies meeting are now topical. Well-established best practices that would work regardless of context are yet to be modelled. However, these practices need to be based on recognised enablers and previously experienced pitfalls and communicated in such a way that it forms general understandings.

Words such as *interdisciplinary*, *multidisciplinary*, *cross-disciplinary* or even *non-disciplinary* have been discussed from different viewpoints in the creative field and the humanities (Zeisel, 1981/2006; Peralta and Moultrie, 2010). Challenges, benefits, pitfalls and new understandings have been compared and the use of the results questioned (Crix, 2010; Niinimäki, Tanttu & Kohtala, 2017; Pirinen, 2016; Solberg, 2018; Scott, 2006; Schildrick et al, 2017). This research borrows Alexander Refsum Jensenius's illustration of what these different words mean, as this illustration clearly shows the level of 'sharing' of experience:

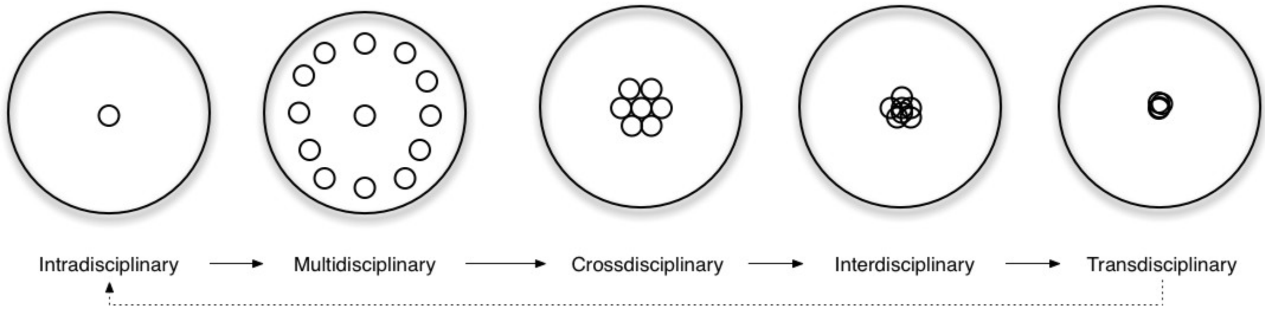

Fig 1. Drawn by Alexander Refsum Jensenius, 2016 (http://www.arj.no/tag/interdisciplinary/), based on an original drawing by Zeigler 1990.

The different modes of interaction shown above are explained by Refsum Jensenius (2016) as follows:

- Intradisciplinary: working within one's own single discipline.
- Multidisciplinary: people from different disciplines working together, but each person drawing on their particular disciplinary knowledge.
- Cross-disciplinary: viewing one discipline from the perspective of another discipline.
- Interdisciplinary: integrating knowledge and methods from multiple different disciplines, synthesising the different approaches.
- Transdisciplinary: creating a unity of intellectual frameworks beyond disciplinary perspectives.

The illustration shows how complex collaborative research is. Several recent conferences have highlighted interdisciplinary research in which creative practices collaborate with different fields of science. The diversity of case studies suggests how a general template is hardly possible as the collaborative fields differ in each case study, and so it is difficult to form general understandings and templates for an ideal collaborative format on the basis of individual research projects.

The present paper stems from a collaborative research project studying biomaterials and material development and involves researchers from the fields of design, crafts, bioart, synthetic biology and biochemistry. The aim of the project is to cross-pollinate research methods and foster experiential knowledge transfer across disciplines through co-creation workshops and discussion. The different fields represented by the project's researchers contribute through diverse interests and approaches to materials and materiality, including experiential knowledge (Niedderer, 2007), new materialism (Bennet, 2010) materiality and innovation (Karana, Pedgley, & Rognoli, 2015), and feminist critique of embodiment and bioart (Radomska, 2016).

For the purpose of this paper, we are interested in general features that could facilitate the transformative exchange of experiential knowledge in such interdisciplinary projects. The authors' background in the field of crafts, design and art inevitably influences the motivations, perspective, design, literature and data analysis of the research. While acknowledging its limitations, we embrace this situatedness (Haraway, 1988) as the basis for reading interdisciplinary research in new materials that do not aim to be either universal or exhaustive, but rather – hopefully – offer valuable specific insights into the field.

In this paper, we take a closer look at how to share experiential knowledge in interdisciplinary research through a set of interviews of researchers working in Finland and Germany, as outlined in the research design section below. In order to encompass the wide field of creative domains that our interviewees refer to, we use *creative practices* to refer to arts such as craft, design and related artistic research (Varto, 2018; Biggs, 2010). When referring to *science* we refer to natural sciences such as biology, chemistry, physics and biotechnology. While acknowledging that these are gross simplifications of the various practice fields included here, we highlight that they are necessary to enable an overarching reading of the different interdisciplinary projects in which our respondents engage.

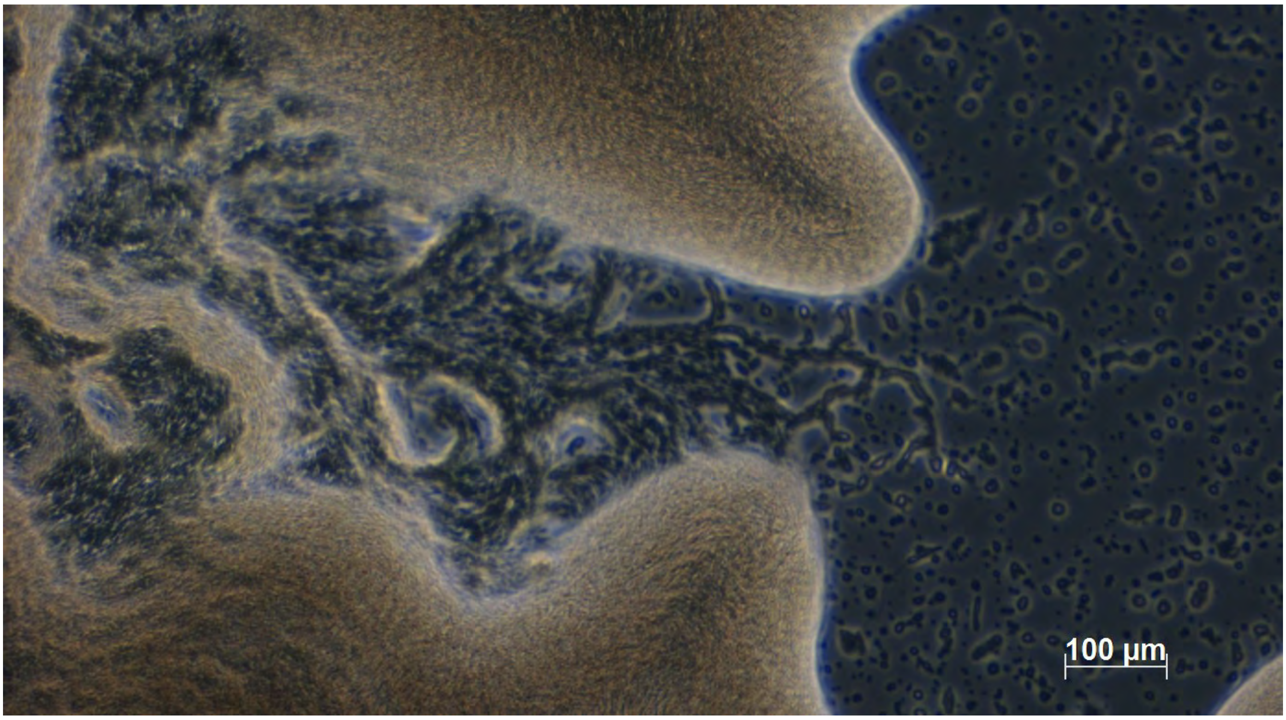

Fig 2. Detail of microbial biofilm, microscope picture by Margherita Pevere 2018

Experiential Knowledge

Experiential knowledge, also called *a posteriori knowledge,* is a type of understanding that can only be gained through experience and never through theorising only, or before the experience (*a priori)*. One can achieve such an understanding through close interaction with the phenomena under study, be this through sensory interaction or mediated by tools. Both the scientific and creative fields use this type of experimentation through a practice-led process which tests assumption and during which new questions might emerge (Candy & Edmonds, 2018).

Evaluations and judgements are based on expertise that grows over time and they are connected to previous experiences. Knowledge becomes embodied in the researcher as tacit or implicit knowledge. Within the same discipline, or between colleagues who share the same research experience, experiential knowledge is more easily shared. However, sharing experiential knowledge beyond disciplinary borders can become challenging, as the research methods and epistemic frameworks might differ radically (Ingold, 2018). However, as Ingold (2013) suggests, by investigating phenomena *through practice* rather than merely observing them, one can capture the true nature of the practice and knowledge is transformational rather than merely documentational (p.3). This transformation means that what we learn changes us and becomes part of who we are. However, such change may not happen in an instant, and often it requires a long time to develop.

Pilot Interview: On Fundamental Epistemological Differences between Scientific and Artistic Research

We formulated our interview questions as follows. First, we worked on our own research notes from the aforementioned research project. On the basis of these notes, we ran a pilot interview with a scientist who has had a long term collaboration with artistic researchers. The pilot interview highlighted the potential for knowledge production, mutual fascination between disciplines, but also friction areas and weak points, such as the different epistemological frameworks underpinning scientific and artistic research. We eventually compared what emerged from the pilot interview with the reference literature outlined above. Providing an exhaustive discussion of the epistemic differences between science and creative practices, as well as between scientific and artistic research, is beyond the scope of this paper as it tackles fundamental issues of knowledge production. However, for the purpose of our research, we must outline a few clusters that emerged from the preliminary research and pilot interview.

Objectivity is crucial in science as it aids reproducibility and production of novel knowledge on the basis of previous research. In artistic research, objectivity is less strict, and even considered unnecessary by some (Varto, 2018) as most processes are conducted in a subjective manner in a qualitative frame with a close, situated approach. Consequently, *verification* of results is not relevant in an artwork and related artistic research processes, whereas in science it is paramount. In the pilot interview, this aspect led to criticism of the validity of the knowledge produced through artistic research and to the differences in artistic practice vs. artistic research practices.

Different understandings of *cause and effect* create challenges, especially in explorative research processes. Artists have a subjective understanding of interaction with materials and may animate their materials in this process. *Language* can vary greatly between the two fields. In science there can be no confusion between what is stated and the nature of facts. In art, metaphors and poetic language are used to make a stronger, immediate connection between experience and conceptualisation.

Finally, *beliefs and politics* tend to be excluded from scientific research. In contrast, beliefs, subjective positioning, political aspects and societal issues form the core of most artistic research. In their report on the qualities of artistic research, Hughes, Dyrssen & Hellström Reimer, (2011, 1) state that ‘The aim (of artistic research) is often to reveal hidden concepts, critically examine social phenomena or highlight alternative values, perspectives and scenarios’ (parenthesis by the researchers), a thought that can be extended to certain design areas such as critical or speculative design.

For the purpose of this article we analyse how our interviewees dealt with the aforementioned topics and how they were or were not able to share their knowledge with others. We dive deeper into how the interviewees perceived their collaborators as benefitting from the understandings they gained together and how they facilitated the knowledge transfer between the participants.

Fig 2. Margherita Pevere performing with microbial biofilm in *Eingeweide* by Marco Donnarumma in collaboration with Margherita Pevere (2018), detail of a picture by Manuel Vason.

Research Design: Special Interest Group Interviews

In order to explore the challenges and potentials of interdisciplinary collaborations, we approached 11 scientists and creative practitioners who had engaged in projects that involved researchers from both creative and scientific fields. Although our respondents worked for large organisations or institutes with various interests, they were all interested in cross-fertilising research and can thus be called a special interest group.

Participants:

We chose the participants on the basis of their recent activities and successful funding applications in the context of interdisciplinary research. Our group of participants was gender-balanced and included scientists (5), creative practitioners (6) and researchers at different career stages: some of the more experienced scientists ran large research teams and had published more than a hundred international research papers. Apart from one, all either had or were pursuing a Doctoral degree in their field. To expand our research beyond a specific national context, and based on our own research experience, we interviewed researchers working in Finland (7) and Germany (4).

In order to obtain uncensored answers in the interviews we keep our interviewees anonymous. For most of the interviewees, interdisciplinary research covered only part of their research activity as interdisciplinary projects only last for a limited period of time. Some of them had education or training in both art and science. Most of them had researched new materials in either long- or short-term research projects. Their role in the collaboration varied from facilitating the research through funding, acquiring staff and materials, and providing and actively participating in discussions on the research issues to concrete hands-on actions and interactions with the materials and other participants. Table 1 below presents our dataset according to the most relevant parameters.

Table 1. Education, country, level of experience, main research field, interdisciplinary project area and role of participants.

Education	Country	PhD	Main research field	Interdisciplinary project area	Role in the project
Creative practitioner with science interest	FI	2008	Design	Biomaterials	Facilitator and participant, hands-on
Science	FI	1997	Chemical engineering	Material research	Facilitator and participant
Science	FI	1980	Neuroscience	Neuroscience and art	Facilitator and discussion partner
Science/ painting	FI	1987	Synthetic biology	Biomaterials, bio art	Facilitator and discussion partner
Creative practice	DE	2018	bioart, media art	Bioart; biomaterials	Hands-on
Science/music	FI	1983	Physics polymers	Bio materials, design	Facilitator
Scientist	DE	2014	Computer scientist	Bioart	Hands on, Facilitator
Humanities, art	FI	exp 2020	Bioart	Material research, bioart	Hands-on and discussion partner
Scientist	DE	1986	Microbiology	Biomaterials, design, humanities	Hands-on, facilitator, discussion partner
Creative practice	FI	No PhD	environmental, media and bioart	Environmental, media and bioart	Hands-on
Scientist	DE	1983	physics	Biomaterials	Facilitator

The Questions:

Our questions explored the underlying epistemological differences and how researchers navigate these in the context of interdisciplinary research. We asked them about the extent of their collaboration, their role in it, what led to the collaboration and what added value the collaboration brought. We explored the participants' views on the differences and similarities between the creative field and sciences, such as different research paradigms, methods, validity or beliefs. We also asked about the language they used, as we were interested in how collaborators created a mutual way of communicating. We also asked what challenges the researchers encountered and what advice they could give. Discrepancies and friction points and how to navigate these and the possible benefits that they saw in engaging in the collaboration were also elicited. Finally, we asked about their individual experiences of success or failure and what had led to these.

The interviews took place orally (except for one), in a conversational situation guided by a set of questions. This method has the advantage of balancing systematic data collection while allowing spontaneous observations to provide further insights. However, conversational situations might lead to rewording, which may reduce the comparability of responses. For the purpose of collecting qualitative data, we decided to prioritise the diversity of information over their comparability and compensated for this with a qualitative analysis of the interviews.

Analysis

Each interview was transcribed and two of the authors conducted an initial meta content analysis to see what types of general features emerged in the discussions. Based on these general features, we carried out a second co-analysis process in which we detected issues that emerged outside the predetermined questions of the interviews. The issues that generally emerged mostly related to the respondents' views on the differences and similarities between their own disciplines and those of the others, the problems or breakthroughs that had emerged, and how to navigate this field. This paper presents the initial analysis of the general features that emerged from the interviews and we account for these though examples from the transcript excerpts.

Results

A central issue that emerged in the interviews was that many of the scientists we interviewed were still unclear about what *artistic research* entails. In Germany, practice-based research in the arts at the doctoral level is still a young discipline, with a discrete number of conferences but very few PhD opportunities. In Finland, on the other hand, the discipline was established in the early 1990s. The existence of interdisciplinary research projects in Germany, some of them newly funded, suggests that the field is expanding. Despite this difference, scientists from both Germany and Finland showed some confusion regarding artistic *research* and art *practice*.

The general attitude among the scientists we interviewed was that the creative fields bring new ways of disseminating scientific research results through either their expressive display or design application. Few scientists embraced the artistic researchers' ability to influence the scientific direction of the project and few took into account the possibility of utilising artistic results in their own research outputs other than through images or prototypes. However, some of the artists reported that their ideas contributed through raising new research questions in their group.

Most of the creative practitioners aimed for truly *transdisciplinary* collaboration, whereas the scientists held a more *multidisciplinary* stance, according to which the two disciplines add to each other's work while maintaining their own expert areas. However, most of the scientists appreciated the potential of interdisciplinary collaboration whereas most of the artistic researchers were frustrated that their full collaboration potential was not understood by their partners beyond a functional purpose. Almost all the participants agreed that if one has to compromise the quality of one's own contribution too much in order to maintain collaborative aspects, collaboration becomes meaningless.

There was consensus on the fact that building trust and solid communication in collaborative research requires regular presence and common activity. The opportunities of knowing together require people to work together in the same space or facilities and engage in the research hands-on and/or through discussions on a regular basis. Some suggested a minimum meeting interval of about one week, but preferably daily interaction. The longevity of the project was mentioned as a key factor for enhancing the understanding between the participants, thus short projects would be unable to affect the participants' way of thinking or how they are able to understand their partners' very different approaches. Engaging in the other partners' literature and way of thinking, although this may mean stepping outside one's own comfort zone, is essential for educating oneself and each other and for building bridges and a common language that can serve as a mutual platform on which to stand in the project.

Naturally, the factors that hindered collaboration were the opposite of the enabling conditions. Trust, respect and appreciation of each other's work and attitudes were considered crucial, and if there was failure in any of these aspects, the collaborations could fall short. Both the creative practitioners and scientists agreed that 'personal chemistry' meant a great deal when inviting collaborators into a shared project, even though this feature was hard to describe. Disagreements between collaborators were avoided using the same recipe. While the participants agreed on these points in general, their expectations of the outcomes differed, as did the notion of successful collaboration or a successful outcome as opposed to unsuccessful ones.

It also emerged that, even between different scientific disciplines, individual interests, personalities, and most importantly epistemic differences may affect collaboration. Some of the interviewees noted how the division into disciplines according to training or research fields may be incorrect even within their own department. Interestingly, a certain ‘boundary-crossing’ emerged in the way both the scientists and creative practitioners related to and spoke about the materials they worked with. Although science generally requires a fundamental objective approach, some of the scientists had no problem relating emotionally or subjectively to their material explorations. In contrast, some of the creative practitioners considered it important to relate to their material processes through a scientifically organised and systematic approach in order to validate their findings in the science contexts and to be able to contribute to publications beyond the creative field.

Providing a generally valid definition of what is a ‘successful’ collaboration in interdisciplinary contexts is hardly possible given the variety of types, duration and objectives of interdisciplinary collaborations. Importantly, measuring success in disciplines that are entirely different involves different acknowledgement systems, value systems, expectations and even career paths. While the above results were the general issues that arose in the interviews, the following discussions focus on the challenges and opportunities of experiential knowledge transfer that the interviewees revealed.

Discussion: Experiential Knowledge Transfer in Interdisciplinary Research Collaborations

An analysis of the interviews outlined some key enabling factors for experiential knowledge transfer in interviewees’ experience. We tracked what the participants considered to be major benefits of the collaboration, the challenges, and the factors that enabled them and grouped them as follows:

1. Close physical and mental collaboration, which is only possible when people work hands-on in the same premises.
2. Motivation to solve the same research problem while using one’s own expertise in the mutual new context.
3. Trust, personal chemistry and the ability to transgress into the uncomfortable: the importance of mutually educating each other and building a new language.

1. Close physical and mental collaboration, which is only possible when people work hands-on in the same premises.

As outlined earlier, for most of the interviewees, the interdisciplinary research covered only part of their research activity. This might have affected an aspect that most of the researchers considered crucial, namely the time spent and the regular work done together. All the interviews highlighted how intensive and regular communication was key for collaborating successfully, as it allowed the partners to meet on a next to daily basis and nurture their mutual understanding of the processes, so that everyone could understand what needed to be done next, why and how. However, also listening to each other’s ideas and being ready to step outside one’s own comfort zone in the process of trying to reach a common understanding was highlighted. Although regular collaboration in physical proximity may facilitate different kinds of collaboration, this may be particularly relevant with regard to research on new materials due to the materiality of the research subject.

One interviewee told us how the discussion and the process of analysing their results together influenced their understanding of new possibilities, but also that failures may bring people closer together:

> We failed completely in our first attempt, but that opened our eyes and we learned to discuss and understand different ways of doing things, and actually the failing was the key in this process of forming the group.

It was also generally understood that the process of finding ways in which to work together takes time:

> I don’t think we can expect very quick results. It actually takes some time to find the right ways of doing it. I think there are very few examples of how to do this combination of research. There are not any methods for it. So, we have to do a lot of searching of ways to go forward.

2. Motivation to solve the same research problem while using one’s own expertise in the mutual new context.

Collaboration only succeeds if partners have a mutual interest in the subject and believe that they can shed light on aspects that cannot be covered by the disciplinary approach only. The respondents agreed that funding alone could not make research partners work successfully or make them motivated to work together. One of the scientists, who was not so pleased with the collaboration, mentioned that motivation to solve a mutual research question was a key enabler:

> But if we all had a common question, (...) then I would have gone straight to him and said let’s start talking every week about this and see how we can do an experiment, how we can find some earlier writing and maybe go to some place and do experiments there. Then we would have a mutual interest, and that certainly is the key!

One of the creative practitioners explained:

> In our team we managed to create new methods and to create new materials and use areas, but we couldn’t have done this without each other’s help. We really needed the scientists and designers working together for this and the combination of these two ways of working led to success.

3. Trust, personal chemistry and the ability to transgress into the uncomfortable: the importance of mutually educating each other and building a new language

Most of our interviewees raised the need to build a common language and clarify the setting in which such language could be used. However, this can only happen with mutual effort to communicate, trust, and understand each other. Although funding bodies request/propose that research positions in a funded project should be open in order to ensure that the best applicant is selected, many of our informants were of the opinion that the team should be handpicked. The reason for this was the awareness that personal chemistry has a great influence on the success and motivation of the collaboration. In the words of one of our respondents:

> Complications arise in all fields, not only in collaboration with artists. It’s about what kind of people are able to work together, about personal chemistries. Communications skills, but not only skills, because if we want to collaborate, we should have a common interest and know that we can learn from each other so that we are both happy to work together.

Another interviewee said:

> I think the chemistry between people is really important for the success of any collaboration, so the formation of groups might be the key to success. Because many scientists are not able to work with creative practitioners, I think we should think more about what kind of people are able to work together. And not just think that ok now we have ‘an artist’ coming to the science lab, because that happens a lot.

Mutual respect and acknowledgement were also paramount. The creative practitioners in our cohort perceived their work as undervalued when it was used for communication purposes only. On the other hand, the scientists did not feel comfortable if they were seen as a mere source of skills or resources. In our interviews, the scientists mentioned the potential for communication of the creative practitioners’ input and the creative practitioners mentioned that collaboration offered the opportunity to access resources and technologies. However, these aspects were only marginally mentioned, and both the scientists and the creative practitioners highlighted mutual learning as the most valuable contribution of the collaboration.

A creative practitioner from the design field had the following experience:

> (…) most scientists want to stay in their own bubble, and it's not that easy to find the kind of scientist who really wants to open their mind, to see new ways of doing things. But, in a couple of groups I worked with we really took huge steps when we trusted and respected each other. But in most cases I think that the scientists thought we were only stylists or product designers, and that's typical. They didn't think we could add value in other ways such as by really bringing about something new or offering new knowledge.

To create mutual understanding and respect that crosses disciplinary borders, more than one participant suggested that their team needed time and dedication to reach such understandings. One experienced scientist told us:

> We've been discussing artistic research in regular meetings for over two years now, including workshops and mutual artistic exercises, we have even been on a retreat together, but it's taken a long time to find ways, and the right words to communicate. We are very interested in each other's work and ideas, and we are working on a mutual paper, but we haven't been able to produce anything concrete yet.

While working hard to understand each other, difficulties also arose. One scientist explained their experiences as follows:

> There is a gap between us, and the gap between scientists and artists is larger than I thought it was. I believe that we can bridge this gap, but the key is that the people involved are willing to do that. Even just negotiating the words so that people just a little outside (their own discipline) could understand.

The way out of such a situation is awareness that it is difficult but that giving up will not take one any further. The friction points should be seen more as possible passages and enablers of change, as they are the point at which a bridge may be built, or where new concepts that both parties may understand should be developed. One of our informants claimed that:

The main point is that in order to understand more in any field there has to also be some contradictions. Somehow people can't be in concert all the time; they need to also find some friction points, some contradiction. In order to proceed from these friction points, you have to be able to communicate with the others.(...) In order to understand how people are in the world and how they understand the world we try to combine these different views, but first we have to bridge the concepts so that we can talk to each other.

However, the usually limited duration of funding challenges regular commitment to interdisciplinary research projects. Many researchers work on several projects simultaneously to ensure a regular income. This in turn makes it difficult to prioritise the process of achieving qualitative results over the dissemination of tasks in the expert fields represented in the collaboration. Thus, the good intentions of interdisciplinary sharing were forcing the collaboration into a multidisciplinary approach in which the different disciplines in fact worked side by side, only combining the different results of their separate processes in the final product of their project, the research article or prototype. Alexander Refsum Jensenius (2016) and Zeisel (1981/2006) also reflect on this notion of thinking that collaboration is inter- or transdisciplinary when in fact it turns out to be multidisciplinary.

Challenges in collaborating might be turned into enablers

The discussion above shows a cluster of factors that can lead to rewarding or even successful collaboration. Most of the interviewees clearly suggested that the lack of factors such as time spent working together or willingness to understand each other's language might negatively affect the research. These conditions might lead to miscommunication, feeble personal connection and trust, and no shared language on which to build or publish. Not acknowledging the work of others can create frustration or distrust among collaborators. Some interviewees referred to further disrupting factors including stolen work, hidden agendas or difficult power relations as a source of distrust and consequent failure.

While these unfavourable conditions certainly set collaboration on the wrong track, we might also think of failure, disruption and miscommunication as opportunities for deeper reflection. Kahane (2017) suggests a strategy for dealing with such instances by 'stretching' the collaboration and shifting away from the wish to control every part of the process or to change the others in the team. Instead we should enter the uncomfortable zone to be able to embrace conflicts and move beyond them (2017, 42). This might enable open-minded experimentation with new possibilities even though it may at first seem to go against what feels natural.

We found that truly interdisciplinary breakthroughs could emerge precisely in the space that nobody could have considered without having to stretch beyond the comfort zone of their familiar discipline. Niinimäki et al. (2017) find that multidisciplinary collaboration in research on new materials requires participants' readiness to step outside the practices of their discipline and learn collaboration (2017). However, as the challenge to understand everything in several disciplines is overwhelming for anyone, Niinimäki et al. suggest that learning is not enough; a new type of knowledge intermediator is needed to bridge knowledge gaps between disciplines, so that shared understanding can happen (2017, 9). In their case this was a textile engineer, but the notion of t-shaped knowledge skills is also common in the area of design, in which professionals have a generally broad understanding combined with a great deal of domain-specific knowledge.

Within a different field of research, Schildrick et al. (2017) give a comprehensive account of an experimental interdisciplinary research project on heart transplantation across medicine, the humanities and art, which shows how an unprecedented research assemblage may lead to a fuller comprehension of the significance and experience [of heart transplantation] as the first part gave a feeling that the multi-disciplinary team collaborated on the heart transplantation procedure/surgery as such (Schildrick et al., 2017, 46). Drawing on previous research (Niinimäki, 2017; Schildrick 2017) and the valuable experience of our respondents, we embrace a daring approach to interdisciplinary research, and hope that it may pave the way for novel paradigms in research.

Conclusion

Based on our interview analysis, we would like to make a general note to researchers embarking on research projects involving both sciences and creative practices, in order to help them facilitate knowledge transfer between participants. Trust and openness are key to communication in most contexts, but the specificity of interdisciplinary fields requires further care. Our respondents' experience clearly shows how mutual understanding and the prerequisites for experiential knowledge transfer need to be built consciously, over a long period of time by engaging in hands-on practices and cognitive activities that exceed all the collaborators' individual comfort zones while the common goals and the research questions are motivating for all of them. Trust and respect need to be nurtured even when the ideas of the other discipline feel unnatural or incomprehensible: breakthroughs may emerge in areas of discrepancy.

While academic research funding agents prompt and encourage interdisciplinary research, the present research suggests that money alone cannot motivate people to work together. Even when the motivation and common goal is found, the short longevity of funding might drive researchers to multitask, and this is counteractive for maintaining the ideal conditions for truly transformational learning and knowing together. Thus, in addition to inviting enabling professionals who have t-shaped experience of two or more disciplines, we suggest the conscious development of novel paradigms that could educate a new generation of thinkers and makers who feel comfortable in the unsettling zone between disciplinary boundaries.

Limitations of the research:

Interviewing a homogenous group of researchers, for instance, only creative practitioners or only scientists, from one country or a single research area could have provided comparable data on factors such as experience, internationality or research objectives. Instead we chose to look at the qualitative aspects before the comparative aspects. Additionally, a mixed author group may have resulted in a more comprehensive research design and data analysis, including more of the scientists view into the subject matter. Although this might give rise to the same challenges our respondents described, an interdisciplinary approach to the subject may create provocative research questions.

Future research:

The formation of novel paradigms that truly combine the sciences, creative practices and humanities still alludes us, and research on interdisciplinary processes that can generate models for best practices is still needed. Another aspect that might be worth addressing is how funding might shape collaboration according to whether it is obtained by scientists or creative practitioners, and how this aspect might affect power structures within the group as well as the continuity of the research.

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Camilla Groth

Camilla Groth has a traditional craft background in the field of ceramics and for her PhD she studied aspects of embodied knowing in design and crafts and developed practice-led research methods. Her research interests revolve around experiential and embodied knowledge and materiality. Groth is currently conducting her post-doctoral research at the University of Gothenburg and also holding a 20% Associate Professorship in arts and crafts at the University of South-Eastern Norway.

Margherita Pevere

Margherita Pevere is an artist and researcher with a visceral interest in biological matter. Bacteria, animals and plants are her allies in the exploration of the underlying theme of ecological complexity, which she pursues with sophisticated bodily aesthetics. Created in both the studio and biological laboratories, Pevere's installations and performances are chimeras which intertwine poetics and controversy, critique and desire. Pevere is a PhD candidate in Artistic Research at Aalto University, Helsinki, in collaboration with Biofilia Laboratory – Base for biological arts. supported by The Finnish National Agency for Education (2017–2018) and the Kone Foundation (2019–2020).

Pirjo Kääriäinen

Pirjo Kääriäinen is a designer and facilitator in the intersection of design and material sciences. She currently works as a Professor of Practice in Design driven fibre innovation at Aalto University, Finland. Kääriäinen has been developing interdisciplinary CHEMARTS collaboration between chemical engineering and design since 2011, focusing on the research of bio-based materials.

Kirsi Niinimäki

Kirsi Niinimäki is an Associate Professor in Design in Aalto University, Finland. Her research focuses on holistic understanding of sustainable fashion and textile fields and connections between design, manufacturing, business models and consumption. Niinimäki has also studied transdisciplinary collaboration and design-driven methods in collaboration. At Aalto University Niinimäki runs the Fashion/Textile Futures research group http://ftfutures.aalto.fi.

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Daniel Östergren

Daniel Östergren is a PhD candidate in Culinary Arts and Meal Science at Örebro University.

In his PhD project, he studies the correspondence between theory, practice and design in meals, from the point of view of how knowledge is learned from a meal context. The concept of bildung is central to the project. The project is theoretically rooted in a phenomenological-hermeneutical tradition, and the empirical data is largely derived from the university education at the School of Culinary Arts and Meal Science at Örebro University. Expected results are focused on development of educative methods. The education period as a doctoral student is 2018-2023.

Daniel holds a Master of Science degree in Culinary Arts and Meal Science from Örebro University as well as a Diploma in Wines and Spirits from Wine & Spirit Education Trust. Daniel has several years of experience in teaching courses on beverage knowledge, sensory experience and wine tasting methodology.

Inger M. Jonsson

Inger M. Jonsson is a professor of Culinary Arts & Meal Science with the perspective of “meals in the society”. She holds the position as head of subject of Culinary Arts and Meal Science at Örebro University, i.e. education with an interdisciplinary scientific perspective including practical and aesthetical perspectives. She has a strong interest in the development of structure and quality in the curriculum for bachelor, advanced and doctoral levels. She is responsible for postgraduate education and PhD student’s seminars in her department. Her personal research interest include what food and meals mean in today's society, especially when it comes to the hospitality industry and the meals in public sector, as well as the people involved in preparing and producing it. Her fields of interest also include gender, class and multicultural perspectives with the meal in focus.

Towards Actionable Forms of Communicating and Sharing Design Knowledge

Joanna Rutkowska, Tallinn University, Estonia

Froukje Sleeswijk Visser, Delft University of Technology, The Netherlands

David Lamas, Tallinn University, Estonia

Abstract

Design research aims to construct knowledge that is useful for designers and non-designers in the processes of designing for various types of challenges: from making products to solving complex social problems. Designers and non-designers seek information and inspiration for their work both in a non-design world, e.g., in films, illustrated magazines, and in various sources and forms of design research. Conference papers are one of many sources of design research insights. Unfortunately, the textual format of conference papers does not allow to convey the richness of design research insights and express them in forms that are *actionable* and available to others, e.g., non-designers. As a result, members of design teams might feel disempowered or do not trust and accept provided design research outputs. Therefore, they do not act upon the provided design research insights and find it challenging to apply them in collaboration.

In this paper, we present the *actionable palette* that consists of nine qualities that act as building blocks of *actionable* forms of sharing and communicating design knowledge. Using the *actionable palette* to review design research outputs from 51 pictorials, we identified six forms of capturing design research insights. We characterize these six forms and analyze them in terms of *actionability* to inspire designers and non-designers to experiment with forms of sharing design research insights and first design ideas based on design research insights. Finally, we provide a set of guidelines to inspire and inform the process of reaching the particular qualities of actionability for design research outputs.

Keywords

Actionable Design Knowledge; Design Research Outputs; Design Research Insights; Pictorials

The goal of design research is to construct knowledge useful for designers and non-designers in the processes of designing for various types of challenges: from making products to solving social problems. In this paper, we understand design knowledge as a reference to two types of outputs in design projects: design research insights and first ideas based on design insights. Design research insights are design opportunities that emerged from the design research process. They provide reexamined understanding of the studied phenomenon and mediate between research and design. The goal of communicating design research insights is to inform and inspire design and support decision-making within a team that is aiming to achieve a shared purpose (Sleeswijk Visser, 2009). An action of two or more people who are working together to create the shared purpose is defined as collaboration. In a design context, collaboration takes place between various stakeholders (e.g., designers, researchers, engineers, decision-makers) during idea generation, problem-solving, or decision-making meetings. When collaborating, designers use artifacts, e.g., design research outputs, to support the application of insights and first ideas. Such artifacts act as boundary objects

(Star & Griesemer, 1989). Therefore, collaboration needs artifacts to support goal-oriented activities and communication within a team. Non-designers, e.g., clients, need to understand and see the relationship between research and design to appreciate and accept the value of design research insights and design ideas. Unfortunately, designers are often not prepared to articulate arguments behind the process of synthesis that is transforming research into design. In consequence, clients reject such ungrounded design research outputs as they seem to be too risky, incomplete or abstract. Kolko (2010) indicates that the lack of formality in the processes of synthesis discounts the value of design research. He argues that there is a need for tangibility and actionability in the context of the outputs of synthesis.

To enable (others) act upon design research outputs designers experiment with various forms of documenting them. The form of design research output can be characterized by various qualities that make a given research asset, result or idea useful and actionable in collaborative settings. According to Manzini (2009 & 2015), in terms of form, design research insights and first ideas should be easy to discuss, clearly expressed, easy to apply and allow others act upon the work that was already done. Such outputs also should sustain empathy towards users and convey rich information in ways that are not overwhelming (Stappers et al., 2007). To present the scope and role of design research outputs, Stappers & Sanders (2012) use the term *the big picture*. *The big picture* is an abstract summary of the most critical learnings from research and the preliminary exploration of the design opportunities.

It is a challenge for design researchers to develop forms of design research outputs that are experiential and adapt to the requirements of different communities.

In academia, we distinguish intermediary design knowledge situated between general knowledge (e.g., theory) and contextual knowledge related to the particular artifacts (Löwgren, 2013). It is the space between verbal and design articulations, therefore is communicable through the combination of both (Pierce, 2014). Annotated portfolios, design guidelines, usability heuristics (Löwgren, 2013), bridging concepts (Dalsgaard & Dindler, 2014) or strong concepts (Höök & Löwgren, 2012) are examples of design research outputs that engage some theory formation or abstraction of concepts from practice and construct intermediate-level of knowledge.

Unfortunately, the nature of intermediary knowledge is not well-known outside the design community. Therefore, there is a risk that it is not easily accessed by non-design stakeholders (Höök et al., 2015).

Furthermore, the majority of academic research papers are presented in the textual format. Therefore, we miss design accounts in the archived contributions of design research outputs (Jarvis et al., 2012). Tacit knowledge embodied in interactions and gained by practicing of 'making' is hard to capture using textual forms of knowledge representation. Pictorial is the new format of full research papers that foregrounds high-quality visual components (e.g., sketches, photographs) over text and regards these visuals as the most critical part of knowledge articulation and main research contribution. Pictorials aim to promote and support the visual and experiential communication of design research outputs.

In design practice (e.g., design agencies, service design teams), documenting design research insights can be time-consuming (Dalsgaard & Halskov, 2012) and bringing *additional bridging work* that is a distraction (Höök et al., 2015*)*. Therefore, while deciding on a form of design research outputs, designers, especially novice once, often prefer to use well-known and accepted forms of design research outputs instead of exploring the needs of their audience and coming up with forms that are custom-made and actionable for non-designers. The examples of such *template* forms of capturing and sharing design knowledge are personas and customer journey maps (Cooper et al., 2007).

Summing it up, there is a need for actionable forms of capturing and communicating design research insights that will serve as sources of design inspiration and artifacts supporting collaboration both in academia and practice. We argue that knowing and exploring the actionable qualities of design research outputs designers will gain vocabulary to create forms that respond to the needs of a given team. As a result, designers, especially novice ones, will be more open to experimenting with various forms of sharing knowledge, not only *templates*. Therefore, the results of this work are aimed to mainly support design practitioners, e.g., service designers, who currently mainly use *template* forms of design research outputs.

Towards Actionability

The 2019 Merriam-Webster Online Dictionary defines actionability *as the quality or a state of being actionable*. *Actionable* means here *capable of being acted on*. The Free Dictionary adds to this the aspects of *relating to or being information that allows a decision to be made* and *capable of being put into practice*. Among synonyms of actionable, there are words such as *useful, usable, serviceable*. Interestingly, words *theoretical, academic,* or *unavailable* are the actionable antonyms.

Our work on actionable forms of capturing and sharing design research outputs was inspired by an example of communicating and crafting a good insight provided by IDEO, a global design company (Insights for Innovation Toolkit, 2017). An insight is understood here as the most critical learning from a project that we want to share with others. It has compelling quality and it:

- informs about people's needs and wants,
- inspires to take action,
- is memorable - it sticks and is easy to share with others.

When IDEO was conducting a project for Innova Schools in Peru, the design team learned that teachers were busy focusing on the children's needs and did not have time for their learning. Building on that knowledge, they presented the iterative process of crafting a good insight:

- 1st iteration: *Teachers do not have time for themselves*

  This sentence is informative, but does not provide a design opportunity and is challenging to remember.
- 2nd iteration: *Teachers crave connections to continue learning*

  It presents teachers' need, but it is still not memorable.
- 3rd iteration: *To reflect teachers need to connect*

  It is memorable, summarizes teachers need and shows directions for design.

Between the first and third iteration, we observe a transition from concentrating on the problem (a negative form of a sentence) to the action-oriented approach (a sentence that suggests a space for design action).

The textual form of an exemplary insight required reframing to become actionable. Qualities such as inspiring, informative, and memorable informed and structured the process of reaching the actionability. We argue that also, visual forms of design research insights require reframing to become actionable. We are interested in investigating the qualities that would act as building blocks of actionable forms of sharing and communicating design research outputs. Therefore, we decided to investigate the actionable forms of design research outputs. The goal of this study is twofold:

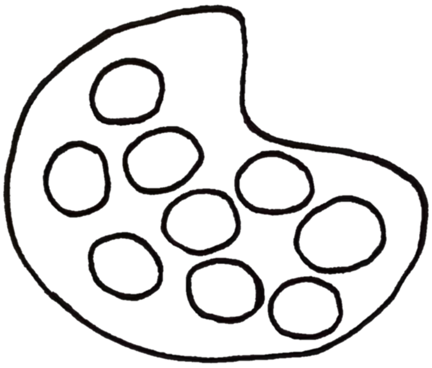
- Searching for forms of communicating and sharing design research outputs that provide *the big picture* (Stappers & Sanders, 2012).
- Identifying and defining qualities that are building blocks of actionability.

Stappers & Sanders (2012) define the five qualities of an effective *big picture* as follows:

- simple - including a concise visual summary of the main idea,
- memorable - easy to remember without taking notes,

- expansive - having many layers of meaning,
- grounded - referring to the sources of data,
- inspiring - showing new directions and perspectives.

Deriving from these qualities, the meaning of *actionable*, and the qualities of an insight proposed by IDEO we came up with a preliminary *actionable palette* (Figure 1) to sum up what is already known and prepare ourselves for reviewing design research outputs in 51 pictorials. The actionable palette presents nine qualities that are meant to inform the process of reaching the actionability of design research insights.



1. inspiring
2. informative
3. memorable
4. experiential
5. playful
6. multilayered
7. grounded in research
8. providing design opportunities
9. capable of being acted on

Fig 1. Nine qualities that act as building blocks of *actionability*

Method

We assumed that pictorials are a valuable source of visual forms of communicating and sharing design research insights. Pictorials provide opportunities for acting upon (somebody's else) research. Therefore, it is an interesting format to search for forms providing *the big picture.*

The goal of this paper is to answer the questions: *How do designers articulate design research insights and first ideas to provide the big picture? What are the qualities of these forms that build actionability? What does make a given form informative, inspiring, grounded in research, etc.?*

In order to answer these questions, we took an explorative and qualitative approach to analyze 51 pictorials published at The Designing Interactive Systems (DIS) conference (2014-2018) and Creativity and Cognition (C&C) conference (2017). Papers were identified by searching in the Association for Computing Machinery (ACM) Digital Library for the format of pictorials.

For each pictorial, we read the work, summarized its goal, methodology, and presented results. Then, we conducted a pattern analysis of visual elements in pictorials inspired by the method shown in Desjardins et al. (2015) and Desjardins et al. (2016).

For each pictorial, we took screenshots of chosen visual and textual representations of design research outputs. We collected 287 screenshots. For each screenshot, we had notes summarizing the role of a given output. All screenshots appearing in this paper come from selected pictorials used with the permission of the authors themselves.

We printed out each screenshot and wrote each unique statement concerning a given screenshot on an individual post-it note, e.g., *a process of unpacking movement into physical visualization is presented in the way that is experienceable*. The analysis was conducted *on the wall* (Sleeswijk Visser, 2009; Sanders & Stappers, 2012). We created an immersive visual display of analyzed materials to support patterns' finding. The pattern analysis *on the wall* was conducted by the first author of the paper what is a limitation of the study. The other authors of the paper were involved in discussions on the reliability and authenticity of the identified patterns.

The analysis was conducted in three iterations (Table 1) to finally receive the set of six forms of capturing and sharing design research knowledge.

1st iteration	We searched for examples of design research outputs that present a reexamined understanding of a studied situation and examples that are assigned to be further used in design processes, e.g., design insight, inspiration. In this way, we strove to pick out representations that have actionable qualities - motivate, inspire, provide opportunities, or that have collaborative capabilities.
2nd iteration	We clustered notes and screenshots representing identified examples of design research insights using the affinity diagram technique (Beyer & Holtzblatt, 1998) in terms of the form and purpose of the design research outputs. We deepen the analysis by asking the questions, e.g., *Why is this output presented visually? What is the role of the text?* Using conventional content analysis (Hsieh & Shannon, 2005), we obtained six forms of capturing and sharing design research knowledge.
3rd iteration	We investigated *What makes a given form actionable?* We used the primary actionable palette to investigate all actionable qualities of the six forms.

Table 1. Three iterations of data analysis

Six Forms of Capturing and Sharing Design Research Insights

We present six forms of providing *the big picture* meant to document design research work and trigger idea generation, inspire and inform design processes. We define each form, present its key elements, mechanism of working, and subcategories. We use selected screenshots from our data set to provide visual examples of a given form.

1. Inspiring Collection

It is a set of images that visually emphasizes a given phenomenon, presents work that was already done, or captures the chosen experience. The collection works as a *whole* that consists of *multiple elements* (Keller, 2005), e.g., photos of project results, snippets from user studies, organized according to a chosen strategy, e.g., theme, emotion, timeline (Figure 2). A collection is a dynamic object - once created by somebody for an implicit purpose it can grow over time by adding new elements to the collection.

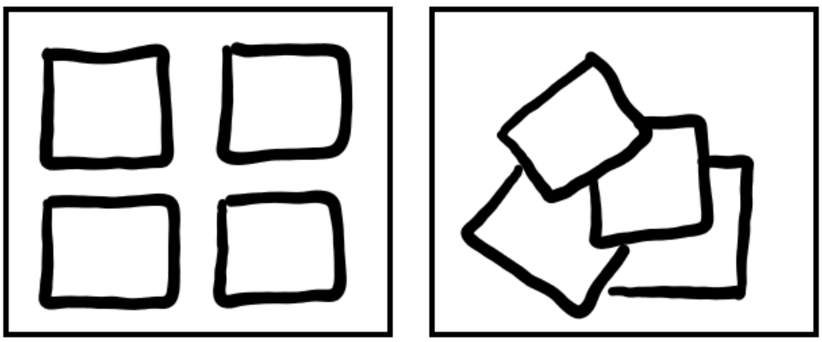


Fig 2. Two layouts typical for collections: structured organization of images on a grid (collection as the design research output) and unstructured clusters of materials (collection as a research tool or method, e.g., collage).

The goal of a collection is to provide a visually rich overview, bring a collective insight into a phenomenon that is studied, and provide a fresh perspective.

We identified four sub-categories of inspiring collections:

Inspirational test-bed (Wensveen et al., 2014) – a catalog containing a set of carefully selected images (Figure 3). It summarizes various materials to introduce emerging field, industry, or theme. It acts as a mediating research artifact, educational material, as well as information for designers or business stakeholders.

Referential inspirations – a collection of sources of inspirations, e.g., objects or interactions that were crucial for developing ideas in the given work. Such collection offers insight into a design process and shows what was before the idea (Figure 4).

Collages – an unstructured collection of visuals, e.g., images, notes, sketches used during the design research process to capture experiences or ideas that are difficult to verbalize. They mediate between understanding and ideating and spark a generation of metaphorical meanings. (Figure 5).

Inspiring puzzles - a subcategory of collections that emerged from the works of Eli Blevis (Blevis & Blevis, 2018; Blevis, 2017; Blevis, 2014; Blevis, 2016). These are galleries of high-quality photos carefully selected and juxtaposed to visualize a chosen theme, e.g., everyday life, and provide space for a reflection (Figure 6). These collections are "*designed to be experienced"* (Blevis, 2017).

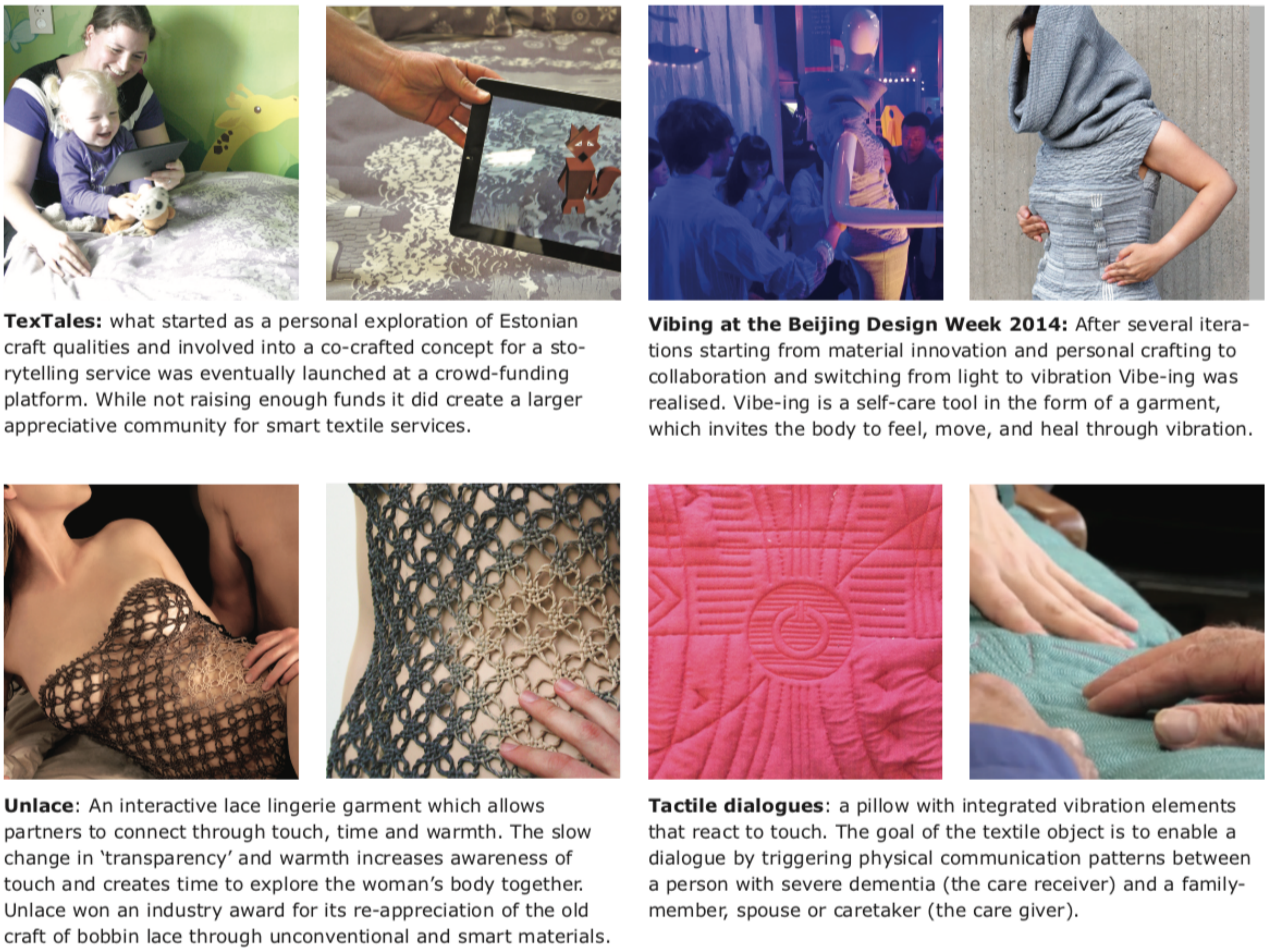


Fig 3. Inspirational test-bed. Wensveen et al. (2014) developed an inspirational test-bed to show the growth of the smart textile industry. They present images of experiments, e.g., with textile technologies, material innovations, crafting techniques for various stages of design, e.g., incubation, adoption.

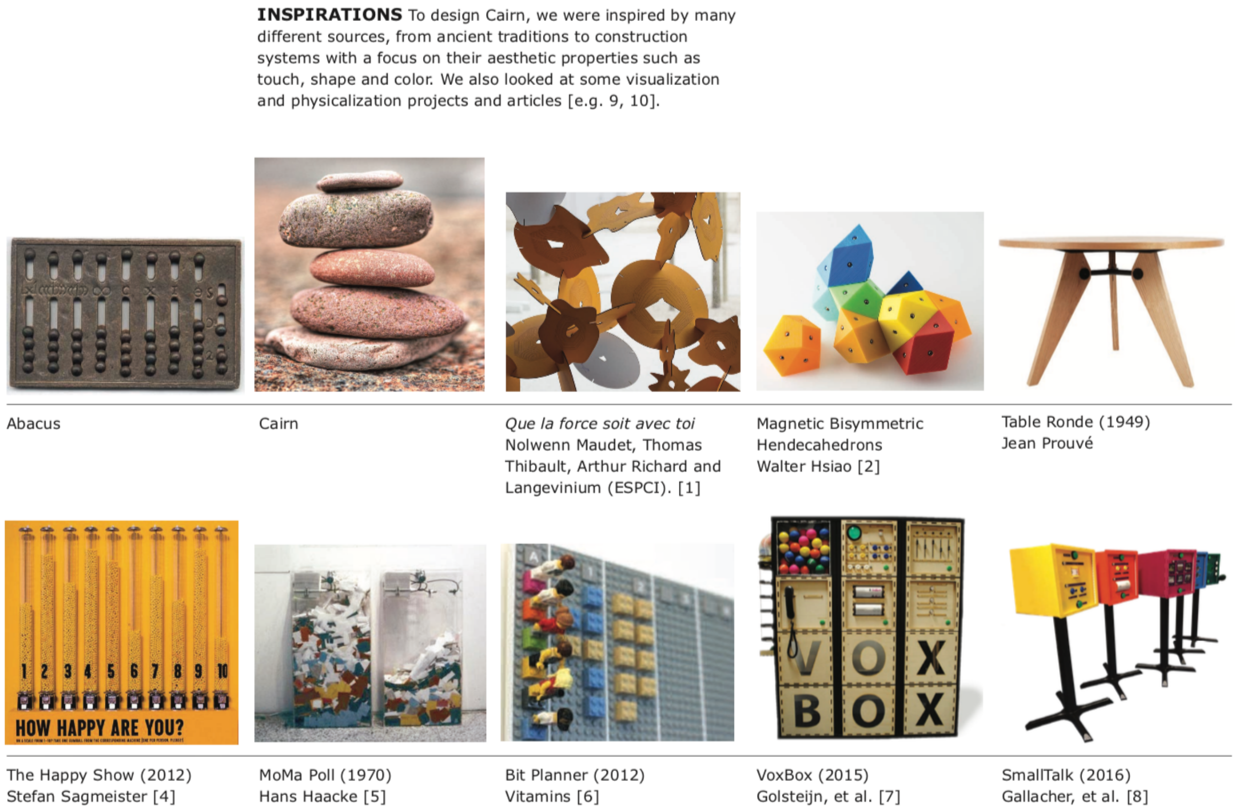


Fig 4. Referential inspirations. Gourlet & Dasee (2017) enrich visual examples of inspirations with references to literature, so it is possible to work with these inspirations further.

Fig 5. Collages. Beuthel & Wilde (2017) present the experience board that is a combination of images, notes, materials, and sketches selected by the participants of the study to express their inner sensations (migraine). For example, an image of insects attacking a human ear was chosen to express experiences occurring during the migraine. Then, this representation has been translated into the sound the crinkled tinfoil. Tinfoil-base material let to use vibration motors in the final prototype.

Fig 6. Inspiring puzzle titled “Woman at Desk.” The author of this photo has strong compositional and curatorial skills, and he fluently plays with visual elements to create inspirational visual puzzles for the viewer (Blevis, 2017). Here, we are invited to contemplate on the image that is out of focus. This task is meant to be regarded as a technique or material quality of interaction design (Blevis, 2017). Eli Blevis © 2017

2. Referential Resources

A set of references, e.g., hashtag, hyperlink to, e.g., a video, a visual gallery that adds interactivity and enriches the standard textual representations of knowledge (Figure 7).

The goal of referential resources is to introduce a context of the given work using interactive media, present research materials, show aspects of design knowledge that were challenging to verbalize and offer design tools or methods in the form of an open-source platform.

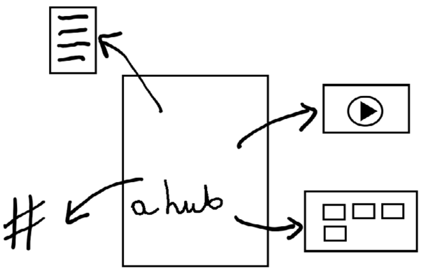


Fig 7. The referential practice of sharing knowledge contains two elements: a hub that is the primary design research output, e.g., full research paper, and a set of references to linking materials or external repositories of knowledge that complement or extend the knowledge presented in the hub.

We identified two sub-categories of inspiring collections:

External supplementary materials (Figure 8) – links to videos, hashtags or open-source platforms embedded in the standard research papers that add an experiential layer to the presented material, e.g., readers of the paper are recommended to watch the video to better understand the dynamic qualities of presented interactions (Peeters et al., 2017).

How-to-guides (Figure 9) – instructions or open-source templates showing step by step how to replicate the work presented in the given paper, e.g., how to create a metaphor card (Logler et al., 2018).

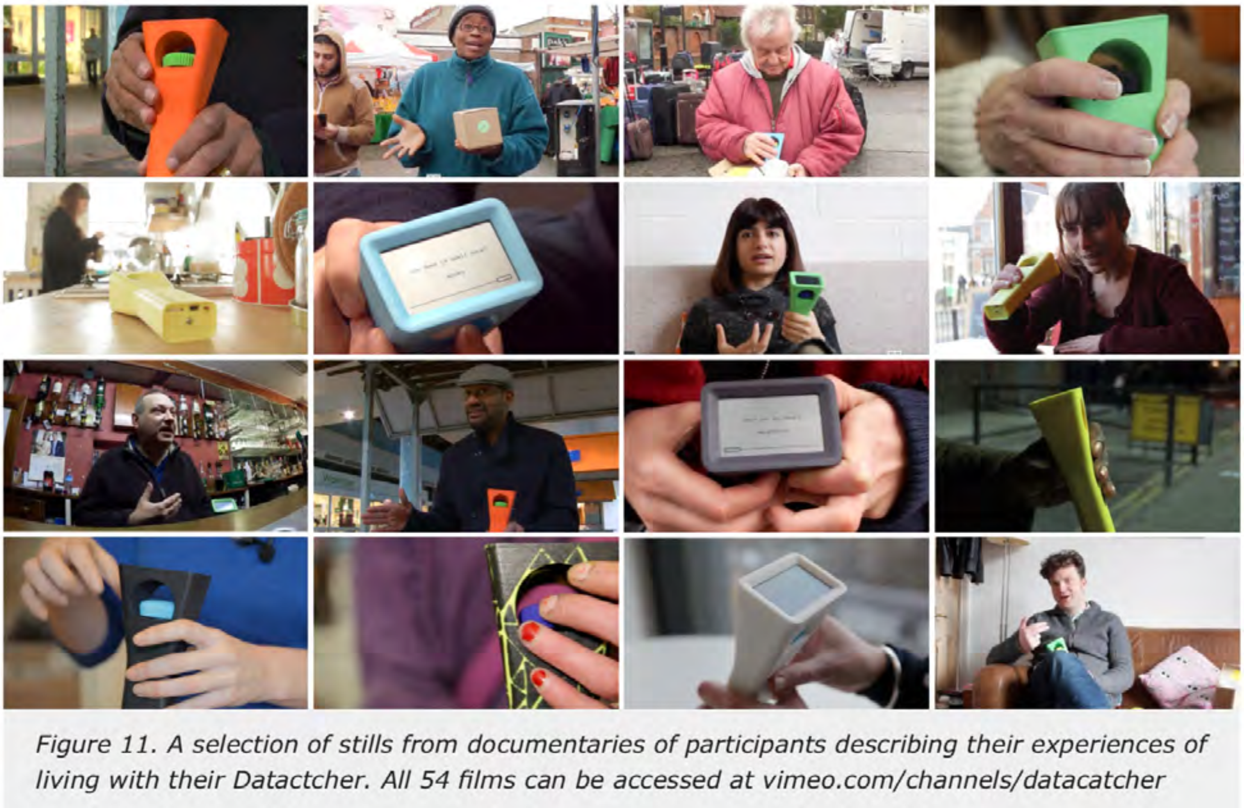
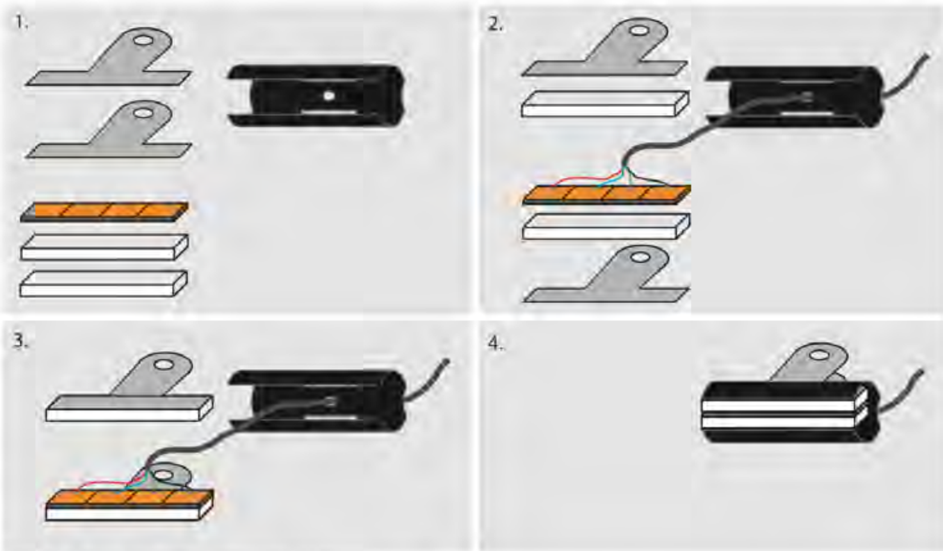


Fig 8. External supplementary material. Boucher (2016) provides a link to a video to refer a reader to documentaries in which participants of the study describe their experiences. © Interaction Design Studio


1. Take the bulldog clip apart; it should have three parts (Figure 6, step 1).

2. Drill a hole in the back of the bulldog clip to allow the cable to come through. Protect the cable with the grommet as the metal can be very sharp and start to cut the cable (Figure 6, step 2).

3. Take the copper board and score separations to accommodate for as many connections as you wish to make. Figure 6 demonstrates a clip for four connections.

4. Strip the end of the cable you have just fed through the drilled hole and solder each cable to the edge of the copper board. Here it is important to create as low a profile solder joint as possible to allow for better clamping (Figure 6, step 2).

Figure 6. A step by step guide to making the bulldog connector.

5. Superglue the two pieces of acrylic to the edge of the metal clamps of the bulldog clip. This makes the 'biting' angle of the bulldog clip less aggressive and helps to create a more reliable connection with the paper. Let that dry and then superglue the back of the copper board to one side of the acrylic (Figure 6, step 3).

6. Now for the tricky part. Hold open the cylindrical part of the bulldog clip and feed everything back in, taking care not to damage your solder joints (Figure 6, step 4).

When connecting this to a paper circuit it is important to have a slightly bigger gap between the printed connectors than on the copper board to prevent short circuiting (see Figures 4 and 5).

Fig 9. How-to-guide. Shorter et al. (2014) invite readers to replicate their make-lab process by providing instruction for building the bulldog clip connector.

3. Tacit mediations

Tacit mediations exploit the characteristic attribute of a chosen form of visualization, e.g., a photograph to provide a tacit layer of meaning to the presented knowledge (Figure 10).

Fig 10. A compound form of capturing design research knowledge. The form adds tacit meaning to the presented information (content).

The goal of tacit mediations is to provide an experience of a chosen phenomenon by utilizing the qualities of the form.

We identified two sub-categories of tacit mediations:

Photographs – various types of photographs that present outputs at the various stages of the design process:

- *the discover stage -* these are, e.g., photos from the field that are usually non-edited and of low-quality, taken by designers, design researchers or participants of the study (e.g., photos captured using mobile phones). They document the events or inspirations to provide direct insight into a situation that was studied, the everyday lives of people, and the *making of* research materials (Figure 11).
- *the define stage -* these are, e.g., portrait photography, drone photography, performative photography that act as a design tool. Visual stimuli construct new realities to provide insight into the future. These photos are abstract, provide artistic value and quality (Figure 11).
- *the develop and deliver -* these are, e.g., product photographs. These photographs present the final outputs of the design process, e.g., research artifacts, prototypes. These photos are usually curated, of high-quality and styled. The goal of these photos is to provide the best possible presentation of a design (research) output and/or show it in the future context of use (Figure 13).

Experiential knowledge – activity or puzzle to be experienced or solved to get a tacit or experiential insight into the studied phenomenon (Figure 14). The mechanic of a puzzle or the experience is based on the metaphor or mimic elements, e.g., a translation of the interaction to the form of the design research output.

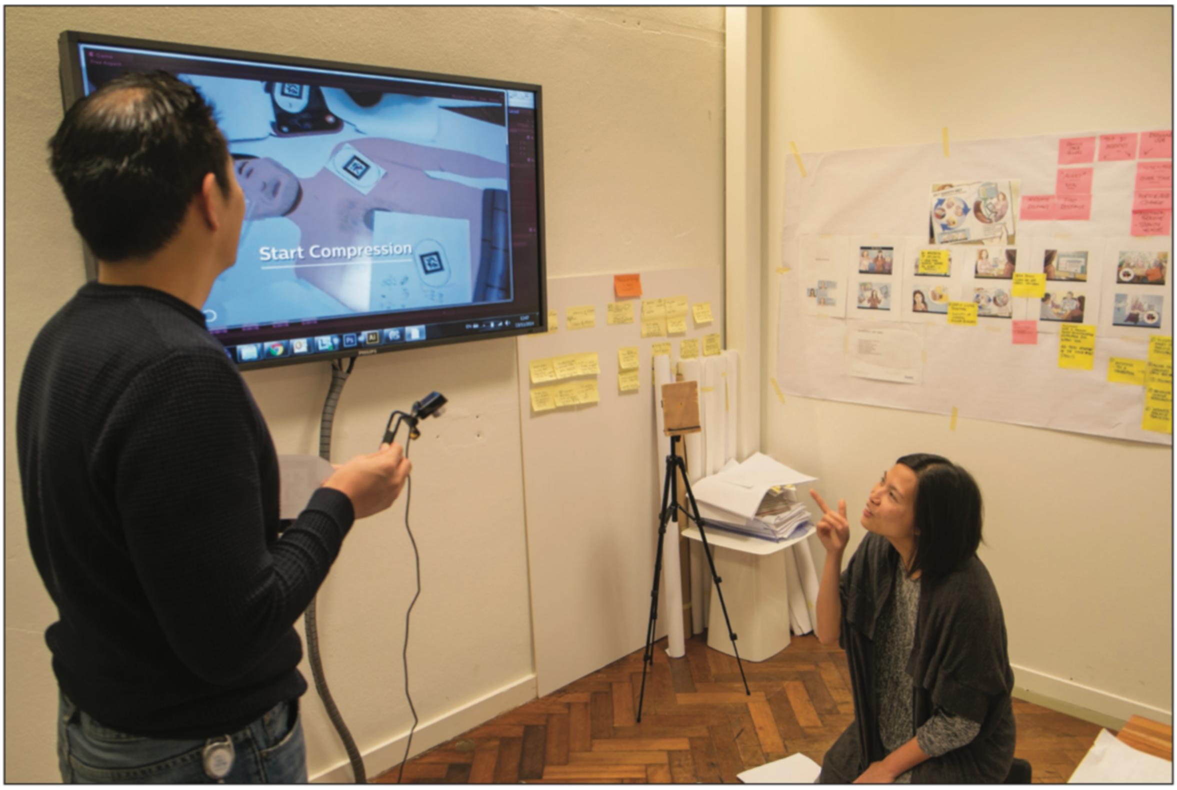


Fig 11. Photograph used at the discover stage of the design process. The *making of* a low-cost AR simulation of a sudden cardiac arrest emergency (Djajadiningrat et al., 2016). Copyright Koninklijke Philips N.V., 2016.

Fig 12. Photograph used at the define stage of the design process. Experimenting with the panorama function in the mobile phone (Time and Space in Broken Panorama; Simbelis, 2017).

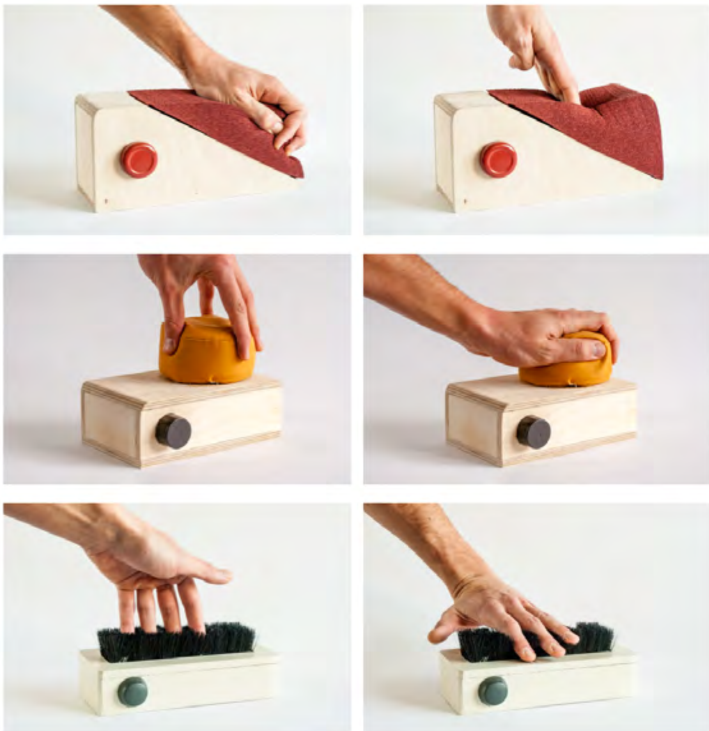


Fig. 13 Photograph used at the develop stage of the design process. Tuning a radio – the exploration of performative qualities of materials (Karana et al., 2016).

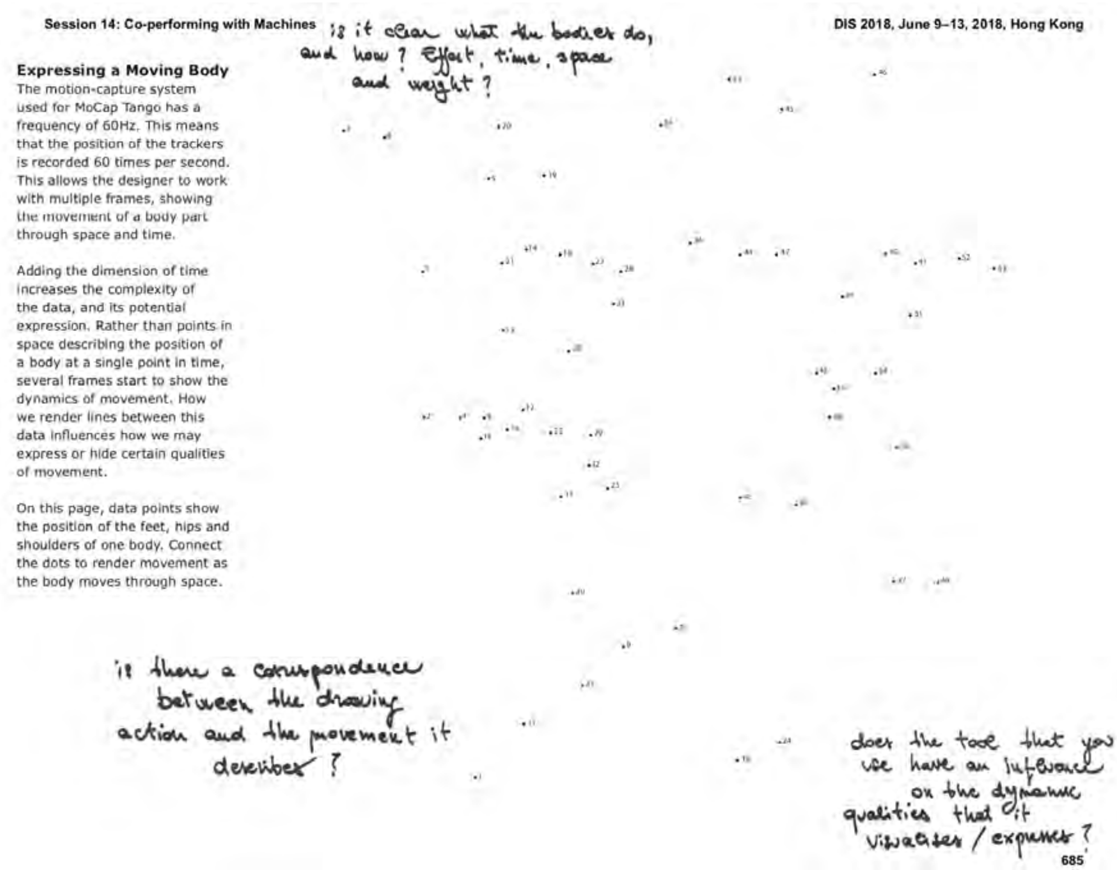


Fig. 14 **Experiential knowledge.** Peeters and Trotto (2018) developed a puzzle containing a sequence of numbered dots. They invite a reader of their paper to connect the dots to *render the movement as the body moves through space* while dancing the tango. The way we draw lines is a metaphor for expressing the qualities of movement. Authors complement the puzzle with follow-up questions to encourage reflection, e.g., *Is there a correspondence between the drawing action and the movement it describes?*

4. Engaging Narratives

The visually enhanced questions and dialogues embedded in the design research outputs. They are meant to add interaction, catch the attention of a reader, and invite to a discussion on a presented knowledge (Figure 15).

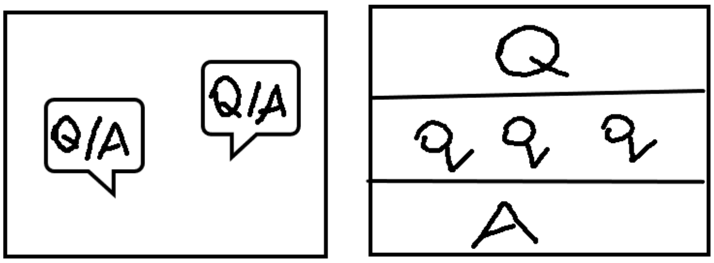


Fig 15. Questions are fundamental for doing research. They set expectations, encourage reflection, and evoke curiosity. Questions build narration by providing answers or constructing engaging dialogues.

We identified three sub-categories of engaging narratives:

Visually enhanced anchoring question*.* It is a visually distinguished main research question of the presented work meant to catch attention and bring focus towards answers, solutions, arguments or facts (Figure 16).

Auxiliary questions - a set of factual questions working as a mechanism to get complete answers and various perspectives on the presented phenomenon. Auxiliary questions derive from the Five Ways questions: *who? what? when? where? why?* complemented with *how?* question.

Comics - it is a medium to express ideas and simplify the presentation of research materials. It combines visuals and text. Textual elements, e.g., speech balloons, give voice to various characters and indicate sound effects. Panels with images are presented as a sequence to create a narration. Images provide an insight into the design process and its context.

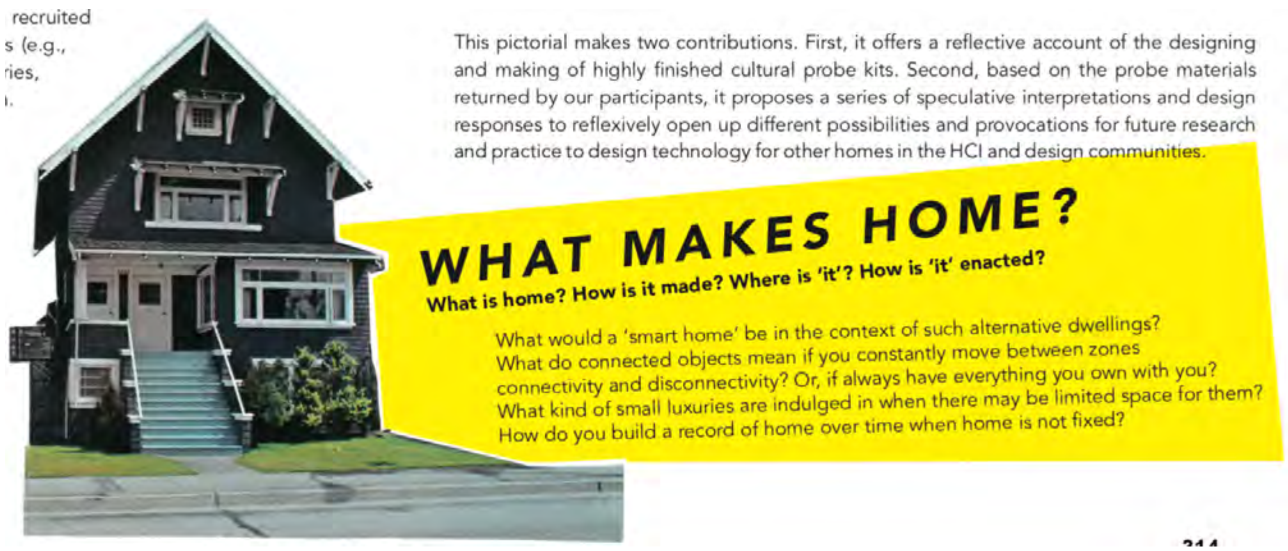


Fig 16. Visually enhanced anchoring question. Oogjes et al. (2018) structured their paper as an answer to graphically presented a set of research questions what catches the attention of the reader. © Everyday Design Studio

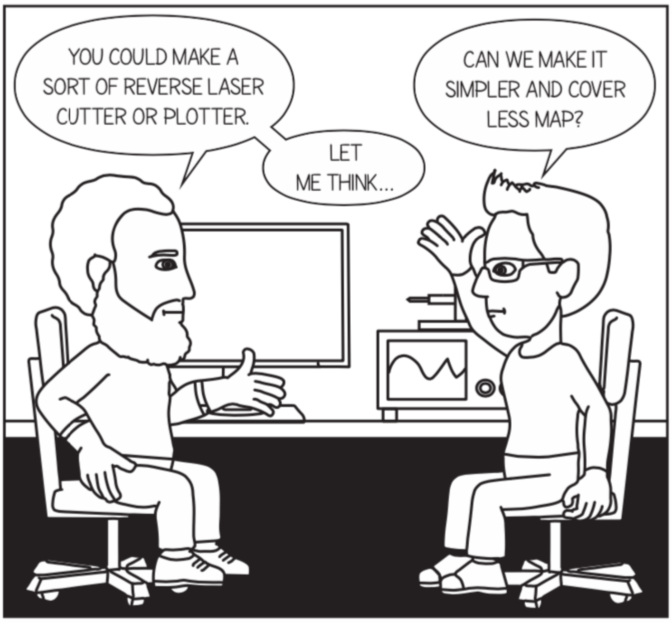


Fig 17. Comics. Dykes et al. (2016) structure their work as a dialogue between two characters: a designer and a technician. Conversations between them add dynamics to presenting knowledge and give an insight into challenging moments in the design process.

5. Granular Discoveries

It is a concise textual or visual digest relevant for a given project. It brings a fresh perspective on the investigated topic and sets a direction for the future (Figure 18). Granular discovery results from design research processes, e.g., a synthesis that is abductive sensemaking (Kolko, 2010) or insightful observation.

The goal of granular discoveries is to inspire and inform the design and motivate to action.

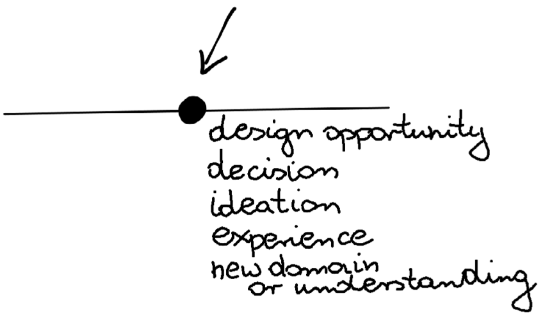


Fig 18. Granular discoveries provide design opportunities, compound presentations of the users' needs or insights into new fields. They usually have a textual form that is supported by direct references from the research, e.g., photos, quotes, videos.

We identified five sub-categories of granular discoveries:

Design opportunity - a precisely defined sentence, theme, or category that results from synthesis and presents opportunities for design (Figure 19).

Tools supporting decision-making - a compressed and structured compilation of various sources of knowledge meant to inform and guide decisions (Figure 20).

Grounded ideation - visual accounts, e.g., photos that document steps of idea generation to bring trust towards novel concepts (Figure 21).

Pallets of experiences - photos that bring the chosen moments of the everyday life of people into the design (Figure 22) or visualizations that provide a fresh perspective on something, e.g., an emotion-centric timeline to show a high-level game progression (Wei & Durango, 2017).

Introduction to a new domain or new understanding - a structured presentation of new chunks of knowledge that introduces emerging methods or fields (Figure 23).

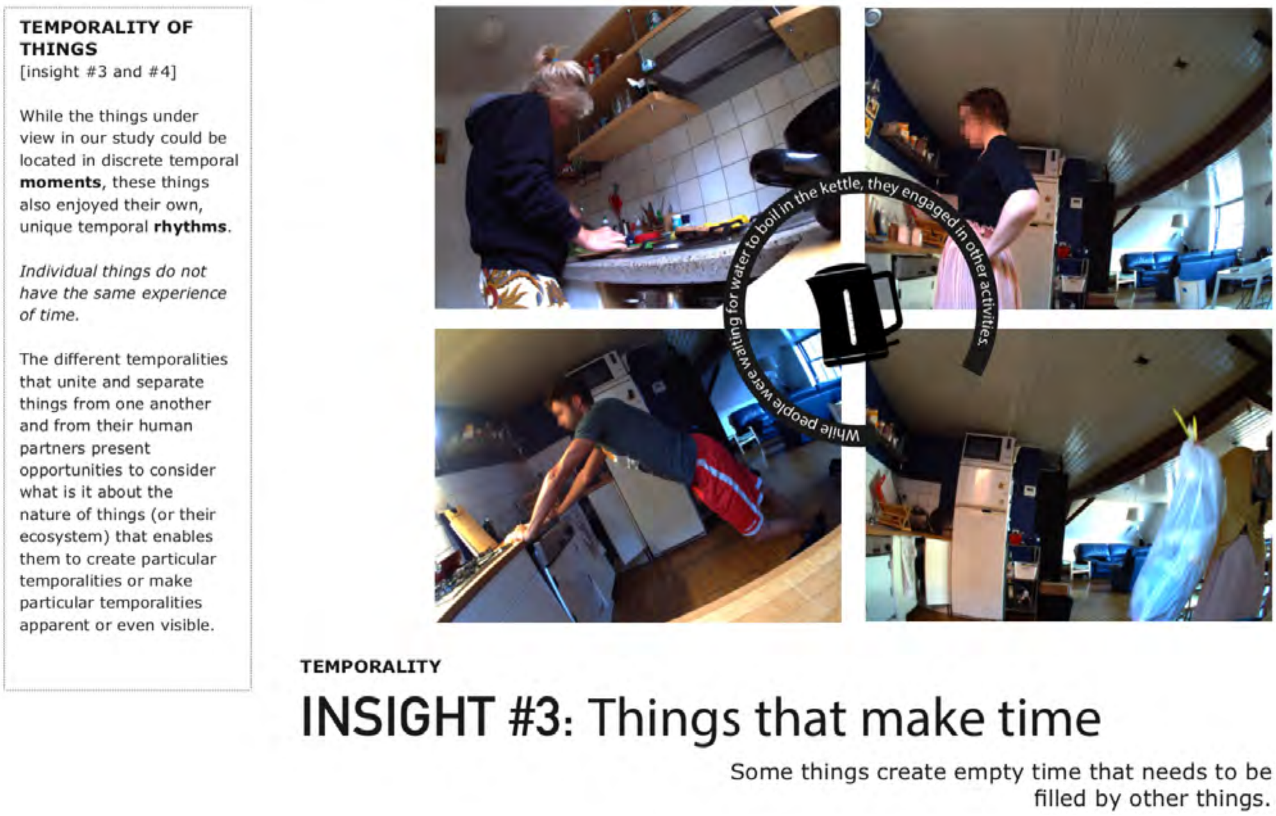


Fig 19. Design opportunity. Giaccardi et al. (2016) use themes called *insights* to structure the presentation of their work. Each of the six insights is a sentence that summarizes clustering and presents new knowledge inspiring design, e.g., *things that make time*.

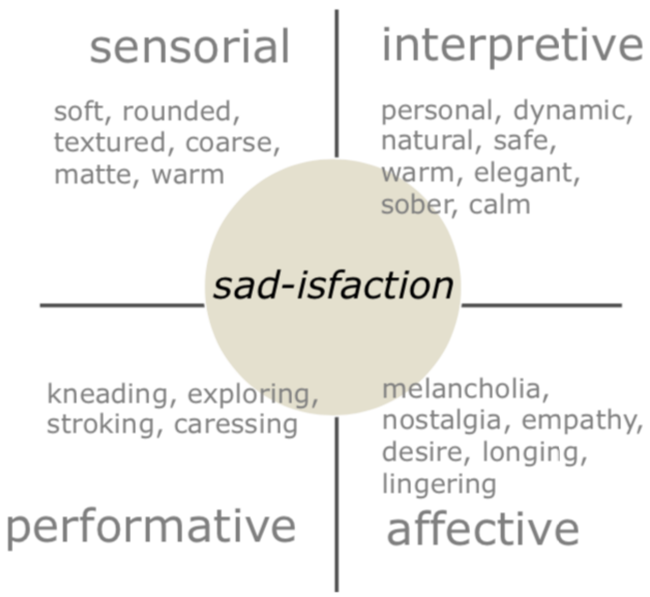


Fig 20. The tool supporting decision-making. Karana et al. (2016) present the ‘Materials Experience Vision.’ It is a grid structure that visually summarizes various findings. The ‘Materials Experience Vision’ acts as a compass and a reference design tool that guides decisions in a design process.

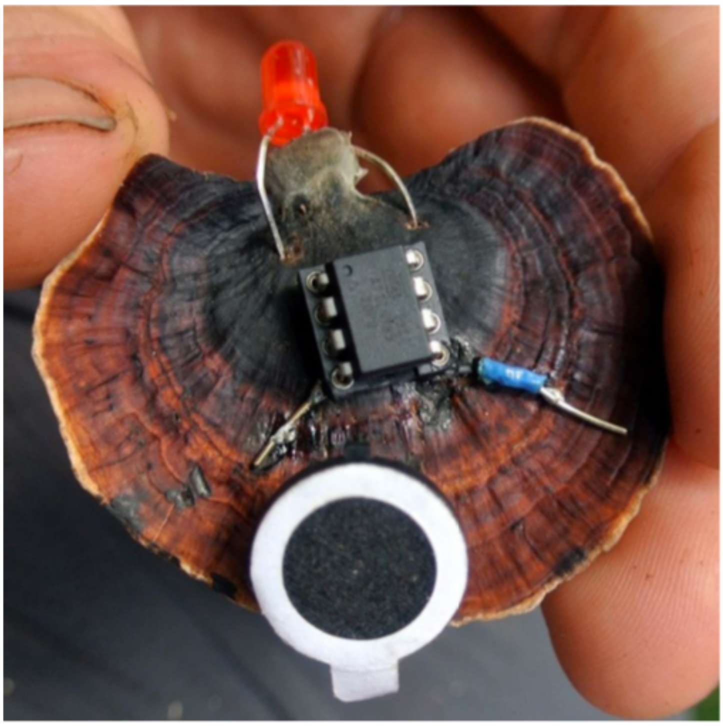


Fig. 21 Grounded ideation. Quitmeyer (2017) shows how the unique context of conducting design workshops (in the woods), introduced interplays between natural and technological materials. He shows a photo of a mushroom that works as a breadboard for prototyping electronic circuits.

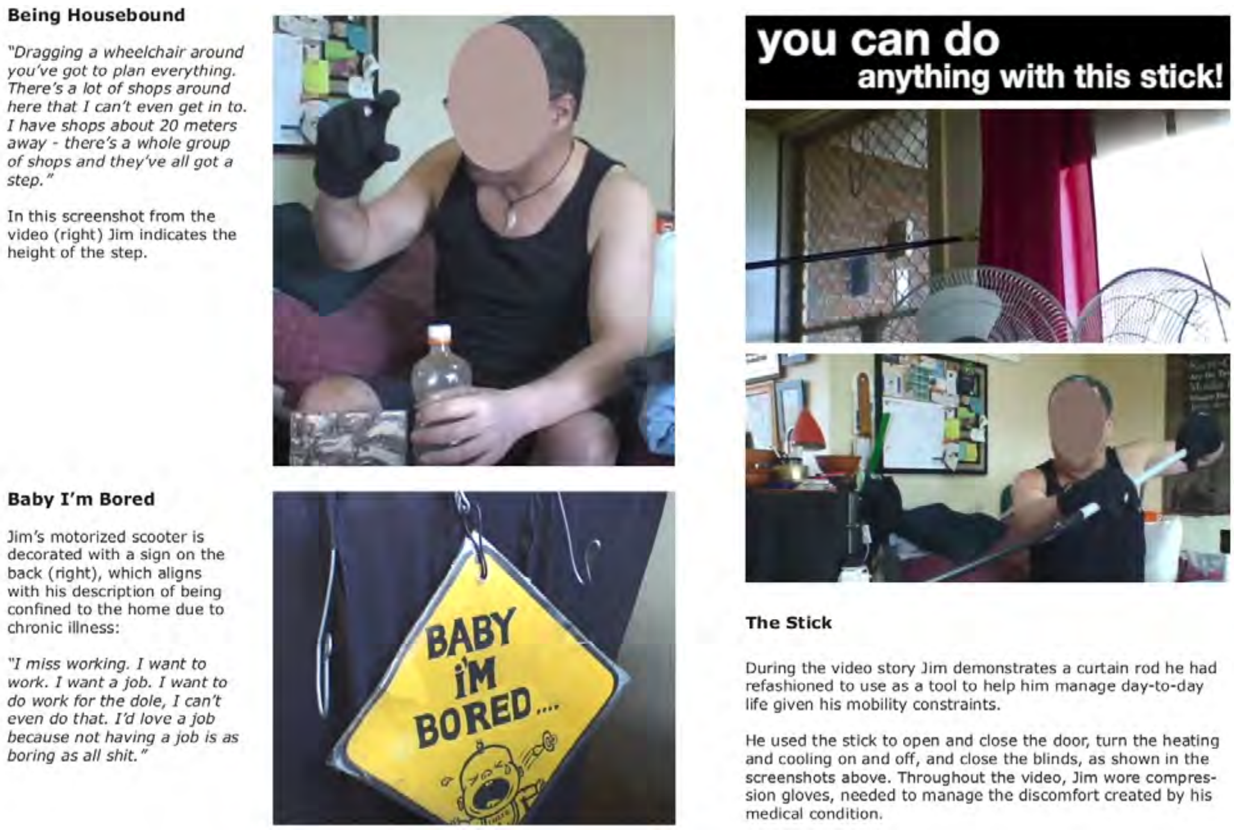


Fig 22. The pallet of experiences. Waycott & Davis (2017) show what does it mean to be housebound. They present two multilayered visual stories of housebound participants of their project. These visual-textual stories are organized around selected quotes that provide crucial snippets of daily routines of housebound people, e.g., *You can do anything with this stick.*

Fig 23. Introduction to a new domain or new understanding. Desjardins et al. (2016) present seven types of observers that can be associated with epistemological commitments in research. Each page of the pictorial presents a single type of observer. It contains a title, photos organized in clusters, research questions, and answers to these questions. Visual organization and identical structure of each page of pictorial enable comprehension and comparison of the presented design knowledge.

6. Juxtapositions

Juxtapositions of various materials, visual and/or textual that create new meanings, spark ideas and encourage reflection (Figure 24).

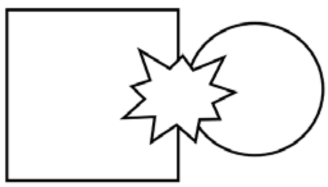


Fig 24. Textual representations of knowledge usually provide explanations, arguments, or solutions. The text brings objectivity, precision, and it is a tool to define the authors' position. Visuals are multilayered. Therefore, they leave space for reflection, interpretation, and discoveries. Juxtapositions bring new understanding and meaning.

We identified three sub-categories of juxtapositions:

Visual juxtapositions – juxtaposed images that interact which each other and create relations. We can juxtapose visuals to increase their similarities or indicate differences, to contradict, and create something new that surprises (Figure 25).

Visual – textual juxtapositions. As text and visuals present different layers of information, their deliberate juxtapositions, e.g., photographs with literature, provide a new dimension of insight into the presented phenomenon (Figure 26).

Meta juxtapositions – a complex visual-textual artifact used as an inspiration, a design research output, a design method or tool, summary, or educational material (Figure 27). Such artifact is multilayered, and it juxtaposes numerous visual and textual elements (e.g., cognitive elements, frames, colors, bold or highlighted text). It has a navigation element to facilitate its use and an interaction with it, e.g., a diagram that presents a sequence of steps.

Fig 25. Visual juxtaposition. Kocaballi and Yorulmaz (2016) use performative photography to create a set of novelty relations of human-technology-world. Then, they use these relations as an inspirational resource for research and design. © Baki Kocaballi.

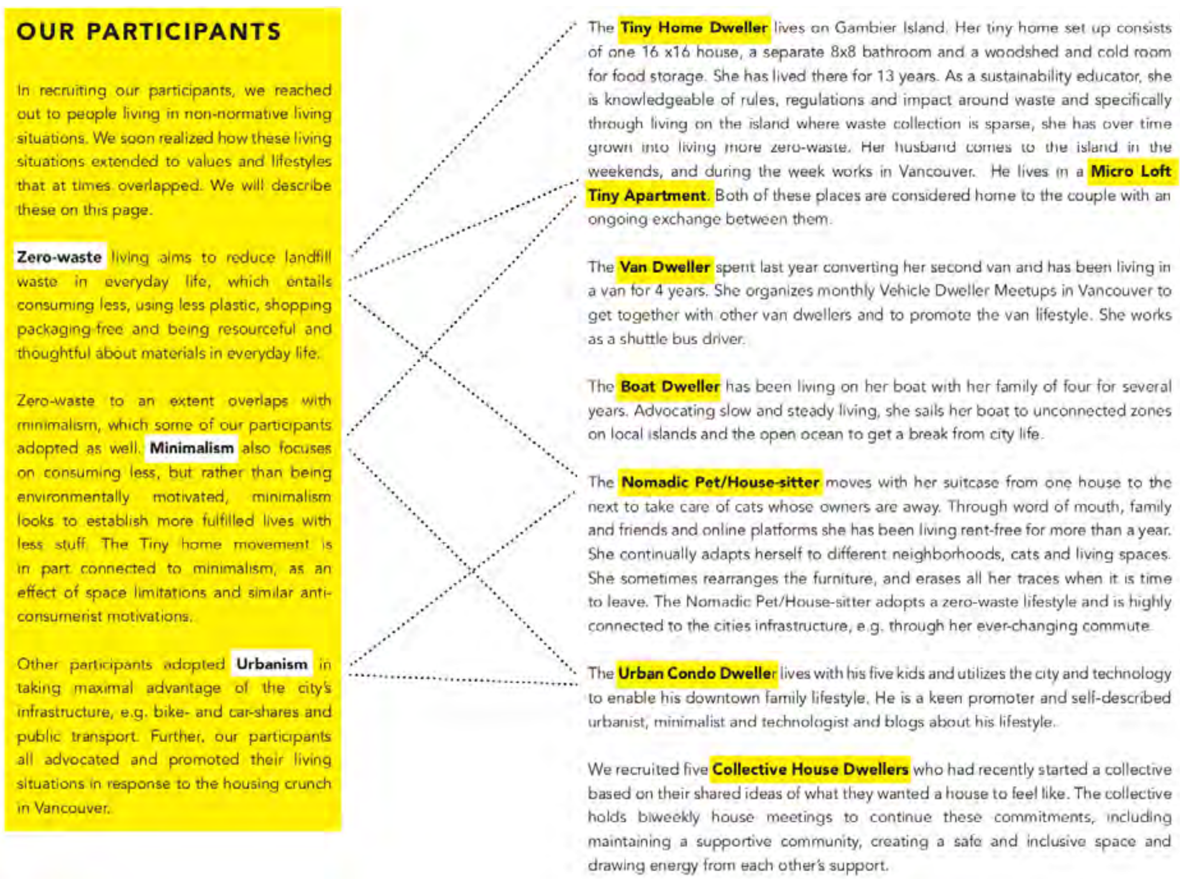


Fig 26. Visual-textual juxtaposition. Oogjes et al. (2018) use juxtapositions to the participants of their study with selected values and lifestyles. They play with color, highlighted text, and lines to show interplays between discussed variables. Such playful representation simplifies the description and invites to come up with various levels of interpretation: to search for new connections, similarities, differences or to add new elements of an interplay. © Everyday Design Studio

Fig 27. Meta juxtaposition. Eclipse: method aimed at eliciting subjective qualities of people's experiences of and relationships with public places (Wakkary et al., 2014).

To sum up, in the table below (Table 2) we present the overview of the six forms of design research outputs indicating their purpose of use, the context of an application and the result of the application. Furthermore, we are suggesting who are the potential target users of the given form.

Form	Purpose of use	Target Users	Context of application	Result of application
Inspiring collection	To provide a rich overview of the work that was already done. To emphasize an investigated phenomenon. To sum something up, catalog, or archive.	Designers, researchers, students, non-design stakeholders, e.g., business decision-makers.	When we want to introduce a new concept, field or industry. During business meetings, when we want to provide an insight into a design process. When we educate or present research results. As research materials – collages.	The inspiring collection is a tangible reference point for conversation. It invites to be developed and updated. Collaboration, new ideas, and reflections.
Referential resources	To add interactivity to textual formats of presentation. To link various materials and present elements that are difficult to verbalize. To simplify a presentation by placing additional materials somewhere else.	The readers of (research) papers, reports, or summaries. Designers, researchers.	When we have limited possibilities of presentation. To share materials, e.g., how-to guides. When we conduct a collective research process and use digital media. When we want to enrich textual formats of presentation.	An action, e.g., somebody downloads the provided material, shares material on Instagram, or is watching a video. Replication of the presented process.
Tacit mediations	To provide an insight into a design process. To present speculations of future possibilities. To inspire. To provide access to tacit knowledge.	Designers, researchers, readers of research papers, reports, summaries. Study participants.	When we want to present something that is difficult to verbalize. When we want to provide access to tacit knowledge.	Experience and reflection on the presented theme, phenomena, or stage of a design process.
Engaging narratives	To engage and invite to the reflection on the presented material. To invite to searching for answers to the posed question.	Readers of the reports, research papers. Participants of the workshops and presentations.	When we want to engage, and invite to reflection, present various roles of people in a project and indicate challenging moments in decision-making processes.	Reflection, discussion dialogue, and idea generation.
Granular experiences	To present the most critical learning (new chunks of knowledge) in the given project and indicate a design opportunity. To inform, inspire, and motivate to action.	Designers, researchers, business stakeholders.	When we need structure to simplify complex materials and synthesize various sources of knowledge. To mediate between research and design.	Ideas, speculations, explorations of indicated research, and design opportunities.
Juxtapositions	To spark ideas and encourage reflection. To create new meanings and surprise.	Designers, researchers, students, participants of design sessions.	When we conduct idea generation or speculate. When we educate, want to sum up our work or offer design tools.	New ideas, reflections.

Table 2. Mapping the characteristics of the six forms of communicating and sharing knowledge.

Discussion

In the previous section, we presented six forms of sharing and communicating design research insights. Such forms support collaboration and communication between designers and non-designers by making intangible aspects of design knowledge shareable and available to others. Here, we add details to the model of the *actionable palette* by discussing the nine qualities of actionability and providing guidelines for actionability.

The Characteristic of Nine Qualities of Actionability

We inspected each of the six forms of design research outputs, e.g., inspiring collection, tacit mediations, to identify which qualities of actionability they meet. By asking questions about each of the nine qualities (Figure 1) e.g., *Is it inspiring? What makes the juxtapositions inspiring?* we obtained answers that informed the definitions of all the nine qualities of actionability. These answers also led us to identify the practical strategies of reaching particular qualities.

Based on the analysis of actionability, we identified that only two forms of sharing and communicating design research outputs fulfill all the nine qualities of actionability. These forms are *granular discoveries* and *juxtapositions*. These are the most complex and synthesized forms of design research outputs. They combine and juxtapose various elements and present information on different levels of sense-making (from key top-level takeaways to visual sources of data). We argue that the more designers contextualize and synthesize design research outputs, the more actionable these forms are.

We also identified the basic qualities of actionability. These are three qualities: *informative*, *inspiring*, and *capable of being acted on*. All six forms met these three qualities. We argue that reaching these qualities does not need *additional bridging work* (Höök et al., 2015) in comparison to reaching the other qualities such as, e.g., *experienceable, memorable*, or *playful.*

The least actionable form of sharing and communicating design research outputs are *referential resources*. They fulfill the three basic qualities (*informative*, *inspiring* and *capable of being acted on*) and are also *experienceable* as through mechanism of references it is possible to interact with various types of materials, e.g., videos and how-to guides.

Below (Figure 28), we present definitions of nine qualities of actionability resulting from the analysis of the six forms of design research insights.

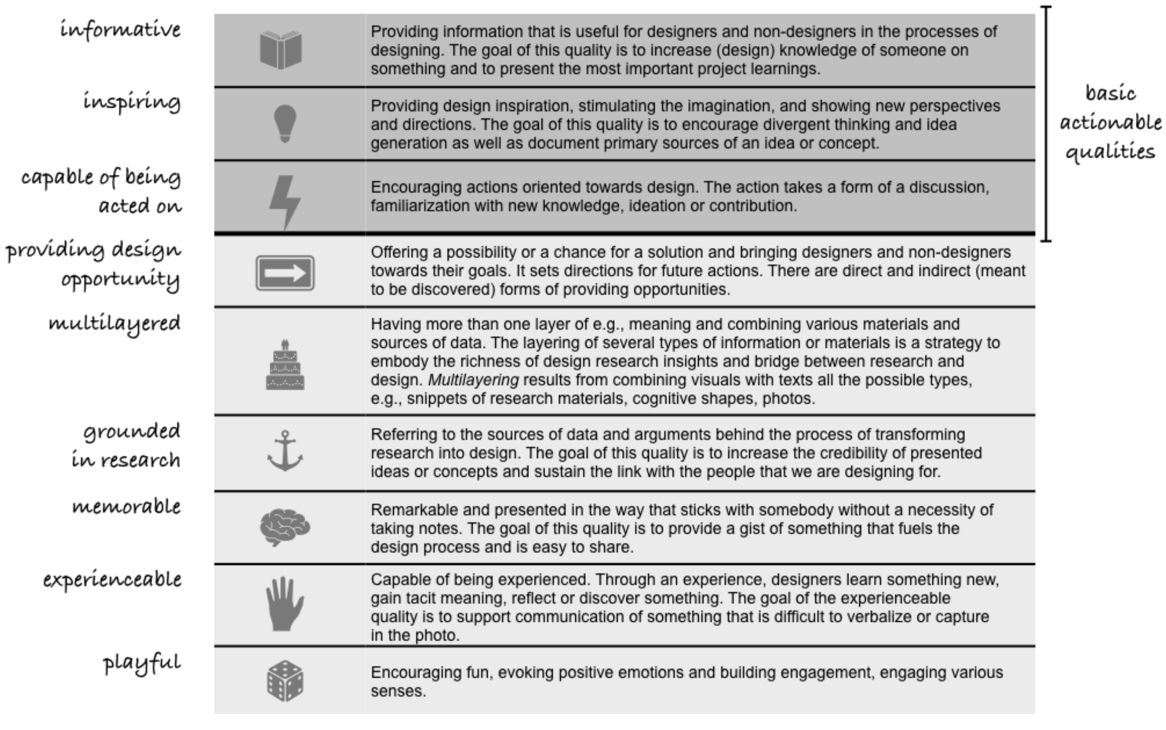


Fig 28. The nine qualities of actionability.

Guidelines for actionability

Inspired by the definitions of the nine qualities of actionability and the six forms of communicating and disseminating design research insights, we developed guidelines for reaching particular actionable qualities (Table 3). These guidelines are directions and inspiration for design practitioners (especially novice ones) for developing design research outputs for collaborative settings. We argue that these guidelines are more useful at the conceptual stages of a design process.

Actionable quality that you want to reach	Guidelines
informative	- provide a rich visual overview of the investigated phenomena, - instruct by sharing templates and how-to guides using e.g., open-source platforms, - set expectation by asking the right questions and ask auxiliary questions, - offer a visual or textual digest, - juxtapose visual and textual materials, - create design tools to use design research insights and ideas in practice, - create booklets to sum up your project, - provide tacit meaning by exploiting a chosen form of knowledge representation.
inspiring	- show a chosen theme from various perspectives, e.g., combine photos with quotes, - show the path of developing an idea and sources of inspiration, - add interactivity to the chosen main form of a design research outcome, - make something to enable to feel something, make intangible tangible, - use metaphors, - ask questions to steer towards new directions, - present portraits of people.
providing design opportunity	- present associations for a chosen theme by using collages or mind-maps and invite to search for new elements of these visualizations, - construct new realities, e.g., by making photographs, - provide concise statements to indicate needs and wants to set directions of future actions, - present key top-level takeaways, - share speculative concepts, - juxtapose various materials to create new meanings.
multilayered	- create associations, e.g., collages, using various materials, - create complementary pairings, e.g., full research paper + pictorial, - combine digital media, e.g., the Instagram hashtag to collect feedback, video to show a context, - create posters and comics, - ask auxiliary questions to provide various perspectives, - exploit the intrinsic qualities of chosen forms of presentation, e.g., photographs, to create layers of information, - juxtapose various elements to tell your story, e.g., cognitive shapes, photos, text, frames; use various colors and techniques, e.g., zoom in, polarize.
grounded in research	- provide an insight into a study using videos, diaries, photographs, etc., - create documentaries – the 'making of' perspective on your project, - show how did you obtain the better question in comparison to the ones you have at the beginning of your project, - offer snippets of research materials, refer to sources of data,
memorable	- sum up your discovery in one sentence that is easy to share and remember, - provide stunning visuals, - pose questions that create a memorable impression, - create surprising juxtapositions, - create puzzles, jigsaws, games that can be remembered because of their experiential form, - prepare a collection in the form of memory cards.

capable of being acted on	- invite to add new elements, e.g., to a collection, - encourage to post a comment or share something on e.g., on Facebook, - enable to download or upload materials, - encourage to use templates, how-to guides, - share speculative concepts, novelty realities and open a discussion about them, - ask questions that drive towards solutions, - add navigation to suggest the particular steps of action, - create frameworks, - create generative tools.
experienceable	- create engaging activities, jigsaws, puzzles, games, - enable to browse something, e.g., a collection, gallery with curated photographs, - think of the possibility of transferring the main interaction of your product to the form of design research output, - think of sequences of actions, e.g., watch the video first, then read a paper, etc., - create a performance, - create design tools and methods.
playful	- create games, puzzles, jigsaws, e.g., connecting the dots, - create comics – give voice to various characters, - create engaging and surprising compilations of various sources of materials, - create design tools enabling to apply the new knowledge in practice, - make intangible tangible, draw the emotions, - surprise by juxtaposing various materials.

Table 3. The guidelines for actionability.

Conclusions and Future Work

In this paper, we presented *the actionable palette* that is a set of nine qualities acting as building blocks of actionable forms of sharing and communicating design research insights. We developed the model of the actionable palette based on the literature review. Then, we provided the model with details by reviewing 51 pictorials published as full conference papers. We end with a set of guidelines for reaching the actionability for design practitioners that work in collaborative settings.

Future studies will focus on the needs of designers and non-designers who capture and share knowledge in the particular processes of designing for various types of challenges, e.g., complex social problems.

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Joanna Rutkowska

Joanna Rutkowska is a Ph.D. candidate in the School of Digital Technologies at Tallinn University in Estonia. Her research interests focus on design methods. In her PhD project, *Actionable design insights*, she investigates the needs of designers and non-designers in terms of capturing and sharing knowledge in the particular processes of designing for various types of challenges, e.g., complex social problems. Her background is in computer science and UXD.

Froukje Sleeswijk Visser

Froukje Sleeswijk Visser (PhD) is assistant professor at Faculty of Industrial Design Engineering at Delft University of Technology (www.studiolab.io.tudelft.nl/sleeswijkvisser) and works as an independent design researcher in design practice (www.contextuqeen.nl). Her research focuses on human centred design, codesign and service design. She is especially interested in developing methodologies that help in creating societal impact through multiple stakeholders collaboration; not only in concept phases but as well as in implementation stages.

David Lamas

David Lamas is a professor of interaction design at Tallinn University's School of Digital Technology. His main research interest is design theory and methodology. He heads the academic area of human-computer interaction, including the master's program in human-computer interaction.

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