DESIGN CULTURE (OF) MAKING
PROCESS MANUFACTURING POST-INDUSTRY
Mario Buono, University of Campania “Luigi Vanvitelli”, Italy
“Design culture and “project making” intercept unexpressed needs satisfiable through flexible and adaptive processes in order to configure and create customizable and evolving artefacts.”

Eujin Pei, Brunel University London, United Kingdom
“This track aims to explore how digital technologies such as Additive Manufacturing (3D Printing) offers designers with benefits, and why we should continue to preserve our understanding of craft making and working with materials.”

Andreas Sicklinger, University of Bologna, Italy
“In the timeless and spaceless digital world of today, making still distinguishes the homo faber: Design is more and more seen as a process rather than as a result, yet the result is the product we use.”

Oscar Tomico, ELISAVA Barcelona School of Design and Engineering, Spain
“Digital production technologies have the potential to transform current socio-technical systems of production towards a more sustainable future.”
A designed generation: Maker's maturity and social responsibility

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Abstract | The following paper is a first step towards a research path that investigates the role of the craftsman and new craftsmanship in the machine society. The research looks at the post-industrial panorama, the actors on stage and the effects that this revolution has brought, is bringing and can bring to the artisan activity. A context with a strong identity and a culture of know-how that has allowed, together with technological progress, the emergence of figures such as the Maker, the digital craftsman. A figure that is only recently beginning to proclaim itself as such, but still floating in a limbo of identity ambiguity. As uncertain instrument of this new 'productive group', also the technological potential risks failing its role. Craftsmanship and post-craftsmanship perhaps have the opportunity to cooperate in order to achieve a result greater than the sum of the parts.

KEYWORDS | IDENTITY, CRAFTMANSHIP, POST-INDUSTRY, AWARENESS, ECONOMY
1. Introduction

“The territorial and production context is defined by the set of skills and experiences settled over time, productive knowledge consolidated at individual, family and group level and, moreover, by the bonds, which are also consolidated between companies and people.” (Tosi, 2010)

Modern production systems find their foundation in the artisan realities and in the culture of know-how typical of a tradition that is slowly disappearing. A production that, in addition to be a pride in the world, is a central sector of an economy that reflects the mechanisms of society (Follesa, 2017). The building blocks of the development process of the global society, the liberalization of markets, have intervened as devastating factors in small-medium enterprises. Today, as reported by the latest ISTAT trade analyzes, in Italy in 2018 there are a total of 1.7 million of craft activities, reporting a decrease of 3% in the last 3 years.

Faced with a crisis in the planet’s resources, the current consumption and production model leads us to redefine and question many practices that have been implemented so far. There are numerous critics and scholars of the current economic system who propose 'lateral' alternatives to development, through the application of concepts such as the necessary degrowth of Serge Latouche (2007) in "La scommessa della decrescita”, or the "Crescita felice" by Francesco Morace (2015). The quantitative approach, according to these studies, must move towards a qualitative approach.

2. Crisis design: facing productivity crisis we produce new production tools

European policies announce for 2020 guidelines based on smart, inclusive, sustainable growth by promoting and developing an economy based on knowledge and innovation, more aware and rigorous in terms of resources. An attitude that at the same time favors both social and territorial cohesion through new indicators of well-being which, according to the "Report by the Commission on the Measurement of Economic Performance and Social Progress" by Joseph Stiglitz (2009), seek to outline aspects beyond of merely economic/monetary values, trying to conceive of well-being as the union and balance of social, environmental and economic capital.

From the material consumption point of view, the European Commission is working to standardize the calculation methods for the main environmental certifications in order to make the consumer more aware and responsible in the purchasing phase. High types of traced and tracer labels attempt to integrate social aspects through recognition of human rights and mapping of the entire production chain, including workers. There are collective scenarios such as those put in place by the Commons Collaborativo (Rifkin, 2014) that are becoming increasingly current and feasible. These aspects, through the concept of interdependence in the network, define new consumption models that go beyond mere possession in favor of exchange and services.
2.1 An unpredictable design: distributed productions generate values that the market cannot control without indulging them

The most recent social and economic transformations have shown, both in the context of global development and in the national economy, a crisis of production balances and questioned the development models that have defined and guided local production in the last forty years, reducing progressively the degree of competitiveness of craft businesses. This loss is exacerbated by the constant contamination of culture carried out by globalization and by the massive industry which tends to amalgamate cultures to expand its catchment area. Lyotard defines the end of the great narratives in "The post-modern condition" (1979) as a loss of identity dictated by a single cultural strand composed of the sharing of certain values. The homologation of these paradigms, which aim at a more economic than ethical model, determines the end of this meta-narration of which the philosopher speaks and marks the departure from traditions and cultural values generating radical movements and works of 'rupture'.

The growing amount of innovation that is emerging thanks to radical and widespread movements such as Open Source, which from the first experiments such as the human genome project (HGP) has evolved to the present day, distinguishing itself as a real means of innovation on a global scale (making the term 'open innovation' coined in just 10 years), favored the advent of new thought tools such as the J.S. Brown's Thinking, a portmanteau of 'thinking' and 'tinkering' (Antonelli, 2011). Regarding this revolution, Andrea Branzi (2017) states that the widespread and distributed nature of modern design (referring to design as much as to architecture) makes it difficult to identify a single will, defining it as a militant and fluid link.

“...just think that during the Salone del Mobile there are more than 400 exhibitions at the same time, all projects not intended for the market, but an expression of an idea of reform of the environment, the city, the habitat, to realize that it is a widespread avant-garde form. Less evident, perhaps, but with an anarchist, reformist base and with a surely greater number of employees than we had.” (Branzi, 2017)

The result is a series of small unpredictable innovations, as Pasquale Gagliardi (2017) defines them, which clashes with a practical market that tends to favor a ‘planned change’. Innovations that fall within a programmed scheme or that are easily recognizable within an economy that, although dynamic, must remain predictable (A scenario extremely dissimilar from that structured by the Schumpeterian theories on which many companies base their business model). The issues related to the relationship with local resources and territorial identity are the basis of projects, studies and actions in different sectors of industrial design and especially in the field of design applied to corporate territorial systems.

In Europe, specific directives on development activities push nations and companies to feed internal production in order to support their own development if they do not want to see their production system reduced to what Bauman calls an economy of only transit and exchange of goods and people.
2.2 A design of necessity: digital manufacturing as creative process design tool

In response to these needs there is a fervent return to the local, a new economy from below, sustainable and respectful of the diversity of the territories that could truly outline a strategic vision of the productive future. Just think of the role of the makers and the rapid social responsiveness of rapid manufacturing which has led to the proliferation of communities and places such as Fablab and Co-hub, where the interdisciplinary exchange of skills is in favor of the development of innovative start-ups and cultural growth of the cities in which they operate. The technological update of Industry 4.0 and the adoption of certain production technologies (such as FDM or SLA / DLP) run in aid of an increasingly demanding market attentive to the central role of the final consumer. This rapid expansion has moved the planned obsolescence market above all, which has obviously felt called into question in the face of an instrument that can reset its competitiveness. An interesting program launched by Groupe SEB (which includes industry giants such as Moulinex, Tefal, Rowenta), is the "10-year reparability commitment", a mapping of ‘repairers’ that offers the possibility of finding 3D printed parts to replace of the components that can break over time in the products. Jan Middendorp of LettError describes the importance of tools for a designer, referring however to artisans as their ancestors. The latter, according to Middendorp, were like disgruntled customers in the ‘tools’ market and for this reason they have always tried to make their own, to personalize their work environment.

“They always had the tendency to personalize their tools, to appropriate them by honing them, converting them or expanding them. The more specialized the work, the greater the demand for customized or individually made instruments.” (Middendorp, 2000)

The opportunity offered by some experimental and consolidated technologies, gained thanks also to the Open Source communities and the digital manufacturing machinery industry, to be able to apply these tools and innovations to any production sector and, as well as design has become more evident participated and a fundamental part of the most disparate disciplines, so the role of the designer is redefined under an ethical key for which the design process itself is the fulcrum of the activity and acts as a coordinating element capable of managing the various skills at stake and work and production flows.

“It is not just about 3D printing technology adoption. Inserting a 3D printing sub-process into traditional stamping will likely require process redesign” (Brody, EY 2016)

Danish designer Olivier van Herpt launched in 2014 Adaptive Manufacturing, a collaborative project with the help of Sander Wassink. The project starts from the assumption that technological production has replaced the craftsman and therefore removed all traces of human and local influence and how this ‘ambiguous’ digital manufacturing process can mediate the language between the two realities.

“At the foundation of every product there is the production process. When we replaced the craftsmen by machines, we lost the translation of local influences into our products. What if
our machines could become more sensory? What if the machine could sense the local environment and incorporate it into the production process?” (Van Herpt, 2014)

The research of the two designers examines the ways in which it becomes possible to regain that lost connection between the production of objects and the objects themselves. To do this, they decided to design scripts that distil shapes and textures from external phenomena. External information, measured by sensors, is then translated into specific printer behaviors via software. A sensory and sensitive machine that perceives the environment and therefore binds to a specific territorial context, translating the input into a specific movement, position or raw material. Here the designer still plays a fundamental role by defining the degree of sensitivity of the machine and the elements to be considered. These approaches and experiments let think about the role of the digital manufacturer. In addition to demonstrating a willingness to declare themselves through their products, making them unequivocally attributable to their work, they show an exquisitely melancholy taste in their past, artisanal, traditional and local realities. Through the readjustment of past products or the use of traditional materials, the need to combine digital manufacturing with a world in decline seems to emerge until questioning if it is out of a real nostalgia or a secret will to confront the massive industry.

3. The responsibility of design: the centrality of design process given by its complexity

Regarding this, Enzo Mari (2006) speaks of an almost criminal role of design in its being an instrument of proliferation of new goods in a world already submerged by them. In fact, Mari condemns the creative process and the search for innovation by attaching an almost criminal role to the current landscape which is dominated by unnecessary overproduction and a senseless frenzy. These words recognize the traits described by Gagliardi of a revolution that is not guided by a thought or a will capable of evaluating the social impacts that such innovations can have. We live in a period full of 'tools', but with ambiguous ends. According to Mari, the designer must look at human needs outside the market conditions when developing a project. With a severe denunciation of the progressive deterioration of today's design work, the main culprit for this situation is the global market that requires an object to be producible and salable in every part of the world. The role of the designer is thus diminished to a simple 'signature' to be affixed to series of objects in which any construction philosophy is lacking.

The designer should be in a position to respond to this 'ambiguity' by providing a complete and reproducible analysis tool that is able to put a more willing and interested market at the service of technological innovation, aware of its development and potential. A working method that would be able to create products from a synergistic process between technological research and the morphological and social spheres. Enzo Frateelli (1969) defines design as the result of the combination of three factors: language, function and meaning as indeed they refer to three specific study areas, morphological, technological and social respectively.

In this sense, the role of the designer acts as director of these categories to favor their synergistic development and offer a result greater than the sum of the parts. However, the
designer is not at the center of the action, but he becomes a multifaceted and dynamic figure that insinuates himself into the individual disciplines and regulates their input and output.

3.1 A complex design: technological development confronts industry with radical changes in production dogmas

A system like that one just introduced perfectly coincides with the description provided by Alberto Gandolfi (1999) of a complex system, which combines the advent of digital, electronic computing, at the moment of true understanding of what really is a complex system and the realization of how this complexity is inherent in everything that surrounds us, from the physical and biological nature of things to the texture of the social fabric, from production systems to political systems. These systems are in fact represented as hierarchical constructs where each level of this scale is regulated by a network of interdependence and continuous circulation of data (input and output) which, thanks to the complexity of the system and of the individual parts that compose it, in order to generate outputs of greater importance than the sum of the inputs.

If, by its definition, design is a process, as such it does not have a single interpretation and result but is a useful tool for understanding a whole series of social, productive and fruitful processes. An interdisciplinary discipline that has now imposed itself in almost all sectors of research and development, as well as production.

"We are not experts in a specific subject ... we are experts in the process that leads a specific subject in bringing innovation" (Kelly, 1999)

Design as discipline has evolved in step with the technologies that have allowed this material to express itself in new forms and, precisely because it is driven by this impetuosity, it has evolved and complex over time to take on so many facets to become an extremely difficult subject to understand. Taking up the words of Bruce M. Tharp, and the study that led him to define the 4 major themes of contemporary design scenario: "Design is pretty much a mess" (Tharp, 2009).

Without a convincing, truly taxonomic way of organizing the design activity, the latter risks leading to misunderstood results; the risk, for the designer, becomes that of being scattered and vague.

3.2 Designing awareness and behavior in front of the innovations

It becomes imperative to endorse critical thinking towards a system that develops responsible and empowering policies. In this way of thinking we look at the Responsible Design, which has a relationship with the market, defining itself ‘commercially available’ and whose primary intent is not a profit maximization but rather to serve the less wealthy (E.g., a public tap that closes itself after a certain period of time). On the other it is possible to talk about an Empowering Design, which has little to do with the market but is closer to a critical intervention towards an attitude to be rectified (E.g., a tap that shows you how much water you are using and gives the user the environmental impact awareness).

In the world of 3D printing, it is not difficult to associate the role of plastics, and it has been,
A designed generation: Maker’s maturity and social responsibility

fortunately, equally easy to find alternative and ecological solutions to the question. Today, various materials are developed directly deriving from industrial plastics that would otherwise risk ending up at the expense of governments or the environment itself. Instead, what is most difficult to see is what has been carried out in productive consumption and waste management. For instance, the waste generated around the food sector and how digital manufacturing has offered an answer. We could be able to produce pseudo meats and edible compounds from food waste, and there is nothing that excludes that one day it will reach our meal consumption. Nonetheless, as per Scionti experiment in 2018, a 3D printed steak, will have to look as a regular steak in order to be recognized as it is. Robert Artigiani (1987) stated that even in front of radical changes, characteristic elements of the previous system must be maintained, in order to achieve a minimum perceptual and existential stability. Just as in 3D printing filament production, we have increasingly sustainable materials (in economic and ecological terms), derived from the recycling of the same bio-plastics, technologically performing and aesthetically appealing but which are produced in a less ecological way (given the limited accessibility of industrial complexes to renewable energies), in an increasingly aggressive and competitive market context and distributed in ABS containers and spools and sealed in common plastics.

4. Towards new products conception

The economic and social crisis, mentioned above, focuses on the need to identify new development models that take into account the deep interdependence now active between the different economies and the potential expressed by the development of communication and data exchange systems. According to the study by Warnier (2014) the development of new small-scale production techniques will allow the transfer of power from the hands of industries and those who regulate the infrastructure to those of the designer and consumer, who today more than ever is identifying himself as the only figure. In fact, Morace redefines the role of the consumer, referring mainly to the Italian context, which is becoming more aware of the production and creative processes and increasingly interested to them so much that he wants to be an integral part of them. From prosumer to ConsumAuthor, a hybrid figure who directly participates in defining and selecting the prototyping lines of products and services, assuming their identity and involvement (2016).

A concept that is closer to the world of luxury and an almost elitist market, but which in an increasingly social and open context is actually spreading like wildfire on almost all market levels. Since the days of Apple, the concept of branding had been introduced, or no more than just brands. A fluid, inclusive system, in constant transformation and improvement where the consumer, the community, feedback play a fundamental role in the development of the activities themselves.

4.1 A physical design: product circulates on digital platforms, but acquires its value when we can touch it

Therefore, the Research investigates the responsibilities that design has developed with regard to everyday products and in particular with the products to which the new generations especially refer, to which the cultural and social values of the context of belonging should be handed down, who today more than ever are able to define, recreate, hack, reprogram this
context. A first question that arises is how is evolving the concept of product by including those that are being created nowadays. To answer this question, perhaps the question can be circumvented not by looking at the present ConsumAuthor, but at those who will come. The well-known digital divide created with the new generations has become consolidated and we increasingly have free access and understanding of digital systems. Nonetheless, the physical interaction and therefore the contact with matter remains, such as the need for the mind to establish a relationship, an experience that is not only visual or auditory, but above all tactile. Mulgan (2017) clarifies how the artifact, the physical object, in each of its declinations, facilitates large-scale coordination (referring to the interaction created in large connective intelligence systems and collaborative societies). We are used to thinking with things and we struggle to do it in their absence. Large-scale cooperation and coordination generate a schematization and vice versa.

4.2 Digital manufacturers identity: the result of a new product and production conception

At the basis of the reflections set out so far, the research deals with the relationship between design and production and the different ways in which the design discipline must be placed towards a post-industrial production, paying particular attention to the identity, defined by the tools themselves, rather than by geopolitical or cultural characters. It must investigate the identity of objects and the different ways in which this is built in relation with the social context and from there with both material and immaterial resources. At the basis of this reasoning there is the assumption that there has always been a correspondence between objects and places and that such correspondence has been interrupted (or at least weakened) with the advent of the machine society, the expansion of an economic system always more open and inclusive, and with the substitution of codified knowledge for practical knowledge.

5. Discussion: what future of Maker holds?

In this socio-economic evolution, design plays a primary role. On one hand because of its being an important discipline in the development of production systems, and therefore central in defining new possible alternative economic scenarios, and its ability over time to have become so multifaceted and interdisciplinary as to play a role in every production system. On the other hand, for the responsibility that is unanimously attributed to it in the development of those consumer dynamics that have accompanied the progress of globalization. Having outlined the panorama, the context, and the direction that the research wants to take, it becomes necessary to filter from the pool of potential results and sectors to which this research can be applied. We are most likely in the middle of what Gandolfi (1999) calls a ‘catastrophic bifurcation’. Micro-oscillations of confusing revolutions (entropy) are about to transport us into a future in which each individual will have full responsibility (enthalpy) for its own work and creation. It can no longer be said that we are at the gates of a revolution and the risk becomes that of letting it get out of hand or worse of using these tools unconsciously. The question emerged at this point becomes: does the designer who 3D...
prints, really develop his design by virtue of 3D printing or exploit manufacturing as a tool for creating a design? We usually think of production systems with two distinct figures: designer and developer, architect and worker, mind and arm. This gap is about to disappear. If we have now witnessed a series of movements that have generated individual verticalized figures on single themes (art, engineering, craftsmanship, gadgets, small and medium productions and so on) now we see hybrid figures capable of operating (not just knowing how to operate) in a more active way on the production scene. Such a change is not only the result of technique or sensitivity, but a way of acting that has been able to generate a result greater than the sum of its parts. Awareness of the tools and design by virtue of these.

6. Conclusion

The intertwining of specific artisan knowledge and the technological updating offered by digital manufacturing systems opens up to growth common, allowing the craftsman to take advantage of an amplified production system, and the activities to demonstrate an increasingly punctual public service. By offering a critical eye to the good practices of knowing how to do in relation to the important social aspects and the union between those consolidated artisan qualities with the enabling technologies of Industry 4.0, the way will open for the definition of a new product social innovation, modeled on the needs of the citizen, guaranteeing the flexibility of digital manufacturing processes. The skills developed and systematized in this way will be able to generate improvements and implications also within the scientific community which will therefore be aware of the potential inherent in the urban and social fabric. The activities as they have been distributed and described, contribute to the implementation of the specific objectives and the achievement of the expected results described with the aim of directing the results of the Research in favor of those realities, whether they are artisanal SMEs or less mature, who can thus be able to experiment with tools, models and products that are both sustainable and compatible with the levels of complexity, flexibility and efficiency that increasingly characterize the contemporary landscape and that are gradually invalidating the traditional ones. With particular attention to the relationship established between the digital craftsman and his role as producer, the figure of the 'Maker' is placed in a context that no longer sees him as just a customer of an instrument market, but an active part of a production sector which has spread its production potential to everyone. An open, distributed and (still) free scenario, which nevertheless carries with it the weight of the moral, ecological and civil responsibility of a power that has long declared its potential.

References


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Accumulation of empirical investigation into joint structures in wooden furniture design

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Abstract | The aim of this study was to explore the joint structures used in traditional furniture to develop innovative designs and crafts that involve alternative materials or different processing methods while preserving the nail-free, mortise and tenon methods of traditional furniture. A total of 12 craftsmen were recruited using a participatory design approach and were invited to attend a three-month design workshop. Progressive guidance was given in three stages. First, several practical activities were arranged for participants to practice fabricating conventional mortise and tenon joints and to exercise their design awareness. Next, participants were asked to experiment with various wooden components to construct joints using available materials and material processing tools. Finally, participants proposed and implemented their designs based on their practice and exploration in the first two stages. To illustrate the reinterpretation of traditional crafts, three of these products were presented and described that best satisfied the study objectives.

KEYWORDS | JOINERY, CRAFT, FURNITURE DESIGN, TRADITIONAL KNOWLEDGE
1. Introduction

1.1 Craft in modern design

In the era of technology, with the influences of contemporary values, machine-made products, and quality expectation, craftsmanship has become a medium for designers to communicate their ideas (Kermik, 2012). Marcel Wanders, Jurgen Bey, and Jaime Hayon are designers that have aimed to make craft design more accessible. Contemporary art critic Risatti (2007) noted that ‘if craft is to survive in the twenty-first century, it must take itself understood as a way of bringing objects into the world that is meaningful in and of itself. The value of the craft is within the capacity of the artisan to manage every step of the process (Sennett, 2008). Moreover, traditional craft is more than a source of inspiration; it enables craftsmen to realize their design potential.

1.2 Joinery: material and making

Joinery originated in ancient Egypt and the Hemudu area, and joinery systems developed separately in the West and East (Wang, 2013; Korn, 2003). Among the various types of joining methods, mortise and tenon joints are often deemed essential in furniture making (Wang, 2013).

The function of joints in wooden furniture has evolved from structural to decorative. For example, furniture makers must consider wood grain or colour matching (Seike, 1977; Chen, 1997; Booth & Plunkett, 2014). Studies on structural strength have revealed that the joints of wooden components are the most vulnerable part of a piece of furniture, and thus determine its loading capacity (Nandanwar, Naidu, & Pandey, 2013; Tankut & Tankut, 2011). Numerous factors affect the loading capacity of the structure. For woodworking joinery, the type of wood and type of mortise and tenon joint must be considered.

1.3 Material selection and inspiration

Structural joints are crucial for determining the loading capacity of furniture (Nandanwar, et al. 2013; Tankut & Tankut 2011). Thus, when innovating in joinery woodwork, craftsmen and designers must apply knowledge of traditional joinery and innovate on the basis of these traditions, which involve a philosophy of crafting. Crafting can be viewed as a manifestation of culture; in addition to altering the substance, crafting adds meaning to the product (Tin, 2007). Materials are a crucial part of crafting. The primary materials and their composition and assembly comprise material manipulation (which is also known as crafting). The properties of materials must be considered during the crafting process (Ingold, 2013).

Through interdisciplinary collaboration, and technology and science of other domains, Contemporary craftsman Trish Belford used interdisciplinary collaboration, material integration and contrast, and other technologies to demonstrate the role of craft in the development of new technologies and the reform of aesthetics (Ravetz, Kettle, & Felcey,
Sörensen (2016) reviewed studies on design and materials and listed four complementary material selection methods: deductive reasoning (selecting materials using a material properties database), inductive reasoning (reviewing existing products that can provide new solutions), similarity (searching for alternatives in property configuration documents), and inspiration (randomly reviewing a series of materials or products) (Ashby & Johnson, 2013). Sörensen (2016) also proposed displaying materials in example products to encourage designers to consider the characteristic and meaning of materials when selecting them in the creation process (Karana, Hekkert & Kandachar, 2010). These studies have highlighted a close relationship between material properties and the crafting process as well as a relationship between materials and the function and performance of the product (Lenau, 2002; Karana, Pedgley, & Rognoli, 2013).

Considering the importance of furniture structure and our attempt to bring innovation to traditional crafts and make breakthroughs, this study, which is the beginning of a series of studies into creativity, followed the following principles: 1) the value of design is derived from a craftsmen’s exploration of materials and 2) inspiration can be obtained from traditional craftsmanship. The aim of the study was to find feasible alternative structures and forms on the basis of craftsmanship, materials, and structure. This study explored the use of wood materials for furniture innovation by testing creative structural joints of woodworking joinery both theoretically and practically. Wood is chosen to be the material here because it is an organic material that the grain reflects meteorological changes in air, humidity, and sunlight.

2. Method

This study adopted a participatory design approach, and a design workshop was held for drawing, conversations, contemplation, planning and design, project development, and prototype construction (Martin & Hanington, 2012). The four complementary material selection methods proposed by Ashby and Johnson (2013) and the materials selection advice provided by Karana, et al. (2010) were referenced for observing and recording participants’ design behaviour and outputs.

The workshop was held during the summer of 2017 in Taiwan through the National Taiwan Craft Research and Development Institute (NTCRI), a government agency in Taiwan that promotes tradition crafting technologies in contemporary design. Two workshop meetings were organised each week for 3 months (16 hours in total). The 12 participants (six novices and six experts) were all Taiwanese and were aged 24 to 53 years; five participants were female and seven were male. Four professional instructors (one experienced designer and three craft technology instructors) assisted the participants in the workshops.

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2.1 Practical Procedure

The workshop comprised three stages. The first stage comprised preparatory practice and concept introduction. During the second stage, material combinations were tested and selected. The final stage was for idea implementation and prototyping. The research framework and flow are illustrated in Figure 1. Details of the process are described in the following sections.
2.2 Stage 1: Preparatory Practice and Concept Introduction

During the first stage, the participants were coached by three craft technology instructors to practice fabricating the cogged scarf joint which was redesignated by the technology instructors to separate the common dovetail tenon in furniture structure. The cogged scarf joint enables simple furniture disassembly and were frequently used in the curved rails of round-back chairs produced during the Ming Dynasty. The introduction of this concept and the hands-on practice prepared the participants for the material selection and design development in the second stage. The design instructors asked the participants to complete a text-and-picture-based perception exercise over a 4-week period. To perform this exercise, the participants first chose a theme (e.g., plants, insects, and pastries) and then completed a sketch and a description of at least five objects each week (Figure 2). The objective of this exercise was to encourage the participants to observe the compositions of objects. Moreover, drawing these objects enhanced participants’ observational memory and perception, thereby preparing them for the material selection during the second stage.
2.3 Stage 2: Sampling and Selecting Materials for Joints

The objective of the second stage was to guide participants to consider the properties and limitations of wood as a material and enable them to experiment with different material combinations and wood processing tools to develop structural joints that preserve the essence of joinery and yield a strong structure. The key components of this stage were material selection based on design and crafting knowledge, structure assembly, and crafting process arrangement. Five professional instructors (three technology instructors, one design instructor, and one researcher) provided consultation to participants on material selection, structure assembly testing, and crafting during the 8-week period of Stage 2. Then, the researcher and the design instructor assisted the participants to develop their design concept from the various combinations tested.

First, the researcher and the design instructor explained the concepts of material joints and testing to the participants. Next, the participants were divided into two equally sized groups in accordance with the additional nonwood materials, brought by the participants, and various material processing tools. The researcher also asked the participants to record their material selection and assembly processes in words or in drawings similarly to the perception exercise completed in Stage 1.

The researcher and the design instructor subsequently guided the participants to consider not only the component crafting process for the wood tenon and mortise structure practiced in Stage 1 but also those of other joint structures commonly used in wood furniture. Participants in the first group used materials such as cotton threads, leather strips, and plastic strapping to join wood or combine other materials with wooden components. Participants in the second group used material processing tools to investigate alternative methods for fabricating wooden joints. For example, an ax can be used to split wood at different angles, and a laser cutter (provided by NTCRI) can be used to cut wood and perform a series of wood bending tests.

Figure 2. Record of the 4-week design perception exercise of Participant B.
Finally, the participants chose five joining methods for their design and development based on the material selection and assembly samples. The orange and red dotted lines in Figure 3 indicate the designs that a material assembly sample can be developed into. The orange dotted line denotes the use of thread for tying the materials in designs A to F in assembly sample 1. The red dotted line denotes hole drilling or colouring in designs C to F as in assembly sample 5. In addition to receiving advice from the researcher and design instructor regarding the development of the material assembly samples, participants were assisted by the technology instructors, who predicted the structural strength of the designs based on their experience and offered suggestions on material processing. Group discussions were organised several times to help participants to determine the most feasible structure based on the structural test results of their chosen materials.

![Designs using of the five material combination samples developed by participant B.](image)

**Figure 3.** Designs using of the five material combination samples developed by participant B.

### 2.4 Stage 3: Idea Implementation and Final Prototypes

Participants individually developed a series of assemblies comprising wood and other materials. For example, some participants used various types of thread and weaving and knitting techniques to create a wooden assembly in which structural joints were formed through friction between the materials. One participant used shrink materials to assemble the structure. In total, 12 products were fabricated in the workshop, and the prototypes and primary material assembly approaches are described for each group in Table 2.
Table 2. Prototypes and primary material assembly approaches (participants were coded alphabetically)

<table>
<thead>
<tr>
<th>Group 1: Existing material assembly testing</th>
<th>Code</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<tr>
<td>Approach</td>
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<tr>
<td>Hole drilling and knitting</td>
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<td>Tying with thread and hole drilling</td>
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<tr>
<td>Tying for fixing</td>
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<td>Code</td>
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<td>Thermoplastic films</td>
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<td>Wax sealing</td>
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<td>Fixing by using a corrugated cardboard structure</td>
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<th>Group 2: Joint structure tested after using material processing tools</th>
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<td>Approach</td>
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<tr>
<td>Surface baking treatment</td>
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<td>K</td>
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<tr>
<td>Wood splitting using an ax</td>
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<tr>
<td>Surface baking treatment</td>
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<td>Code</td>
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<td>Approach</td>
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<tr>
<td>Surface spraying</td>
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<td>Surface processing by using Eastern gouache</td>
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The results indicated that participants in Group 1, who used available materials for testing wood joints, were more successful than their counterparts in Group 2 in generating prototypes that met the objective of the experiment. The participants in Group 2, who tested assemblies after using material processing tools, had insufficient time for the convergence of their designs because the materials for assembly testing must first be
Accumulation of empirical investigation into joint structures in wooden furniture design

processed using tools. Consequently, only Participant L managed to produce a prototype in the time provided. Regarding the prototypes created by Participants G to K, the material processing was applied either partially or fully to the prototype surfaces and the structures of their finished products used the traditional mortise and tenon joints.

3. Illustrations

Prototypes that best satisfied the requirements of this study are illustrated herein. These three cases are from Group 1, and they used binding, knitting, and tying for materials assembly. Records of these prototypes are presented as follows:

3.1 Case 1: Bind

The participant used tying by thread and hole drilling to replace the traditional joint structure. After several discussions with the researcher and the four experts, the participant applied the method to a traditional Taiwanese wooden stool (Figure 4); holes were drilled on the surface of the seat for the legs, which could be easily assembled or disassembled through binding.

Figure 4. Traditional Taiwanese wooden stool (Photo: Author)

This participant applied the binding method to the stool, which reduced the labyrinth of crafting joints with multiple angles (i.e. A, B, and C; Figure 4). To stabilise the structure, the participant retained the traditional cross lap joint structure (D) and the leg joint (B). In addition, the participant used binding to secure the seat and the legs, thus improving the sustainability of the wooden stool by enabling the user to replace worn threads (Figure 5).
3.2 Case 2: Knitting

This participant applied knitting expertise to material assembly samples and tested various threads (e.g., cotton thread, aluminium wire, and wool yarn) and knitting styles to identify the approach that best stabilised the wood joints. Several trials revealed that joints created using knitting with wool yarn or cotton thread yielded the optimal joint stability. This joint comprised continuous intermeshing loops, and wool yarn and cotton thread yielded greater friction than aluminium wire, thus improving the stability of the joint.

Figure 5. Series of experiments for material selection and combined with ramie and cotton thread and final prototype. Photo: Participant No. B /NTCRI.
After discussions with the researcher and the four experts, the participant decided to implement this approach in wooden panels joined using a dovetail joint (Figure 6). The participant tested the feasibility of the structure using material combination samples 2 and 3 (Figure 6) and proposed a desk design (Figure 7) as the prototype.

Figure 6. The dovetail joint structure (left) generally applied in making cabinets and tables. Photo: Author.

Figure 7. Series of experiments for material selection and knitting connection and final prototype. Photo: Participant No. A / NTCRI.
Case 3: Tying

This participant’s material combination sample contained long strips of materials (e.g., wide paper strips, plastic strapping, and bamboo strips). The participant first drilled holes in the wooden materials and then tied the materials together for testing. After discussions with the researcher and the design instructor, the participant implemented the design in a Taiwanese farmhouse-style bench. Similarly to Case 1, crafting the joints of the bench legs is relatively challenging. Because this participant was an experienced carpenter, the design instructor encouraged the participant use materials other than threads to secure the joints. Following this suggestion, the participant developed a tying method that creates friction between long leather strips and wood. This tying method enables the user to fully disassemble the bench (Figures 8 and 9).

Figure 8. Series of experiments for material selection and wearing ways and final prototype. Photo: Participant No. C / NTCRI.
4. Findings from Implications of design

This was a pilot study exploring alternative materials combinations for traditional furniture joinery. When developing their designs based on trials of material assembly or material processing tools after discussions with the researcher and experts, most of the participants proposed designs associated with traditional furniture structures or designs that incorporated concepts of traditional furniture structure. The three cases presented in this paper were all inspired by the structure and form of a traditional mortise and tenon joint. The use of leather strips and cotton threads to replace the mortise function is one unexpected example.

For participants who were experienced carpenters, processing wood was not a difficult task. By contrast, their challenge was to supersede their existing thinking and training as craftsmen. Participants required knowledge and experience to identify appropriate materials. For example, in Case 1, although the overall assembly should have been secured by thread according to the study requirements, the traditional cross lap joint was retained as the primary supporting structure of the prototype to meet the load-carrying capacity of the wood stool.

Among the participants in the second group, who performed trials of material processing tools, only one (Participant L) successfully completed the task. This participant performed trials using a laser cutter to cut the surface of wood. They then used bendable wood pieces—cut using the laser cutter—to replace the hinge structure of a cabinet cover panel. This idea was inspired by design plans obtained from Pinterest (www.pinterest.com), and the technology instructor approved its feasibility. Although this approach was not novel, it used modern tools and approaches to replace the conventional method, thus providing a new direction for this study. The other participants applied splitting, baking, and Eastern gouache to the surface of wood; because they spent most of their time on material processing, they failed to develop a concept that related to joint structure. These participants completed only one product using their material processing method. Therefore,
the researcher should have clearly instructed the participants on applying the processing tools during the implementation stage.

5. Reflections and future work

The selection of a material combination requires repeated practice, which is crucial in this study considering that the focus was on traditional wood joinery, the physical properties of which render it a relatively challenging material. Conversations between participants and the researcher and design and technology instructors as well as conversations among the participants played a critical role during the implementation stage; these discussions enabled the participants to clarify their concerns regarding the appropriateness of materials combinations. Moreover, participants were able to obtain suggestions from others and perform trials. No participants were experts on all subjects, but they could identify a participant familiar with their chosen materials.

When exploring the material combination, the participant in Case 3 identified methods to exploit material properties such as firmness, friction, and flexibility. In future studies, material properties can be explored and applied to the fabrication of novel wooden joinery structures. In addition, methods for incorporating digital-aided design and digital manufacturing into the crafting process and design brainstorming should be considered to expand the value of traditional crafting technology. The experiences of this design workshop on material combinations and selection will be applied to bamboo, metal, and ceramic crafts. Subsequent studies in this series will explore the ability of craftsmen to apply bentwood and digital crafting to joint structures and to innovate on the forms of these joint structures.

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Acknowledgements: For enthusiastically participating and supporting our study, we would like to heartily thank NTCRI in Taiwan, the craft technology instructors, the design mentor and all participants who take part in the craftsmen training project of NTCRI.
Amorphous Stacks: A Low-Tech Construction Method for Jointless Cast Structures

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Abstract | The project explores an experimental fabrication method to reinvigorate masonry techniques and stereotomy (stone-cutting) construction. It introduces amorphic blocks cast from a pressure-driven scaffold system, stacked into four archetypal structures to examine the method’s performance and applicability. The low-tech, self-explanatory, and hand-craft aspect of this construction method contributes to greater accessibility and the potential for widespread application in areas devoid of technology and resources.

KEYWORDS | FORMATION OF FLUID MATTER, AMORPHOUS GEOMETRY, GEOMETRIC STACKING SYSTEM, JOINTLESS STRUCTURE, DIY MASONRY CONSTRUCTION
1. Introduction

This paper explores the creation of a new dry-stacked system of an interlocking family of distinct amorphous units cast in fluid material. The use of a stacking system in constructing structural and ornamental architectural features with discrete and modulated units is evident throughout the history of stonemasonry. From the Roman concrete arches stacked with mortar to the dry-stacked Inca stone walls and the extensively used mass-producible brick constructions of modern architecture, the art and science of stacking systems in masonry have evolved both structurally and aesthetically, reflecting the increasing needs of high efficiency and new aesthetics in the culture of building.

The current practice of stone masonry construction is divided into two broad categories according to the fabrication method: stone-cutting and solid-casting. Both categories have adopted innovative materials and construction techniques through research and practice while presenting different architectural applications. In the case of stone-cutting in masonry construction, many practices combine traditional craftsmanship with digital fabrication technology and structural analysis. *Cyclopean Cannibalism*, a research project led by Brandon Clifford and Wes McGee (2018), successfully translated the ancient construction methodology of Cyclopean masonry into a contemporary digital procedure with high accuracy and efficiency through the use of a six-axis robotic arm to carve each stone unit of a Cyclopean masonry wall. Other contemporary research on stereotomy has integrated digital computation in the design process. The *Sean Collier Memorial*, designed by Höweler + Yoon (2015), combined new digital fabrication methods, including computational graphic statics and robotic machine milling, to build a five-way vault geometry with traditional stonemasonry techniques.

Similarly, solid-casting construction has evolved with digital modeling and fabrication tools yet has strayed from a holistic approach by limiting the material’s structural capability. Current experimental practice and forefront research in solid-casting tend to focus on developing computational techniques to produce complex geometries and visual aesthetics while overlooking the potential to accentuate the nature of the material and materiality. The application of cast stone continues to be used primarily for cultured stone and ornaments to mimic prehistoric aesthetics. Innovations in cast concrete are mostly limited to the cladding system, focusing on visual appearance rather than the construction process and structural integration. The *Broad Museum* in Los Angeles, designed by Diller Scofidio + Renfro, is characteristic of its parametric precast concrete façade composed of glass-fiber-reinforced concrete (GFRC) panels that were cast in digitally fabricated molds, showcasing a versatile and rapid prototyping workflow. While it combines the precast technique with complex geometry, the method requires a substantial supporting structure to hold up the cladding system. However, the current trajectory undertaken by architectural designers and researchers calls for more attention to exploring the materiality of fluid materials for casting.

As Pier Luigi Nervi stated, although the casting of fluid material (i.e., reinforced concrete) has been used in architecture for over a hundred years, "few of its properties and potentialities..."
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have been fully exploited” (West, 2017, pp.4). While the geometry of stereotomy (cutting) is limited to ruled surfaces since the generative surface follows the trajectory of the cutting blade, the plasticity of the casting material allows an extraordinary variety of forms with non-developable surface geometries with the introduction of flexible formworks. With the exploration of stacking units’ surface geometry, there is the possibility of a new construction method that supports itself (without mortar). The accessibility of fluid materials around the world also suggests its great potential to be popularized by larger user groups, specifically those in remote regions that have limited construction resources and technology.

Another challenge of contemporary masonry construction, as well as in other material constructions, arises from the perishing value of craftsmanship in the culture of making. As the stereotomic problem has become creating “a whole that must be made of various parts” (Sanabria, 1989, pp. 266), the fabrication system has gradually transformed into a standardized mass production process that produces uniform building units, such as bricks, resulting in maximal productivity and economic benefits. However, these two trajectories of mass production and technology-oriented development have rarely reflected the inherent value of traditional masonry that resides in its technical virtuosity. Mass production and advanced digital technology not only remove the marks of the builders’ hands from the artifacts but their required high level of expertise and background knowledge further hinder the popularization of the techniques and constrain access to only specific user groups with status and resources (Eglash et al., 2004); people from remote or isolated areas with limited resources have restricted opportunities to use these new techniques. This phenomenon reveals the social challenge of the contemporary construction paradigm and the need to address the broader socio-economic problems and propose sustainable solutions.

How can modern architecture reinvigorate tradition without losing the value of craftsmanship? What are the opportunities in fabrication to challenge accessible means of construction? In exploring of an approach alternative to those centered on technologies, this study addresses the challenges of the lost value of making and the urgent social need for accessible construction techniques in underdeveloped places. This paper reconsiders the casting technique in masonry construction and reexamines the materiality of fluid materials to offer new possibilities in expressing the intrinsic qualities of the material. Through prototyping and speculative design, it reflects on a new understanding of an integrated and reciprocal relationship between material and human experience in the course of making.

This paper presents three primary objectives on the subject matter after an introduction to the fabrication methodology. Firstly, it examines the applicability of the new construction method by prototype testing four archetypal structures. Secondly, it discusses the potential and limitations of the method based on the results drawn from the first section, followed by reflections on future exploration and development. Finally, it proposes a possible application of the technique to solving real-life architectural problems. By drawing results from physical models, this investigation aims to contribute to the diversity of possible research approaches to masonry construction methods.
2. New Masonry Construction Method

2.1 Casting From Flexible Formwork

This study adopted plaster casting as the primary fabrication technique to engage the thinking of matter as a participant in generating form. There are several advantages to casting as a fabrication method. It is a relatively simple construction method that requires very little technological support, offering the possibility of construction in situ. Common materials for casting, such as concrete and plaster, are highly accessible and can be executed. The plasticity of the fluid materials also facilitates the subject of this study. The casting materials’ transitional phase between liquid and solid states allows the manipulation of their form. Their fluid nature implies a self-activated form-finding process that responds to their surroundings. As the mold mostly constrains the casting outcome, the utilization of a flexible mold (fabric and inflatable materials) is crucial in the sense that it implements the materials’ intrinsic qualities instead of discounting and overpowering them. Paired with the use of the flexible mold (in this case, the latex balloon), the materials “actively seek the shape of their own stability in the gravitational field” (West, 2017, p.6). As Mark West noted in his explorative research on the use of fabric formworks in concrete casting, the materials in play are “alive”: they arrive at the final geometry in a kinetic way, engaging in “a kind of formal self-invention in real-time” (West, 2017, p.6). Plaster was adopted as the material for casting prototypes due to its similarity with concrete and soil, yet with a shorter curing time.

The study uses the surface geometry of stacking units manipulated by a flexible scaffold system (Figure 1) to create an interlocking system without the use of mortar. Under the same method, architectural applicability was tested using the construction of three phasing prototypes: the fabrication of a column structure, an inclined column and wall structure, and a conical wall structure. The geometry of the latex balloons filled with liquid plaster was manipulated by external pressure generated by a cubic scaffold system to create organic forms with concave and convex surfaces (Figure 2). The formwork also utilized temporary fabric support in place of possible wooden falsework. Between the amorphous blocks, the seamless fitting of concave and convex surfaces behaved as joinery that interlocked the masses. During the casting process, each unique block became a part of the scaffolding system for the succeeding one, providing sufficient friction for structural stability. The realized form reflected the means of its construction from the geometric properties of each individual and mutually-responsive unit. This simple construction method would allow users to build it themselves with minimal equipment. Embracing the characteristic of irregularity in material crafts, no specific patterns of the arrangement were employed intentionally during the fabrication process. This flexibility in making opposes the strict uniformity required by mass production and the high precision prescribed by technology, offering greater freedom of creation and accessibility.
2.2 Pressure-Driven Scaffold System

A customizable pressure-driven scaffold system was designed to fabricate the stacking structure (Figure 1). Builders were able to construct the entire structure solely by this system without additional tools and machines. In addition, it was composed of simple components that could be disassembled and reassembled easily, providing an advantage of mobility. As a type of force, pressure can take various forms and effectively transform the shape of soft matter. In this study, spheres of different radii were used as the pressure impetus. The perforated panels of the formwork enabled the spherical force to enter the cubic scaffold system from the exterior in axial directions in order to apply force onto the plaster volume, while the grid pattern established a customizable and controllable system for axial pressure in multiple configurations. This scaffold system also included a sheet of heavy-duty fabric, which was placed and secured around the wooden frame. The fabric sheet helped to offer temporary support for the structure, creating a flexible platform for manipulation. The plaster volume confined in the balloon was left to cure after it found its own shape of static equilibrium through the back-and-forth adjustments of pressurizing and depressurizing. Thus, the geometric outcome of the stacking units was subjected to both the imposed pressure and the surrounding context (gravitational force). The combination of the prescribed parameters and the open-ended factor implies a more holistic construction method than an entirely prescriptive one.
2.3 Surface Geometry as Joinery

The connection between each block was achieved by its surface geometry without the use of mortar cement. After casting one block, the next block was cast on top of the previous one, which became part of the scaffold for the succeeding block. Thus, a concave surface on the previous block would form a convex surface on the latter one, and vice versa (Figure 1). The seamless fitting of concave and convex surfaces increased the contact surface area between the two blocks and provided greater friction for structural stability. The concave and convex geometry also behaved as the joinery system that interlocked the two blocks by eliminating the rotational movement. The greater the depth of the concave and convex surfaces, the stronger the anchoring function they perform. Moreover, a larger distance between the centers of gravity of the two blocks would not only require a greater surface curvature, but also the weight of the upper unit to stabilize the structure (Figure 3). This connection system shares similar principles with those of Inca masonry techniques; Inca stonemasons utilized the friction between precisely-cut matching faces of neighboring stones as a connecting mechanism. However, the surface geometry’s behavior as joinery in this study differs from the Inca prismatic ones in its amorphous geometry, contributing new aesthetics to the conventional masonry practice.
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3. Structure Prototypes

3.1 Column Structure

The architectural applicability of this construction method was tested through three major studies that included four archetypal structures: a vertical column, inclined columns, an inclined wall, and finally, an inclined conical wall. The first study investigated a 6-feet vertical column structure constructed by a 2’X2’X2’ cubic scaffold to examine the applicability of the new method (Figure 4). The vertical column was composed of 10 unique plaster blocks with an average size of 1’X1’X1’. This size of the stacking block allowed an approximately 20 minutes for the workable form before it was left to cure, which would take up to 24 hours. The structure eventually attained its global static equilibrium when the final keystone was set in place. With this fabrication method, the stacking structure achieves static stability only after completing the assembly process.

The process of finding the global equilibrium was one of trial and error, a course that was more intuitive than computational or systematic. This constructive process is a concern that resides in most handcraft traditions, which has been solved mainly by the accumulation of experience. Recent research has integrated computational modeling and solver-based simulation to test and revise the structural performance before fabrication, establishing a more efficient design workflow that ensures a successful outcome. Examples include the use of the Grasshopper component to calculate the center of gravity in the Quarra Cairn.
research project completed through a collaborative effort between the Massachusetts Institute of Technology and the University of Michigan (Clifford et al., 2017). This limitation of the innovative construction technique appeals for further explorations and research on designing a solver-based computational program that can simulate the optimal positions for each stacking unit in advance.

The paradoxically stabilizing function of the keystone in the amorphous stack recalls the argument stated by Charles Perrault in the 17th century and mentioned in Richard Etlin’s introduction to Stereotomy: Modern Stone Architecture and Its Historical Legacy. Perrault described stereotomy as being based on the paradox that the practice employed “the weight of the stone against itself by making it hover in space through the very weight that should make it fall down” (Fallacara & Stigliano, 2012). Stonemasons in different eras have addressed this problem from different approaches according to the available contemporary technology and knowledge. Inca stonemasons confronted the problem by solely using the weight of stones to achieve stability (Protzen, 1985), whereas Roman builders avoided this problem by using temporary wooden formwork and thick mortar joints (Sanabria, 1989). A majority of recent research on stereotomy has centered on integrating technology that relies on auxiliary support and joinery systems, as in Roman architecture. This study, however, takes an approach aligned with that of the Inca builders, where the form solves the problem of physics with its mass and geometric characteristics, resulting in a direct and responsive relationship between form and structure. This approach considers the matter’s resistance to weight as a virtue rather than as an obstruction to be overcome (West, 2017).

Figure 5. Detail views of the 6 feet column structure.
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Figure 4. Prototype of a 6 feet column structure.
3.2 Inclined Column and Wall Structure

The second study continued to develop the fabrication method to resolve the static equilibrium of inclined columns and wall structure by adding two fixed planes to the formwork. As each amorphic block offsets the others in a linear fashion, it will form a leaning structure with an angled central axis. Two fixed planes were added to the top and bottom of the scaffold to prevent the structure from collapsing. A key knob was attached to each panel, acting as a pin joint to prevent blocks from sliding and rotating. A piece of fabric, which was later removed, was secured to the two panels at a certain angle, functioning as temporary support for the inclined structure during the fabrication process. Besides the adjustment of the scaffold system, other fabrication processes remained the same, including the use of latex balloons and casting in plaster. As the last unit was cast in place, the inclining structure reached its static equilibrium and no longer needed the fabric support.

This study examined one-foot tall column structures at two different inclining angles: one at 20 degrees (Figure 6) and the other at 45 degrees (Figure 8). Both structures maintained a static equilibrium after all blocks were cast and the fabric was removed. The success of the two prototypes suggests the wider potential of this technique’s application in architectural construction. After two inclined column prototypes, this study proceeded to explore the possibility of applying the technique to construct an inclining surface structure by examining a half-foot tall inclining wall structure at 30 degrees (Figure 11). In this wall structure, the relationship between the amorphic blocks was no longer a one-to-one dialogue but multi-directional and dynamic. Each amorphic block not only related to its vertical neighbors but also to the horizontally adjacent ones. This network interrelation with multiple directionalities added extra structural stability to the wall section.
Figure 7. Sequence of prototyping the inclined column structure at 20°.

Figure 8. One-foot tall inclined column structure at 45°.

Figure 10. Sequence of prototyping the inclined column structure at 45°.

Figure 11. Prototype of the half-foot tall inclined wall structure at 30°.
3.3 Inclined Complex Wall Structure

The third study proceeded to fabricate a larger-scale prototype with highly complex geometry to further examine the potential of the construction technique. The increase of scale led to a strengthening of the scaffold’s structural capabilities to face the challenge of large scale constructions. An inverted conical surface was chosen to introduce geometric complexity (Figure 12). The entire structure was constructed by a 3’x1.5’x3’ scaffold and consisted of 104 stacking units of 1/2’x1/4’x1/4’ plaster blocks, with 20 degrees of inclination. The structure successfully held itself up; however, it failed after removing the supporting fabric due to the deformation of the fabric caused by overweight. Another leading reason was the disproportional relation between the scale of each stacking block and the entire structure. The scale of each stacking block was demonstrated to be too small for the scale of the overall structure, which resulted in a much larger number of the units that led to a higher probability of collapsing in this dried-stack structure without mortar. In conclusion, this complex prototype proves the potential of this construction method in building organic forms and dynamic structure. The result of this prototype also suggests that a complex geometric structure and larger scale constructions in question require more thoughtful planning of scale and material usage than a column structure in order to be free from collapsing.

Figure 12. Prototype of the 3’x1.5’x3’ inclined conical wall structure.
Amorphous Stacks: A Low-Tech Construction Method for Jointless Cast Structures

Figure 13. Sequence of prototyping the 3’X1.5’X3’inclined conical wall structure.

Figure 14. Detail view of the inclined conical wall structure.
4. Discussion and Conclusion

The prototype testing results of the four archetypal structures prove the validity and applicability of this innovative fabrication technique and suggest its potential in constructing a structure of greater complexity. During the prototyping process, several variables emerge to be crucial for the effectiveness of the construction: the surface curvatures of the concave and the convex, the inclination degree, the relationship between the total number of units within each self-standing structure, and the structural capacity of the scaffold system when facing the challenge of large scale construction. A conjecture can be drawn from the testing result of the four archetypal structures that there is a right domain of ratio between the structure’s total volume and its unit count for the practicability of the construction method.

Utilizing the fluid property of liquid casting, this construction method reflects the relationship between form and physics in the fabrication process. The use of the surface geometry of each block as the joinery system eliminates the need for additional adhesion or mechanical joints, which establishes a direct and responsive relationship between form and structure. Although the interlocking system improves structural stability, the center of gravity must be monitored to achieve a global equilibrium. The intuitive aspect of the search for global equilibrium during the fabrication process presents an opportunity to incorporate a new computational program. This combination of craftsmanship and digital computing could potentially yield a hybrid model in which technology and human hands are codependent.

The design and the prototype examination of this fluid-cast and pressure-driven fabrication method rethink the potential of liquid-casting materials and the curing process in constructing organic forms and structures. Its low-tech and crafts-based attributes inform itself of a non-standardized and self-explanatory construction method that could be adopted in areas of limited resources, technology, and skilled-builders. The widely accessible casting materials, including concrete and plaster, allow users to build structures in places with difficulties in transportation, such as high mountains or remote islands. The DIY aspect of this technique blurred the boundary between users and builders by lowering the prerequisites and skill demands. With the support of computational parametricism and algorithms, the hand-built approach gradually abolishes in favor of robotic arms. By utilizing the virtue of the fluid material, this fabrication method’s flexibility and plasticity challenge the standardization of mass production and the prescriptive design, offering greater freedom of creation and accessibility. This exploration presents an alternative approach to masonry construction, inheriting the legacy of past knowledge to imbue the making tradition with greater accessibility.
References


About the Authors:

**Liqiong Huo** is a design researcher who investigates the integration of emerging technologies and human-oriented design in the context of art and architecture. She studied Interior Architecture from Rhode Island School of Design, where she focused on installation and adaptive reuse projects.

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An Exploratory Study about Communicating 4D Printing between Product Designers and Manufacturing Engineers

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* FatenEzrin.Azhar@brunel.ac.uk

Abstract | 4D Printing is an emerging technology that combines Additive Manufacturing and stimuli-responsive shape memory materials to produce freeform parts that can evolve over time. In this paper, we suggest that using conventional sketches to communicate 4D Printing does not fully convey the design intent. This paper provides evidence of poor communication between Product Designers and Manufacturing Engineers when describing 4D Printed parts. Literature review highlighted that very little studies have been carried out to investigate the communication of the shape transformation process. The study found that the marks made on paper were spontaneous and unpredictable. For example, participants used random colours, arrows and shading. Time was indicated by using ‘symbols’ and splitting this into two separate sketches to define the differences in speed. The main study involving fourteen pairs of Product Designers and Manufacturing Engineers aimed to capture the participants’ gaze and behavioural activity during sketching using OBS Studio Software and with a Wacom Bamboo Tablet. To track the Product Designers’ and Manufacturing Engineers’ sketching process, the participants were asked to view an animation that showed the shape change behaviour. Next, they were asked to make annotations to specify the geometric relations using symbols, dimensions, angle, alignment and symmetry on the sketch to communicate the shape change behaviour of the 4D Printed parts. In summary, this study has found that a framework could be further developed as a guideline to communicate the shape changing behaviour of the 4D Printing process. The main contribution to knowledge is to enable Product Designers and Manufacturing Designers to communicate the use of 4D Printing during the idea generation phase.

KEYWORDS | 4D PRINTING, COMMUNICATION, SYMBOLS, PRODUCT DESIGNER, MANUFACTURING ENGINEER
1. Introduction

The fourth dimension of 4D Printing refers to the element of ‘time’ where parts can transform or reshape (Tibbits et al., 2014; Pei et al., 2017). 4D Printing uses materials that can remember and recover to a programmed deformation when parts are exposed to an external stimuli (Ge et al., 2014). During the early stages of the design process, sketches or drawings are often used as a visual communication tool (Eitz et al., 2012). In this context, the medium for communication is important because poor representations could potentially lead to confusion (Alcaide-Marzal et al., 2013). Sketches are often the most effective way for Product Designers and Manufacturing Engineers to capture their thoughts and ideas about a design solution. According to Baronio et al. (2016), sketching and dimensioning is required as requirement for designers and engineers before they proceed to use Computer Aided Design (CAD) to create two-dimensional (2D) drawings or three-dimensional (3D) models. Figure 1 shows an example in the use of symbols referring to a technical drawing that shows information about a hydraulic circuit system. We can identify the moving parts of the system such as the motor and the pump unit by means of arrows and other associated symbols.

![Open-loop hydraulic circuit](image)

![Closed-loop hydraulic circuit](image)

**Figure 1. Example of symbols used in hydraulic circuits.**

Our earlier work identified existing challenges for 4D Printing to be communicated during the early stages of the design process. We found that participants made random marks on paper and there were no recognised or established symbols available to explain or represent 4D Printing, especially for shape transformations. For this study, the use of symbols was chosen so that visual communication of the core message could be easily conveyed. This paper describes the study in which the main objective was to evaluate whether the use of established symbols could be effectively used to communicate the shape change effect of 4D Printed parts.

1.1 Shape Changing Behaviour in 4D Printing

Nam and Pei (2019) classified 4D Printing shape-change behaviours into three categories, namely basic shape change, complex shape change, and a combination of shape change. In
this research we focus on eleven different shape-change behaviours, including folding, bending, rolling, helixing, twisting, waving, curling, curving, topographical change, buckling and expansion. According to Nam and Pei (ibid), a fold is a sharp curvature caused by deformation along a crease. As shown in Figure 2, it is different from a bend which is a more evenly distributed deformation of a material along the deflected area that creates the curvature. Rolling is a different behaviour, in which the shape moves by turning over and over on its own axis. On the other hand, twisting is dominated by in-plane stretching. A helix is a type of smooth deformation in which a curve occurs in a three-dimensional space. Buckling is characterized by a sudden sideways failure of a structural member subjected to high compressive stress or force. Curving is the amount by which the surface of a geometric object deviates from a flat plane. Topographical change results in a distorted shape that resembles the physical features of a ground terrain. Expansion and contraction shape-changing behaviours are based on a shape-memory cycle. The waving behaviour results in a shape that has undulating features or a wavy up-and-down form. Lastly, curling produces a similar resultant effect as curved creases along a continuous surface. There are also notable differences in the degree of shape change (Nam & Pei, 2019). Curving, twisting and helixing shape-change behaviours have deformation angles occurring in the hinge area; while bending, topographical and twisting shape-change behaviours have a deformation that results in less than 360°. If this is more than 360°, the deformation is classed as rolling, buckling or curling.

![Diagram showing differences between folding, bending, rolling, and multiple rolling.](image)

**Figure 2.** The differences between folding, bending, rolling and multiple rolling (Nam & Pei, 2019).

1.2 Symbols and Icons

The word ‘icon’ is derived from the Greek word ‘eikon’ which refers to ‘the image’ (Yan,
Empirical studies about iconography and symbols can be regarded as a subgroup of visually descriptive or figurative language (Wagner, 2015). Both icons and symbols are used to represent pictographs which are graphs that encode words through the medium of representation (Bottero, 2004). Icons usually represent only visible things, whereas symbols represent the idea. Icons are defined as clear graphical representations with little need for translation. On the other hand, one has to learn what a symbol stands for, as it is not similar to what it represents (Rogers, 1989). Icons are also restricted to the graphical representation of objects and one can easily understand what they refer to.

2. Empirical Research

The main objective of this study is to evaluate whether the use of symbols could be effectively used to communicate the shape change effect of 4D Printed parts. A set of 33 symbols representing the shape-change effect of 4D Printing was first created. An initial study involved one post-doctorate designer and one post-doctorate engineer. This was created to ascertain the total duration of the task that would be required, as well as to clarify the sequence of activities. We found that the pilot study took an average of one hour to complete. For the main study, we recruited fourteen designers and engineers from the Department of Design, College of Engineering, Design and Physical Sciences at Brunel University London in the United Kingdom and also from the Faculty of Engineering, Universiti Teknikal Malaysia Melaka, Malaysia. In this focus group study, the participants needed to have a background in either design or engineering. In terms of the limitations of this study, our main concern was that the number of participants who took part in the focus group was small (n=14), and it was also difficult to recruit participants who had a good knowledge of 4D Printing.

The focus group consisted of three main tasks, involving a (1) ‘Classification Test’, (2) ‘Visual Test’ and (3) ‘Development Test’. For the ‘classification test’, the participants had to match the text that described the shape-change behaviour with three symbols that were provided. This task introduces the eleven 4D Printing shape-changes, so as to enable the participants to understand the 4D Printing deformations (Figure 3). The participants were asked to match each symbol with their corresponding shape-change behaviour for this first task and the correct matching and error rates were collected. For the ‘visual test’, the participants had to rate each of the three symbols according to good, average and poor. For this second task, we wanted to find out which symbols had the best preference. Lastly in the ‘development test’, the participants were asked to further suggest two other alternative symbols for each of the 4D Printing Shape-Change behaviours. The purpose of this task was to allow participants to create alternative designs of the symbols.

Before starting the task, the participants were briefed about the purpose and the procedure of the study. They were asked to read an information sheet before completing a consent form to participate in this study, in line with the university’s ethical process. The participants...
were not timed and they were given sufficient time to complete all the tasks. The average time required to complete the focus group was approximately an hour (Figure 4).

<table>
<thead>
<tr>
<th>4D Printing Shape-changes</th>
<th>Propose Icons</th>
<th>4D Printing Shape-changes</th>
<th>Propose Icons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folding</td>
<td><img src="image1" alt="Image" /></td>
<td>Curling</td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>Bending</td>
<td><img src="image3" alt="Image" /></td>
<td>Curving</td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>Rolling</td>
<td><img src="image5" alt="Image" /></td>
<td>Topographical change</td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>Helixing</td>
<td><img src="image7" alt="Image" /></td>
<td>Buckling</td>
<td><img src="image8" alt="Image" /></td>
</tr>
<tr>
<td>Twisting</td>
<td><img src="image9" alt="Image" /></td>
<td>Expansion</td>
<td><img src="image10" alt="Image" /></td>
</tr>
<tr>
<td>Waving</td>
<td><img src="image11" alt="Image" /></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.** Symbols designed for the ‘classification test’.

**Figure 4.** Participants undertaking the experiments.
3. Analysis and Results

The results of Task 1 ‘Classification Test’ are presented in Table 1. The first column showed the representative symbols of the shape-changes symbols for folding, bending, rolling, helixing, twisting, waving, curling, curving, topographical change, buckling and expansion or contraction. The second column showed the correct answer that the participant should answer. And the third column showed the total of participant that choose the correct answers. The table refers to the Participant number. It was found that 8 out of 14 participants received correct answers in Task 1. The 8 participants matched correctly all of the symbols with 4D Printing shape-change behaviours. In addition, we also found that folding, rolling and helixing were correctly matched by all participants. Conversely, ‘topographical change’ was the symbol that was the worst matched which 4 out of 14 participants answered it wrongly. Next, ‘curving’ received 3 out of 14 participants who matched incorrectly and they were confused with the ‘topographical change’ symbol.

*Table 1. Task 1 required participant to match the set of symbols with the corresponding 4D Printing shape-change behaviour.*

<table>
<thead>
<tr>
<th>Proposed 4D Printing Shapeshift Symbols</th>
<th>Answers</th>
<th>Total Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E Folding</td>
<td>14/14</td>
</tr>
<tr>
<td></td>
<td>H (Bending)</td>
<td>12/14</td>
</tr>
<tr>
<td></td>
<td>K (Rolling)</td>
<td>14/14</td>
</tr>
<tr>
<td></td>
<td>G (Helixing)</td>
<td>14/14</td>
</tr>
<tr>
<td></td>
<td>J (Twisting)</td>
<td>13/14</td>
</tr>
<tr>
<td></td>
<td>A (Waving)</td>
<td>13/14</td>
</tr>
</tbody>
</table>
From this task, it was found that folding, rolling and helixing had the highest score (14 participants who matched the icons correctly). Twisting, waving and expansion had the next highest score (13 participants who matched the icons correctly). Bending, curling and buckling had 12 participants who matched the icons correctly. Curving had 11 participants who matched the icons correctly, and Topographical Change had 10 participants who matched the icons correctly, giving this icon the poorest score.

For Task 2 ‘Visual Test’ there were 3 symbols for them to choose, as shown in Table 2. The participants had to rate their most preferred symbols, with the ‘1’ rating referred to good, ‘2’ rating referred to average, and ‘3’ rating referred to poor. From this task, the most agreed symbols for all 4D Printing shape-changes behaviour were found. Among them, the folding shape-change behaviour received the best results with 14 of the participants agree with the middle symbol as shown in Table 2 being their most preferred and easiest to understand representation. However, the first symbols received only 5 agreements. Similarly, in the second column referring to the bending shape-change behaviour, 10 participants rated the middle symbol as their most preferred representation. From this exercise in Task 2, a summary of their preferred choice of symbols is shown in Table 2.

Table 2. The results of the most preferred symbols selected by the participants to represent the 4D Printing shape-change behaviour.
For Task 3 ‘Development Test’, the participants were asked to create two symbols with their own idea to represent the 4D Printing shape-changing behaviour. With 14 participants participating in the study, generating 22 symbols per participant, a total of 308 icons were created. For this task, there was no restriction on the number of strokes, orientation or sketching style used to represent the 4D Printing shape-changing behaviour. However, the

<table>
<thead>
<tr>
<th>Symbol Description</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>E Folding</td>
<td>n=14</td>
</tr>
<tr>
<td>H (Bending)</td>
<td>n=10</td>
</tr>
<tr>
<td>K (Rolling)</td>
<td>n=12</td>
</tr>
<tr>
<td>G (Helixing)</td>
<td>n=11</td>
</tr>
<tr>
<td>J (Twisting)</td>
<td>n=11</td>
</tr>
<tr>
<td>A (Waving)</td>
<td>n=13</td>
</tr>
<tr>
<td>I (Curling)</td>
<td>n=12</td>
</tr>
<tr>
<td>B (Curving)</td>
<td>n=12</td>
</tr>
<tr>
<td>C (Topographical change)</td>
<td>n=13</td>
</tr>
<tr>
<td>D (Buckling)</td>
<td>n=13</td>
</tr>
<tr>
<td>F (Expansion)</td>
<td>n=13</td>
</tr>
</tbody>
</table>
symbols had to be drawn in black and white and had to be sketched within the boxes that were provided. This ensured consistency across all participants and the space given within the box ensured that the icons created could be seen when shown within a tight constraint. The results indicated that there were significant similarities among engineering participants where they usually included a known symbol that represented the angle, or force, etc. Conversely, most designers only used arrows and shading to define the features, especially in the ‘topographical change’ shape-changing behaviour. In order to completely analyze the 308 symbols generated, we observed and scrutinized every single symbol, and made 3 distinct observations for each symbol as summarized in Table 3.

Table 3. Task 3 required participant to create two icons based on their own idea.

<table>
<thead>
<tr>
<th>4D Printing Shape-change behaviour</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folding</td>
<td>1. Arrow to indicate direction and folding sequence.</td>
</tr>
<tr>
<td></td>
<td>2. Symbol for view angle.</td>
</tr>
<tr>
<td></td>
<td>3. Dash line to indicate axis of folding.</td>
</tr>
<tr>
<td></td>
<td>4. Preferred 1D or 2D shape to indicate folding symbol.</td>
</tr>
<tr>
<td>Bending</td>
<td>1. Symbol ‘F’ to indicate force.</td>
</tr>
<tr>
<td></td>
<td>2. ‘G’ indicate as Gear in bending machine.</td>
</tr>
<tr>
<td></td>
<td>3. More than one arrow to indicate direction</td>
</tr>
<tr>
<td>Rolling</td>
<td>1. Curve arrows to indicate roll direction</td>
</tr>
<tr>
<td></td>
<td>2. 3D shape to represent rolling shape.</td>
</tr>
<tr>
<td></td>
<td>3. Rolling dash line.</td>
</tr>
<tr>
<td>Helixing</td>
<td>1. Used double line to indicate helix shape.</td>
</tr>
<tr>
<td></td>
<td>2. Cross line and dash line.</td>
</tr>
<tr>
<td></td>
<td>3. Curve arrows to indicate movement.</td>
</tr>
<tr>
<td>Twisting</td>
<td>1. Arrows circle around symbol to indicate twist</td>
</tr>
<tr>
<td></td>
<td>2. 3D shape to represent twisting.</td>
</tr>
<tr>
<td></td>
<td>3. Curve up and down arrows to indicate twist movement.</td>
</tr>
<tr>
<td>Waving</td>
<td>1. Wiggly line represent wave shape.</td>
</tr>
<tr>
<td></td>
<td>2. Shadings to differentiate changes shape.</td>
</tr>
</tbody>
</table>
### 3.1 Discussion of observations

From the observation of task 3 and task 2, there is some mismatch found between participant’s sketches and rated symbols proposed by the researcher indicating shape-change behaviours. For example, most participants used arrows, angles, and sequences of folding either in 1D or 2D shape to indicate folding symbol as presented in Table 3. However, in task 2, the highest agreement received for the agreeable symbol was in 2D shape and did not show any angles and arrows, as shown in Table 2. Therefore, from this observation, the researcher can conclude that it is easier for the participants understanding a 2D shape symbol including arrows and angles to represent a shape-change behaviour of 4D Printing.

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curling</td>
<td></td>
</tr>
<tr>
<td>1. Single curling line.</td>
<td></td>
</tr>
<tr>
<td>2. Thick curl line represent 3D curl shape.</td>
<td></td>
</tr>
<tr>
<td>3. Arrows to indicate curling movement.</td>
<td></td>
</tr>
<tr>
<td>Curving</td>
<td></td>
</tr>
<tr>
<td>1. Show two views represent shape changes.</td>
<td></td>
</tr>
<tr>
<td>2. Dash semi curve line above straight line to indicate curving shape.</td>
<td></td>
</tr>
<tr>
<td>3. Semi curve 3D shape.</td>
<td></td>
</tr>
<tr>
<td>Topographical change</td>
<td></td>
</tr>
<tr>
<td>1. Some of participant indicate differentiate movement with colour.</td>
<td></td>
</tr>
<tr>
<td>2. Shading differentiate different surface</td>
<td></td>
</tr>
<tr>
<td>3. Dash line differentiate different surface and movement.</td>
<td></td>
</tr>
<tr>
<td>Buckling</td>
<td></td>
</tr>
<tr>
<td>1. Two arrows facing each other to indicate force.</td>
<td></td>
</tr>
<tr>
<td>2. ‘F’ symbol to indicate force.</td>
<td></td>
</tr>
<tr>
<td>3. Sharp edge to indicate high compressive stress.</td>
<td></td>
</tr>
<tr>
<td>Expansions</td>
<td></td>
</tr>
<tr>
<td>1. Four or more arrows in every corner.</td>
<td></td>
</tr>
<tr>
<td>2. Two different size of box to indicate expansion.</td>
<td></td>
</tr>
<tr>
<td>3. Different size of circle to indicate changes of size.</td>
<td></td>
</tr>
</tbody>
</table>
An Exploratory Study about Communicating 4D Printing between Product Designers and Manufacturing Engineers.

From the observation of task 3 and task 2, there is some mismatch found between participant’s sketches and rated symbols proposed by the researcher indicating shape-change behaviours. For example, most participants used arrows, angles, and sequences of folding either in 1D or 2D shape to indicate folding symbol as presented in Table 3. However, in task 2, the highest agreement received for the agreeable symbol was in 2D shape and did not show any angles and arrows, as shown in Table 2. Therefore, from this observation, the researcher can conclude that it is easier for the participants understanding a 2D shape symbol including arrows and angles to represent a shape-change behaviour of 4D Printing.

4. Conclusions and Future Work

Sketching facilitates the communication of ideas in the early stages of the design process. There are very few established methods available to communicate the shape-changing behaviour of 4D Printing. Our study has found that the use of icons to represent 4D Printing shape-changing behaviours could potentially help product designers and manufacturing engineers apply proper representations to communicate with each other during the design stage. For future work, we will develop a more thorough framework by applying the symbols in Table 2 into the actual design process and observe the communication when designing 4D Printed parts.
### 5. Appendix. Responses from Task 3

<table>
<thead>
<tr>
<th>PARTICIPANTS</th>
<th>SHAPE - CHANGES BEHAVIOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Folding</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PARTICIPANTS</th>
<th>SHAPE - CHANGES BEHAVIOR</th>
</tr>
</thead>
</table>
References


About the Authors:

Faten Ezrin Azhar She is a full-time PhD student in the Design Department at Brunel University of London. She is supervised under Dr. Eujin Pei who is a Programme Director for the BSc Product Design; and Programme Director for the BSc Product Design Engineering courses at Brunel University. Ezrin holds a Master’s degree in Art and Design from University Technology MARA Malaysia. Being awarded the chance to study further in her field at the Brunel University London is an incredible opportunity for her and she intends to seize wholeheartedly without reservation. Currently, she is doing her research on 4D Printing regarding her research topic ‘Improving Communication between Product Designers and Manufacturing Engineers when Designing 4D Printed Parts. This research aims to propose the use of symbol that can support communication between designers and engineers, particularly when designing parts for 4D Printing. Communication in design incorporates the elements of great virtual design and takes things a step further by considering the way users understand visuals.

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Biotextiles applied to everyday objects.

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Abstract | Our daily life is surrounded by materials, but we are not necessarily aware of them. However, their importance in human society is undeniable at many levels. This paper views materials as objects of dialogue which can move us towards a sustainable consumer culture and evaluates present alternatives based on the fourth industrial revolution. The paper focuses on practice-led research by a transdisciplinary group of designers and engineers, using agroindustry waste to bio-fabricate prototypes of everyday life objects. Several mechanical characterization methods have been applied to test permeability, flexibility, strength and absorption. The results have revealed both functional and aesthetic possibilities. Lastly, the paper concludes with a road map that analyses bio fabrication and circular economy alternatives in South America, to illustrate my vision that through plausible collective actions and policy change scenarios we can design new consumer choices.

KEYWORDS | WASTE REMEDIATION, BIOMATERIALS, CIRCULAR ECONOMY, EVERYDAY OBJECTS, BIOTEKTILES
1. Introduction

Materials are a fundamental part of our culture, but we are often disconnected and ignorant as to where they come from and how they are manufactured. Materials are part of a continuous, often disposable, behaviour network: we allow ourselves to buy, use and discard them. Materials are political, as their production and manufacture at low cost allows citizens to buy more and discard easily. This behaviour is not compatible with the actual earth we live in. There is an urgent need to develop sustainable strategies, rethink mass consumption, and plan according to real future scenarios throughout the entire supply chain. It’s necessary to talk about materials’ political agenda to support sustainable innovations and embrace brands to commit to move towards zero discharge of toxic chemicals in various industries. We are focused on addressing the fast fashion industry, as its one of the major polluting agents due to its vast overproduction of fashion items, the use of synthetic fibers, agricultural pollution, massive freshwater and ocean water pollution and soil degradation. This is a heated topic of discussion regarding global warming goals, even though there hasn’t been any real action towards harder policies that lower industries’ emissions within its full supply chain. These policies could include the creation of incentives to support new alternatives at a large scale to reduce petroleum as a main resource, or alternatives to cotton to decrease water consumption and electricity. Using natural dyes would reduce water pollution, acting local would decrease transportation. The consumer is also responsible for this impact and there is no sign that we want to change our consumption habits. Therefore, it’s important to create competitive consumer choices by designing systems that economically support sustainable brands. The One of 17 SDG goals set in 2015 by the United Nations under the ‘sustainable consumption and production patterns’ goals, is to educate consumers on sustainable consumption and lifestyles, providing them with adequate information through standards and labels and engaging in sustainable public procurement, among others (UN, 2015). After 5 years trying to reach this goal, it doesn’t seem like they will hit their mark by 2030.

On the other hand, sustainable material alternatives are increasingly being explored. We are living in the fourth industrial revolution. The first and second industrial revolutions harnessed water, steam, and electric power, challenging the traditional system of craft-based production. The third industrial revolution harnessed information technology and data analysis, giving birth to the fast fashion movement. The fourth industrial revolution is based on innovations across the physical, digital, and biological worlds, driving a new wave of change across the economy (Abnett, 2016).

Communities of makers, biohackers, designers, engineers, biologists, architects, and artists have risen up working collaboratively, with raw materials, observing nature and taking inspiration from ancestral wisdom and new technologies. Today, we can control the growth of microorganisms, fractionate matter, or purify ultra-cellular structures that by themselves have very interesting physiochemical characteristics (Carvajal, 2011). Furthermore, the textile industry innovation such as “Functional Fashion, E-Textiles, Smart Fabric, Smart
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Clothing – is slated to be worth $3 billion by 2018 or $9 billion by 2024” (Suikkanen, 2019, p. 2). Moreover, initiatives to reduce the environmental impact of fabric manufacturing will likely increase those numbers even further. These practices also have a huge potential in fields such as packaging, fashion, architecture, and medicine, among others.

“Although many of these new textile innovations are still at the early development stage, the sportswear and fashion industry is embracing the use of bio-based textiles and designers are beginning to challenge themselves to create entirely bio-based products” (Prahl, 2018).

As a result, a lot of research is being devoted into dyeing and chemical processing of biopolymers of value as textiles. Although not every biomaterial is able to become a fiber, there is plenty of research on plausible applications for the future. Thus, these techniques do not yet seek industrialization but alternative applications based on raw materials.

“Brands are expected to announce partnerships with businesses that have figured out ways to make leather without cows, silk without worms, fur without animals and fabrics from recycled waste. Salvatore Ferragamo has been selling scarves made of orange fibers while Stella McCartney produced outfits made with vegan spider inspired silk for Adidas since 2017.” (Wendlandt, 2017)

A more unusual waste stream is cow manure, as explored by Dutch designer and entrepreneur Jalila Essaïdi through her start-up Mestic. They developed technology to deconstruct manure and convert the cellulose into biomaterials including bioplastic, biopaper and bio textiles; “demonstrating that the most disgusting matter is inherently beautiful” (Essaïdi, 2017).

“In addition to creating a fully biodegradable textile, this process helps reduce the production of harmful methane gas and can prevent the contamination of soil and water caused by intensive farming” (Prahl, 2018).

Although scaling these new innovations for industrial applications is a possibility, most of these initiatives have not come from big companies but from artists, architects, designers with limited capital, driven by material innovation in a holistic way. These initiatives have triggered a material revolution demonstrating how bio fabrication plays an important role in shaping the future. Neri Oxman, Associate Professor of Media Arts and Sciences at the MIT Media Lab, focuses her research on “the relationship between the built, natural, and biological environments” (MIT, 2019). She employs design principles inspired and engineered by nature, such as the famous Silk Pavilion installation in 2013, built at an architectural scale through biological fabrication. Another example is the Pavilion grown from mycelium made entirely from bio-based materials as a pop-up performance space at Dutch Design Week 2019 by designer and artist Pascal Leboucq in collaboration with Erik Klarenbeek's studio Krown Design. Mycelium has the potential to compete with plastics. They are naturally fire-retardant without need of using any chemicals, naturally hydrophobic and resist higher melting temperatures than plastics. Moreover, mycelium is compostable. (Lee, 2019)
In our process, we focus on local available materials as starting point to reimagine possible futures where new users and assemblages emerge. We ask ourselves, what if materials are engineered by citizens at home? What if these designs are made for communities living in remote areas? What if textiles are grown locally? How can bio-design contribute to a circular economy? How can we create alternatives that respond to future environmental threats? These questions trigger our designs, situating ourselves in different environmental conditions in the present and reimagining human-nature interaction.

2. Materials and Methods

The present work has been carried out by an interdisciplinary team comprised of designers and chemical, and materials engineering, using local agroindustry waste to create starch-based bio textiles. Our making process began by scaling up biomaterial Petri dish samples to a large-scale frame of one by one meter. Through practice-led research methods, we iterate through prototyping to apply functional and aesthetic solutions to materials. We focus on properties such as elasticity, permeability, flexibility, and most importantly, biodegradability - to produce creative design solutions applied to everyday objects. Moreover, workshops and conferences have been held to engage the community with the importance of rethinking material alternatives outside the laboratory.

2.1 The raw materials used in the process:

Table 1. Quantities used from cassava starch-based formula

<table>
<thead>
<tr>
<th>Component</th>
<th>Working composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava Starch</td>
<td>5% w/v</td>
</tr>
<tr>
<td>Glycerin</td>
<td>2% w/v</td>
</tr>
<tr>
<td>Poly vinyl alcohol (PVA)</td>
<td>5% w/v</td>
</tr>
</tbody>
</table>

To prepare the base material, the compositions specified in Table 1 were used. Cassava starch was suspended in distilled water, and gelatinized at 80°C for 1h, under constant stirring. At the same time, PVA was dissolved in distilled water at 60°C. Both solutions, along with the glycerin, were mixed in an industrial blender and casted onto 1x1m molds, to be later dried in an industrial oven at 50°C.

We made physical and chemical material characterisation tests to determine its properties. We analysed its water absorption capacities with swelling tests in water. Its p morphology was assessed through Scanning Electron Microscopy (SEM). Its absorption was tested through measuring the contact angle of the biomaterial. The analysis of its mechanical properties was done through tensile strength tests and elongation at breakage.
2.2 Applying prototyping techniques to the biomaterial

The bioplastic based on cassava starch, PVA and glycerine formulation has been tested through practice-led research prototypes using techniques to form it in different ways such as sewing machine, laser cutting and thermoforming.

When sewing, a thickness between 1 to 2mm is best. When the material is less than 1mm, it becomes too thin and sticks to itself, behaving more like a plastic film. When the material is over 2mm, it becomes too thick and is difficult to manage, even with an industrial sewing machine.

When using the laser cutting machine cutting at thicknesses between 0.1mm to 2mm were successful. An aspect to consider with this fabrication method is that if there is too much detail on the design, the bioplastic tends to burn during the cut. Another aspect to consider is that if there is too much detail to cut, the bioplastic loses its stability. Its joints are assembled by joinery, defining connections between part edges in the assembly designed for laser cut. Other assembly biomaterial options are to glue pieces with water, or by a sewing machine.

Thermoforming works best with homogeneous materials. As not all these films are 100% homogeneous, when thermoforming some areas break more easily than others. While working with mostly homogeneous biomaterial with 1mm or more of thickness, the material thermoforms at 167°C with positive results.

Figure 1. Sewing prototyping technique.
Figure 2. First prototypes using laser cutting technique.

Figure 3. Material glued with water prototyping technique.
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Figure 4. *Thermoforming prototyping technique.*

2.3 Workshops

One way in which we are rethinking material alternatives is through holding events such as workshops, talks and conferences. It allows professionals, academia and other practitioners from many fields to hold a joint dialogue about how materials and objects are managed in the present, and the need to be co-create new alternatives. Creating the spaces of conversation engages the community with material matters, even if some are in a still distant future or very hypothetical scenarios. Most of all, it opens up spaces for this work to take place outside laboratories, giving people confidence to engage hands-on with biomaterials, and understanding how to produce their own resources with waste.
3. Results

The process of reimagining plausible future scenarios through bio-materials raises more questions than answers. The agency of materials sets new interaction possibilities with waste and the way we buy and consume ‘stuff’. The prototypes we create are not inspired by dystopian scenarios but by possible interactions within an uncertain future. Some examples are 100% biodegradable edible objects, garments that deliver data or work as probiotics for our body. They include garments that double as ‘seed carriers’ in case of nomadic emergencies, and materials that are entirely engineered and composted at home. These are only a few of the possibilities in reimagining material processes, manufacturing, use and adaptation to natural surroundings and potential future environmental threats.

3.1 Characterization methods

The results from characterization methods showed a high level of swelling the first 30 minutes, but then it loses its stability. As for its water absorption, the result shows little hydrophobic capacity. On the other side, its elongation test showed the bio plastic is able to expand to twice its original size. Furthermore, the film shows different breakage stress values due to its non-homogeneous result. Finally, it is shown through its degree of swelling
and absorption that the film is not as stable in an aqueous medium, thus natural fibres can be added to the formulation to improve this characteristic.

3.2 First tests

At first, we carried out research tests with different foods from which starch could be extracted such as sweet potato and cassava. After selecting the best Petri Dish samples, we tried to scale them to 33x25cm trays. After a few iterations varying the mixtures and the starch extraction base, we were successful with cassava starch. We began to perform more tests only with cassava but varying percentages of glycerine, starch and PVA. After a few tests we could obtain bioplastic variations. The tests showed the resulting material can be as flexible as a plastic bag, others more resistant as semi-rigid packaging, and in other cases have a more leather-like appearance. Furthermore, we tried shaking the mix before drying, obtaining a foamy appearance on the film. We also started to test with natural dyes. We used cochineal dye found in Andean local communities, where a very small quantity adds strong colours to the film. We mixed the cochineal dye with cream of tartar and water, adjusting the amounts to test colour intensity and water variations.

Figure 6. Cassava starch tests showed the resulting material can be flexible as a plastic bag (a); if using more amount of material have a more leather-like appearance (b); or if shaking the mix before drying a foamy appearance is obtained (c).
Once we had a homogeneous result on the 33x25 cm trays, we were able to scale the formula to a cassava starch film of 1x1 meter. The scaled films still present some degree of inhomogeneity but they have been improved through iteration that allowed us to start making real-scale prototypes. We went through an experimental process adding different dyes such as *juglans neotropica*, moringa, rose stem, and others. Also, we applied different densities to the trays to try various thicknesses.

Meanwhile, we also started carrying out tests with orange peels by extracting pectin. These materials haven’t been characterised nor have mechanical tests been done, but we are continuing research through prototyping to understand its potential applications.
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Figure 8. First test on 1x1 meter cassava starch film.

3.3 Bio materials applied to everyday objects

Biodegradable packaging is one of the potential applications for bioplastics, as we continue to phase out single-use plastic and paper bags from our lives. Our culture is moving slowly but contagiously into a conscious mindset that ‘things’ do not go away after throwing them away. Technologically we are already there on bio-based alternatives such as starch, wheat, banana, mycelium, or chitin; but our culture needs to catch up to demand competitive changes in the industry. This biopolymer based disposable packaging made from waste can also be produced and disposed of in environmentally sustainable ways. “They represent a possible shift away from plastics that can help detach humans from our reliance on fossil fuels” (Kandelin, 2019).

What if biomaterials are able to preserve food fresh longer, change color according to food freshness, be eaten, planted, composted or even add flavour to food?
Figure 9. Cassava starch bag.

Figure 10. Cassava starch film.
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Figure 11. Pectin based fruit packaging.

Figure 12. Cassava starch popcorn packaging
Figure 13. Cassava starch hotdog packaging.

Figure 14. Cassava starch French fries based on McDonald’s packaging.
The fashion industry is slowly changing but mass consumption still needs to catch up. “An estimated 50 million tons of clothing are discarded every year, and most of it will not biodegrade in a landfill” (Farra, 2019). What relationships should be built with consumers and clothes in order to add sustainable values to what we wear? These prototypes are inspired by this question: garments that give us data about our environment, edible clothes with added vitamins, multifunctional dresses, and ‘seed carrier’ garments. All of these prototypes reimagine the way we make our clothes: grown locally, made from agro-waste, or fabricated in local centers with open source designs that can be downloaded anywhere, and finally, eaten or composted at home.

Figure 15. This cassava starch swimsuit represents plastic garbage islands in the sea. The data represents 2018 patch between Central America and Europe (Law, 2019).
Figure 16. Cassava starch gloves offering skin benefits such as hydration, removes scars and spots.

Figure 17. Cassava starch with native seeds, serving as a seed carrier textile in case of emergencies were communities have to move more nomadically in a plausible future.
Each year, “more than 640,000 tonnes of nets, lines, pots and traps used in commercial fishing are dumped and discarded in the sea every year” (Laville, 2019). No matter how deep scuba divers search, fishing nets are found in the sea all over the South American coasts. These prototypes are based on objects that are able to be discarded and biodegrade gradually. For this reason, pectin-based bio textiles have been used for fishing nets, which resist water longer. Other accessories such as a hammock suggest crafted objects to be used while travelling, made from waste.

Figure 18. Pectin-based fishing net.
4. Conclusion

Bioplastics formulations presented in this paper show their exciting potential to be applied to everyday objects. However, it is necessary for our society to better understand the potential of these nature-based technologies, and to change behaviors and practices prioritising renewable life, standardized new systems and healthier interactions between us and our planet. The system that we live in today is not sustainable for the earth. We need to create models where humans imitate nature, changing our urban metabolism into circular relations with materials and energy within healthier cities.

“The ways in which goods, water, commuters, or food move through the urban ecosystem determines a city’s health and sustainability within larger regional and global natural systems”. (Eberlein, 2018)

Thus, the materials revolution can contribute to a more circular economy “based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems” (Macarthur, 2017).

The collaboration between academia and business will accelerate research to be applied to mass production. While our practice-led research inside academia is to create plausible applications, the industry can invest according to its interests, migrating its supply chain into sustainable solutions. According to CGS studies, “more that 50% of generation Z are willing
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to pay more for a sustainable product” (CGS, 2019). It will not only be about market incentives for greener products but also that consumers finally demand it worldwide.

Collaboration between disciplines is essential to develop a design and science-based approach, able to embrace complex systems and simplify them through fresh perspectives and navigating ambiguity. It allows the problem to speak through interdisciplinarity, facilitating understanding and making information more digestible. Furthermore, research through design facilitates spaces of dialogue that provide agency to materials through diverse scenarios. When the public can visualize a potential reality, they are more able to embrace innovation and engage with conversations that cross science, art, politics, geography and biology. While all these disciplines seek sustainable futures, design uniquely contributes to research through product, services and experiences that imagine sustainable concepts for multiple audiences.

So, where is all this going? After analysing increasing alternatives within biofabrication, I created a future road map based on this materials revolution. The aim of the roadmap is to describe the path from the present state towards a future vision providing a summary of various factors on different levels at a glance (Itälä et al, 2015). Throughout this roadmap, I analyse the present of biofabrication and circular fashion alternatives in South America. Then I draw my vision based on plausible collective actions and policy change scenarios that design a version of new consumer choices.

Figure 20. Road Map.
Figure 21. Experimental findings are seen through an interdisciplinary approach. Biohacker spaces, Fab Labs or bio laboratories are DIY labs usually collaborating with different fields of academia. Some are oriented to product development and use art as a medium to present plausible applications; others use biomaterials as a medium to make art.

The zeitgeist from the present is uncertainty about the future. Today’s generations feel responsibility to act game changers due to world’s climate change. Technology might solve climate emergencies, but there is an urgent need to awake from comfort, to act with awareness as individuals and mostly, to act collectively for a social transformation that drive positive changes forward.

References


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**Acknowledgements:** Thanks to Universidad San Francisco de Quito for its constant support to interdisciplinary and applied research. Thanks to Anastasia Pistofidou for sharing her knowledge widely.
Abstract | This investigation of textile entrepreneur Claudio Alcorso (1913-2000) provides new insights into the agency of the Italian design diaspora on global connections in the textile industry of the late twentieth century. The Alcorso family’s Jewish ancestry triggered the expropriation of their textile businesses in Rome by the Fascist regime in 1939. Desiring a move far from imminent war, they established Silk & Textile Printers Ltd (STP) in Sydney, producing silk and rayon fabrics using the then cutting-edge technology of screen printing. The business expanded, establishing networks with global textile producers, eventually becoming the largest textile printing operation in the southern hemisphere. The Alcorso’s business networks included Carrington & Dewhurst, Courtaulds and Sekers’ in Britain, Cohn-Hall-Marx (Cohama) in the USA and Toray and Teijin in Japan. Global connections enabled diffusion of innovative strategies that facilitated development of differentiated products to stimulate consumer demand in the face of increased competition.

KEYWORDS | DESIGN, CULTURE, MANUFACTURING, TEXTILES, GLOBALISATION
1. Introduction
The influence of the European diaspora on art, design and culture in the post-war era has been examined in fields ranging from photography to architecture. However, these investigations have yet to uncover the true extent to which Italian émigrés influenced the global diffusion and democratization of dress and textiles. This paper argues the importance of Italian-born Claudio Alcorso (1913-2000) in the manufacture of artist-designed textiles for fashion and furnishing for Australian and international markets, from 1945 to 1970.

2. The Piperno-Alcorso family in Italy
The Piperno family was well known in Italian textile circles, owning two departments stores and a factory in Rome (Italian Jewish Goods Commission, 2001). Patriarch Amilcare Piperno (1886-1961) served as government comptroller of woollens during World War I, receiving the Knight Commander of the Royal Order of the Crown of Italy in recognition for his service (Draper of Australasia, 1961). Amilcare later diversified his business into fancy silks, opening ‘Amilcare Piperno Al Corso’ at 172 Corso Umberto I in 1929 (Lupano & Vaccari, 2009). The store specialised in printed silk fabrics, catering to the sartorial needs of the Italian aristocracy, as well as fashionable patricians who had their clothing made to measure. A second store opened at 53 Piazza Fiume in 1937. It was a testament to modernity after extensive renovations by modernist architect Melchiorre Bega (1898-1976), who designed a sinuous interior staircase mimicking the swathes of fabric in the store windows (Università Roma, 2017; Behance Gallery n.d.). The interior featured Bega’s sleek, modern timber and glass cabinetry, used to display bolts of fabrics and all the trimmings required to produce the latest fashions for the stores’ clients (Villani, 1938). A catalogue celebrating the second store’s opening was designed by another modernist, Futurist artist and aviator Olga Biglieri Scurto (1913-2002), who worked under the pseudonym ‘Barbara’ (Ministero Per I Bene e Le Attivita Culturali, 2011). The cover showed a map of Rome from the air, marking the locations of Piperno Al Corso as an integral part of the eternal city, alongside historic sites including Hadrian’s Column, the Colosseum and the Victor Emmanuel Monument (Piperno Alcorso, 1937). Costume designer and fashion authority Mario Vigolo (n.d.) was retailed to design illustrations interpreting the latest Paris fashions in fabrications sold by the store (Lupano & Vacari, 2009). The business eventually came to define the family, who changed their family name to ‘Alcorso’ in the 1920s. Apart from the stores and factory at 24 Via de Campo Marzio, Amilcare had interests in several Roman properties (Camerano, 2004). He held shares in the De Angeli Frua silk mill, and had financial connections to Abraham, Brauchbar et Cie, a Swiss textile business that owned a printing factory in Lyon (National Archives of Australia, 1940-1954). Amilcare’s sons Claudio and Orlando had known Vittorio and Bruno Mussolini, the sons of the Italian dictator, since high school. Orlando attended classes with Vittorio, while Claudio had completed his compulsory national service in the Italian air force with Bruno (National Archives of Australia, 1940-1954). It was the Mussolini family that warned the Alcorsos of...
Claudio Alcorso and Post-war Textile Culture

their denouncement as Jewish descendants, and the imminent confiscation of their businesses (Alcorso C., 2016). The Alcorsos quickly began liquidating whatever assets they could to raise funds for their escape from Italy. It was one of Amilcare’s contacts, a manager at Abraham & Brauchbar in Zurich who introduced him to Alfred Gugenheim of St Gall, a provedore who smuggled the equivalent of £60,000 across the border into Switzerland in his fruit trucks (National Archives of Australia, 1940-1954). Claudio had driven to London earlier with his father’s assistant Paolo Sonnino, ostensibly to take a course at the London School of Economics. Orlando, who was studying languages in Switzerland, was soon joined by his parents, who brought other valuables that they soon liquidated, lodging their escape funds in a Swiss bank account (National Archives of Australia, 1940-1954). After fleeing from Italy, the family’s business interests were overseen by a Mr Storoni, a possible member of “Society Taccol”, a consortium of former employees, who bought the businesses after their expropriation by the Fascists (National Archives of Australia, 1940-1954; Italian Jewish Goods Commission, 2001).

The Alcorso family reunited in London, and began investigating options to establish a business as far away as possible from the coming European conflict. After researching opportunities in several countries, they decided on Australia. Their research revealed that it had the highest per-capita consumption of printed fabrics and few textile printing factories. The family decided that it would be the perfect location for a screen-printing factory producing silk and rayon dress materials (Alcorso C., The Wind You Say, 1993).

3. Silk & Textile Printers (STP) Australia

Arriving in Sydney in early 1939, Claudio, Orlando and Paolo Sonnino established a textile agency they called FISMA (France, Italian, Swiss, Manufacturers, Australia) using sample swatches they had brought from European print houses. Australian department stores, draperies and fashion manufacturers welcomed the Italians, who brought sophisticated designs that added variety to the ranges of more conventional prints that they bought through their British suppliers (Alcorso C., The Wind You Say, 1993). Gilkes Brothers & Hoskins Ltd were the only Sydney-based producer of screen-printed fabrics at the time (Lech, 2005). The market depended on imported prints, mostly from Britain. Cheaper prints came from Japan, and were relatively inexpensive due to a low exchange rate (The Textile Journal of Australia, 1934). The indent orders brokered through FISMA helped the family to establish client relationships and assess local taste and buying patterns whilst they built their printing factory. By early 1940, Silk & Textile Printers Ltd (STP) was operational, staffed by technicians and designers trained at East Sydney Technical College, who were ready to develop original textile designs along similar lines to FISMA’s European best-sellers (Alcorso C., The Wind You Say, 1993).

However, World War II interrupted the Alcorso’s plans. Claudio and Orlando’s friendship with the Mussolinis became known first to the Australian press and then to the military authorities, who arrested and interned them and Paolo Sonnino as enemy aliens in early 1940 (Alcorso C., The Wind You Say, 1993). Amilcare Alcorso and his wife Delia had by then
embarked on a ship bound for New York. Their Australian re-entry visas were revoked, and despite lobbying the Australian government, they found themselves stranded in New York. Amilcare set up an office in the Rockefeller Center, managing his Australian business through correspondence with Eric Hearnsaw, an accountant employed at STP (National Archives of Australia, 1940-1954).

Production at STP was co-opted by the Australian military authorities to print camouflage fabrics for the war effort, but there was some printing of fashion and furnishing fabrics on a restricted range of base cloths. Three young women artists employed in the design studio – Avis Higgs (1918-2016), Mary Curtis (n.d.) and Betty Skowronski (n.d.), managed the design of fashion fabrics, producing a series of monotone prints that sold quickly to retailers and manufacturers eager to obtain any stock due to wartime shortages. Higgs, Curtis and Skowronski engaged with the local artistic community, taking lessons from Hungarian émigré artist Desiderius Orban (1884-1986). Higgs joined the NSW Society of Artists, led by publisher and artist Sydney Ure Smith, exhibiting in their annual exhibitions. Hearnsaw saw the positive impact of Orban’s art lessons on STP’s output, agreeing that he could provide art lessons for the entire design team (Lloyd-Jenkins, 2000).

Herbert Read’s Art and Industry was a major influence on manufacturing at the time. Read’s position was that artists were well placed to provide integrated design solutions for industrial purposes, rather than applying pattern to utilitarian products as an afterthought (Read, 1966). His ideas were readily adopted at STP, who launched their collections from 1943 to 1946 under the title ‘Art in Industry’. Fabrics were exhibited next to the original artwork for each design, at major hotels and art galleries in Sydney and Melbourne. Product launches attracted glowing editorials in newspapers and women’s magazines, often illustrated with photographs of the attractive Higgs, Curtis and Skowronski standing next to their designs (Lloyd-Jenkins, 2000).

Claudio and Paolo Sonnino were finally released from internment when Italy surrendered to the Allies in 1943. Paolo immediately joined the Air Force, whilst Claudio took some time to recover from his internment with Nazis and Fascists whose politics he abhorred. Orlando, whose friendship with the Mussolinis was closer, was not released until sometime later. Hearnsaw continued to operate STP on a day to day basis, reporting frequently to Amilcare in New York. He also acted as Amilcare’s agent, brokering the purchase of textiles by Australian wholesalers on behalf of the General Overseas Corporation (Textile Division), the American company with which Amilcare was now affiliated (National Archives of Australia, 1940-1954).

4. Modernage

By 1944 Claudio Alcorso was back at STP as Managing Director, and business was brisk. He endorsed the design direction initiated by his designers and the art lessons delivered by Orban. The Australian government had released stocks of Italian rayon fabrics impounded at the beginning of the war, providing badly needed materials for fashion prints. STP developed a new shrink-resistant, fine wool fabric that they called “Peau d’Ange” (Angel’s Skin), with a
view to establishing an export market for printed Australian woollens (Lloyd-Jenkins 2001). The designers created striking prints illustrating the potential of the new cloth to buyers in the USA, South Africa and India (National Archives of Australia, 1940-1954). The family received good news in May 1945 from Mr Storoni in Italy, advising that ownership of Piperno Al Corso had been restored (National Archives of Australia, 1940-1954). Though little evidence remains about their post-war operations, it is likely that the stores remained under family control. Both were still trading under the Piperno Al Corso name during the Autumn-Winter 1949-50 season, and Amilcare and other members of the Alcorso family travelled often to Italy after the war (Piperno Alcorso, 1949; The Mercury, 1952). Meanwhile, Claudio and Orlando continued to manage STP with support from Paolo Sonnino and Eric Hearnshaw.

In the early post-war period a number of textile producers including Ascher in London and Wesley Simpson in the USA began producing collections of textile prints designed by prominent visual artists (Rayner et al, 2012). In March 1946 costume designer Matilda Etches (1898-1974) brought a collection of Ascher textile prints by artists including Cecil Beaton (1904-1980), Feliks Topolski (1907-1989) and Henry Moore (1898-1986) to Australia to great public acclaim. This direct manifestation of Read’s thesis on the importance of art in industry inspired Alcorso to commission his first collection of prints designed by prominent Australian painters. Alcorso approached Sydney Ure Smith to provide introductions to the members of the NSW Society of Artists. Many eagerly agreed to provide designs. Alcorso provided no design brief, preferring that artists draw from their own artistic idiom – original designs could easily be adapted into repeats by STP’s technical staff. Rather than buying the designs outright as was the norm, Alcorso offered a royalty of 2 shillings for every yard sold, a potential future revenue stream that proved attractive. STP tested a limited number of the artist’s designs in their 1946 ‘Art in Industry’ collection. Designs by Russell Drysdale (1912-1981), William Dobell (1899-1970), Margaret Preston (1875-1963), James Gleeson (1915-2008) and Donald Friend (1915-1989) were shown to an enthusiastic trade and public audience at exhibitions opening at the Hotel Australia in Sydney and the Sedon Galleries in Melbourne in September 1946 (Museum of Applied Arts & Sciences, 2000).
Department store David Jones, owned by Charles Lloyd-Jones, an amateur painter and member of the NSW Society of Artists, bought heavily from the collection, which was expanded in 1947 and given the title ‘Modernage’. Modernage comprised of 46 prints by Australian artists and the design team at STP. As part of a desire to create a national design style, some artists misguidedly translated Aboriginal motifs for their designs, ignorant of their symbolism and of the distress that their cultural appropriation caused to First Nation artists. At the time, Aboriginal people did not hold citizenship, and were regarded as ‘protected species’, not unlike Australia’s distinctive flora and fauna – a resource to be exploited for commercial gain.

Modernage was heavily promoted in women’s magazines and the metropolitan and regional press. In June 1947 the Australian Trade Commission launched a textile exhibition including Modernage at the Australian Trade Display Centre in the Rockefeller Center, New York. “Peau d’Ange” woollens were well received, with the fashion writer of the New York Herald Tribune devoting half her column to praise for the sheer, woollen fabric (The Textile Journal of Australia, 1948). Modernage was also used to promote modern Australian design on ocean liners travelling between Britain and Australia. The RMS Orcades and RMS Orontes, built by the Orient Line in 1947 and 1948 respectively, incorporated several Modernage.
designs in decorating schemes designed by New Zealand architect Brian O’Rorke. One of these was “Pearl Divers”, (Figure 2) designed by Donald Friend (The Textile Journal of Australia, 1949).

Figure 2: Donald Friend for STP, “Pearl Divers”, 1947, Screen-printed cotton. Approx. 96 x 89cm. Author’s photograph, National Gallery of Victoria, Melbourne, September 2012.

Alcorso positioned Modernage at the top end of the market. A premium price was charged in line with its association with fine art, and high consumer demand due to post-war textile shortages (The Draper of Australasia, 1947). 36-inch-wide cottons were priced at 17/4 shillings per yard, whilst competitor’s fabrics were priced at 13/8 per yard for 48-inch width (The Australian Home Beautiful, 1947). Whilst the collection was supported by glowing editorial and advertising, sales were only moderate, and there were few repeat orders. Alcorso believed that the modernist designs may have been too visually challenging for most Australian consumers (Alcorso C., The Wind You Say, 1993). The best-selling design was “Foliage” by Adrian Feint (Figure 3), a traditional design that presaged STP’s subsequent return to more commercial floral prints. It was felt that the majority of Australians were not culturally equipped to comprehend modernist design. As Bourdieu (1999) observed, art appreciation and perception involves a “deciphering operation” that is dependent on the viewer’s own understanding of aesthetics. This deciphering may not result in appreciation when...“one unconsciously applies the code which is good....for the deciphering of familiar objects to works in a foreign tradition”. A mainstream consumer with little aesthetic training or exposure to modernist design might find designs like Drysdale’s “Stone and Wood” (Figure 1) somewhat more challenging than a conventional floral. However, it is clear that overly optimistic expectations, combined with high prices and a limited range of narrow
width base-cloths also had a negative impact on sales.

Figure 3: Adrian Feint for STP, “Foliage” 1947, screen-printed cotton, approx. 52 x 90cm. Author’s Photograph, National Gallery of Victoria, Melbourne, September 2012.

A positive outcome of Modernage was that it demonstrated STP’s capability as textile printers. The factory was soon unable to keep up with orders, and new locations were sought to expand their production base. STP were offered a newly built, former munitions factory in Derwent Park, Tasmania, together with loans, concessions and incentives to relocate their business. Over the next two years STP relocated their entire printing operations from Sydney to Hobart. During the move, all of the screens and artwork for the Modernage collection were lost (Alcorso C., The Wind You Say, 1993).

5. The Leroy-Alcorso Signature Print textile competition

By 1951, STP had diversified into spinning and weaving in addition to printing around four million yards of textile piece-goods annually (The Textile Journal of Australia, 1951). New investments were made in technology, and the company enjoyed nearly a decade of continuous profits. Alcorso secured a loyal workforce from the suburbs surrounding Derwent Park, as well as skilled migrants arriving from the United Kingdom and Italy. He commissioned Australian architect Roy Grounds (1905-1981) to design purpose-built, three bedroom houses at the “Alcorso Village” at Moonah for sale to STP’s workers through subsidised loans. These incentives, combined with excellent working conditions ensured that sick-days and accidents were minimised, supporting efficient production continuity (Edwards, 1958).
Alcorso had not forgotten the importance of Australian artists in developing original prints. In 1953, he partnered with a major client, Melbourne fashion manufacturer The House of Leroy in the Leroy-Alcorso Signature Print Textile Design Competition. He hoped the competition would bring international recognition to Australian artists, as winning designs would not only be printed by STP for Australasia, but also licensed by the Cohn-Hall-Mark Company (Cohama) in the United States and the Berne Silk Manufacturing Company in Great Britain. Designers would be paid 2d commission on each yard sold, with a further prize of £100 awarded to the designer of the best-selling design the following year (The Australian Home Beautiful, 1954). Once again, this royalty-based model provided a cost effective way to commission artist-designed textiles without excessive risk to Leroy or STP, also providing artists with a suitable incentive.

Entries were received from over 750 amateur, student and professional artists, including many artists that had designed for Modernage. Douglas Annand (1903-1976), a Modernage veteran, won first prize of £300 for his design of torn pieces of monotone spotted paper set against a brightly coloured background (The Mercury, 1954, p. 5). The Leroy-Alcorso Signature Print competition ran for a second time in 1955. That year, there were two joint winners each receiving £150, both of whom were amateur artists. The reasons behind the competition’s demise remain unclear. It may have been the victim of a changed relationship between STP and Leroy, or complexities associated with paying royalties to artists. Changes occurring in international textile markets may also have been a factor. Japan’s textile industry was printing high-quality cotton fabrics at prices that could not be matched in Australia. Other Asian nations were also producing printed textiles that were cheaper than Australian equivalents, despite punitive import tariffs imposed by customs (Owen, 2010). In response to this increased competition, STP strengthened its’ networks with producers overseas, and concentrated on their strengths – printing silks, rayons and the new, easy care synthetic fabrics that were then then taking the international fashion industry by storm.

6. International networks

Alcorso began a close business relationship with Sekers Silk, the Australian branch of Sir Nicholas (‘Miki’) Sekers’ West Cumberland Silk Mills, founded in Britain in 1938. The Australian branch was managed by Sekers’ friends, fellow Hungarian émigrés Andrew and Vera Kaldor, who arrived in Australia in 1952. Sekers’ European ranges had found their way into the Paris collections of Christian Dior, Elsa Schiaparelli, the House of Worth and Jean Patou during the early 1950s. He was regarded as a textile innovator, producing synthetic dress textiles as early as 1945, and 48-inch-wide fabrics for fashion when the norm was 36-inches (Coulam, 1953).

Like Alcorso, Sekers recognised the value of artist-designed prints (Sekers Silk, 1959). In 1960 he accompanied a collection of prints designed by Cecil Beaton, Graham Sutherland (1903-1980) and Oliver Messel (1904-1978) that were exhibited in major department stores around Australia (Draper of Australasia, 1960). Miki Sekers also recognised that it was more efficient for an Australian production facility to print fabrics for his customers in the Far East,
Australasia and South Africa, instead of shipping finished cloth from the UK. STP was well equipped to take on contract printing for Sekers and other European and American textile houses. In August 1961, STP and Sekers cemented their alliance with an agreement appointing Sekers as exclusive distributors of printed and plain silk fabrics produced by STP (Clothing News, 1961).

Alcorso developed direct sourcing strategies to ensure the ongoing supply of base cloths that could not be produced viably by STP. He visited Communist China regularly from 1957, years before diplomatic relations were restored with western nations, securing a direct supply of silk base cloths for dyeing and printing (Alcorso C., The Wind You Say, 1993). This ensured that Sekers led the market for printed silks in the southern hemisphere.

STP’s design team produced original designs, which were supplemented by designs bought by Alcorso from the Paris studio of designer Georges Delhomme, and designs from Sekers’ UK collections, which were re-coloured for the Australasian market by STP’s design team under the direction of Vera Kaldor. Best-selling prints from the southern hemisphere also found their way back into Sekers European collections (Clothing News, 1962).

Andrew and Vera Kaldor’s son John began working at STP in 1957 as Alcorso’s assistant, after a textile design course under Bauhaus teacher Johannes Itten in Switzerland, followed by an internship with his godfather Miki Sekers. By 1960, John Kaldor was back working at Sekers as a textile stylist (Graham & Kaldor, 2008). In 1962, he created “Sekers’ Australian Artists Originals”, a collection paying direct homage to Alcorso’s Modernage. Designs for cotton furnishing textiles were commissioned from Australian artists including Modernage alumni Drysdale, Gleeson and Friend and other prominent painters including Cedric Flower (1920-2000), Elaine Haxton (1909-1999), Judy Cassab (1920-2015), John Olsen (1928-), John Coburn (1925-2006), Ian Van Wieringen (1943-) and sculptor Clement Meadmore (1929-2005) (Cochrane, 1992). The collection was launched in February 1963 in an exhibition titled “Art in Décor”, at Sydney’s Dominion Galleries and the Museum of Modern Art (Heide) in Melbourne (Clothing News, 1963). However, the fabrics were printed by Kanebo in Japan rather than by STP in Hobart, highlighting the high quality and low cost of Japanese printed cottons that was making Australian production increasingly unviable (The Australian Home Beautiful, 1963).

Alcorso stepped up STP’s export programs in response. In his memoir, he recalled how proud his father Amilcare would have been, had he known that STP sold 200 rolls of printed silks to Galtrucco in Milan, which he regarded as the best fabric shop in Italy (Alcorso C., The Wind You Say, 1993). In 1964, STP participated in the Australian Trade Commission’s floating exhibition on the trade ship ‘Centaur’, which travelled through Asia carrying displays, public relations staff and fashion models, staging events and meetings with buyers at each port of call (Clothing News, 1964). STP’s exports to England, Europe, Hong Kong and New Zealand increased from £98,000 in 1961 to £170,000 by the end of the 1963-64 financial year (STP Holdings Ltd, 1964). Alcorso’s successful export performance was recognised by the Australian Trade Commission with a number of special export awards (Clothing News, 1964).

By 1967, STP had merged with Sekers Australia and their main competitor, Tennyson Textiles of Sydney, forming Universal Textiles (Australia) Ltd (UTA). The merger consolidated and
rationalised production operations, creating a more efficient, integrated supply chain (Universal Textiles (Australia) Ltd, 1967). UTA diversified their products, producing new fabrics for niche markets. ‘Contender’ sail-cloth was produced for the marine market; special, hard wearing synthetic blends were produced for school uniforms and furnishing products such as readymade curtains were manufactured and pre-packaged for direct sale to retailers (Universal Textiles (Australia) Ltd, 1968). The company invested in new technologies including sublistatic (heat-transfer) and rotary screen-printing, providing increased production flexibility (Universal Textiles (Australia) Ltd, 1968). The business attracted interest from overseas and a number of prominent international textile companies held significant shareholdings in UTA. Lancashire firm Carrington & Dewhurst held 420,000 shares, as did James Nelson (Australia) Pty Ltd, a wholly owned subsidiary of Courtaulds in the UK. Both the Toyo Rayon Company Ltd (Toray) and Teijin in Japan held 300,000 shares each; Sekers (UK) held approximately 167,000, whilst Bruck Mills (Australia) Ltd, the local subsidiary of the Canadian-based producer held nearly 62,000 shares (Universal Textiles (Australia) Ltd, 1967). Throughout the 1960s Alcorso continued his patronage of the arts through UTA, together with his like-minded colleague John Kaldor, who now managed design direction and marketing for the company. In 1966 they established the ‘Alcorso Sekers Travelling Scholarship Award for Sculpture’, providing £1,000 annually to fund overseas travel for an artist (The Sydney Morning Herald, 1965). The competition ran until 1969, receiving many entries from the crème of Australia’s sculptors, including Col Jordan (1935-), Michael Kitching (1940- ), Robert Parr (1923- ), Ken Reinhard (1936- ) and George Baldessin (1939-1978) (Art Gallery of NSW, 1967). However, in 1969, its final year, the travelling scholarship was somewhat overshadowed by another of Kaldor’s art initiatives. When it was completed in 1969, ‘Wrapped Coast’, the installation by Christo and Jeanne-Claude at Little Bay, Sydney, was the largest single artwork in the world. More than one hundred workers, including professional mountain climbers, art teachers and students contributed to the realisation of the artist’s vision to package the landscape in textiles. UTA donated the fabric used by Christo to wrap the coastline - it was another of their new specialized products - a durable agricultural grade textile designed to suppress weed growth (Safe, 2013).

7. Sheridan
In 1967 UTA launched printed bed-linen under their existing “Sheridan” brand (Sheridan UK). Based on an international trend exemplified by Cannon and Fieldcrest in the United States, Sheridan produced sheets primarily in bright printed florals. Advertising agency Ogilvy and Mather developed a promotional campaign using endorsement from high-profile Australians including fashion designer Merivale Hemmes, explicitly targeting an emerging market of young fashion followers (Sheridan, 1970). The advertising was sometimes controversial, earning Sheridan and Ogilvy & Mather notoriety as well as publicity. Liberal Party Minister for the Army Andrew Peacock offered to resign his position over the appearance of his
fashionable wife Susan in advertising for Sheridan in late 1970. Susan Peacock had donated her $100 fee to charity, but her endorsement still caused a scandal. Sanity eventually prevailed and Peacock’s resignation was rejected (The Canberra Times, 1970).

UTA soon became a prime target for a corporate takeover. It had attracted the interest of Dunlop (Australia) Ltd, who saw an opportunity to add the newly rationalised business to its local textile and apparel operations. The Alcorso family, still major shareholders and directors of UTA, did not oppose the offer – thought that it would be good for the industry and their workers. The takeover was completed in June 1969. Claudio and Paolo Sonnino joined the board of Dunlop, whilst Orlando left the business to pursue other interests (Alcorso C., The Wind You Say, 1993).

It was soon obvious that the Board of Dunlop had little time for art patronage, or any social concerns that characterised Alcorso’s management style. They questioned the donation of fabric to Christo. They made it clear that they wanted immediate results from all product lines, and were unsympathetic about the performance of the Sheridan, still a fledgling brand. Alcorso became increasingly disillusioned with the Dunlop’s lack of vision, resigning from the Board in 1970 (Alcorso C., The Wind You Say, 1993). He was soon followed by John Kaldor, who set up his eponymous business ‘John Kaldor Fabricmaker’, shortly thereafter (Safe, 2013).

In the 1980s Sheridan developed an iconic collection of artist-designed bed-linen that finally enabled Alcorso’s vision for homes furnished with textiles designed by Australian artists to become a reality. From 1984 Sheridan produced a series of quilt cover sets designed by artists including Jenny Kee (1947- ) and Ken Done (1940- ). At the time there was international interest in the ‘Australiana Pop’ aesthetic - kitsch interpretations of Aboriginalia and Australia’s unique flora, fauna and tourist attractions including the Sydney Harbour Bridge and Luna Park, incorporated into colourful and often comical graphics. The comparatively lower cost and durability of Sheridan’s Australiana bed-linen, with its ability to change a room instantaneously, was an attractive option for mainstream consumers, compared with the limited appeal of Modernage fabrics twenty years earlier.

Sheridan opened a flagship store on Madison Avenue, New York City. Macy’s and the Federation Group also stocked the brand, together with major retailers in Asia including Daimaru in Japan. At one time, the company was making bedlinen in 110 different sizes to comply with sizes in multiple overseas markets (Sheridan, 2012). Sheridan continued to honour their founder’s goal to unite art with industry. In 2014 they launched the ‘Modern Art Series’ of artist-designed quilt cover sets with a catalogue including Alcorso’s biography (Sheridan, Summer 2014). In 2017, the company revived an internationally successful collaboration with Australian artist Ken Done, who produced a new collection of quilt cover sets similar to those he produced for Sheridan in 1985 (Figure 4).
Claudio Alcorso is not only remembered for his work in textiles, but also for other significant contributions to Australian culture. He helped re-establish wine production in Tasmania by founding the ‘Moorilla’ winery at his home in Berriedale in 1958, now the site of the Museum of Old and New Art, “MONA” (Alcorso, 1993). From 1970 to 1974, he led the Australian Opera to autonomy (Talia, 2000). As chairman of the Tasmanian Arts Advisory Board, he ensured that heritage buildings at Salamanca in Hobart were saved from demolition. He later initiated a grand vision to restore Hobart’s former ‘IXL’ factory buildings, repurposing them as an international boutique hotel and an arts centre, now part of the University of Tasmania (Alcorso C., The Wind You Say, 1993).

Claudio Alcorso was a champion of Tasmania’s pristine environment, writing extensively on the high quality foods, craft furniture and leather goods produced there by artisanal makers. As a prominent member of the Tasmanian environmental movement, he campaigned to prevent the damming of the Gordon Below Franklin River, a landmark victory of the Australian conservation movement. As a migrant, he was a strong supporter of a multicultural Australia, and an advocate of equality for Australia’s First Peoples, speaking...
often at Aboriginal Land Rights rallies (Alcorso, 1993). He was also an outspoken proponent of the Australian Republican movement, up to his death in 2000.

9. Conclusion

This investigation of the life and business activities of Claudio Alcorso provides new insights into the agency of the Italian design diaspora on global interconnectedness in the textile industry. It demonstrates how migration facilitated the diffusion of innovative business strategies that enabled the development of new, differentiated products to stimulate consumer demand in the face of increased globalization. It has enabled new connections to be made between the production of art, design, culture and textile manufacturing, against the backdrop of late twentieth century globalisation.

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Acknowledgements: This paper is based on doctoral research conducted by the author at the University of Technology Sydney from 2011 to 2019. The author wishes to acknowledge Distinguished Professor Peter McNeil, Dr Alexandra Fowler and her colleagues in the Imagining Fashion Futures Laboratory, Faculty of Design, Architecture and Building for their support of this research project.
Abstract | Contemporary arts and design practitioners are mobile, diverse and interdisciplinary. Often operating as micro-businesses or solo practitioners, they need new and innovative approaches that promote collaborative knowledge exchange and transdisciplinary experimentation. This ongoing practice-based research covers the developing co-creative relationships that arise through integrating digital making and data-driven processes as inspiration within collaborative distributed networks of design and making. The authors developed an analogue/digital transformation process for sound-inspired pattern creation, initially explored in the context of textile pattern design with a cohort of practitioners geographically distributed across Scotland, and now expanding out across other craft/design disciplines. Through a participatory design approach (Bannon & Ehn 2012), the project developed a series of collaborative workshops where the practitioners worked together with the researchers to develop new processes for inventing and generating transdisciplinary designs using non-traditional approaches, with designs taking inspiration from the “heard” rather than “seen” environment. It uses the robust multi-sensory process to promote alternative environmental attunement to place and landscape, whilst experimenting within a collaborative digital platform. Through these different lines of work, we explore what it means to be a practitioner in the twenty-first century in Scotland and beyond, including challenging the arts/crafts and craft/design divide through collaborative interdisciplinary participation.

KEYWORDS | COLLABORATIVE MAKING, DATA-DRIVEN DESIGN, DISTRIBUTED COLLECTIVES
1. Introduction

In the arts and crafts the notion of the lone genius creator is a common trope. Even in co-located arts collectives, collaboration tends to be limited to teaching, administrative or financial situations to share in the burden of these issues, rather than collaborating in an extended fashion on creative endeavours (Montouri & Purser 1995, Sennett 2009). Yet, this image of the lone creator is a limiting concept for the modern practitioner, particularly in an age when technologies permit collaboration at distance and where even remote geographies are digitally accessible. Modern arts/crafts practitioners are mobile, diverse and interdisciplinary; they expect to access information, skills and knowledge digitally; and they need to compete more and more with larger commercial/industrial enterprises across the same digital and analogue platforms (Bennett 2018). The need for new techniques and acknowledgement of cooperative approaches to design and creation, whether between groups of designer-creators or co-creating designs with other stakeholders are needed and mechanisms that support these new interactions are required.

This article explores the ongoing work and insights of the Royal Society of Edinburgh (RSE)-funded project Distributed Capacities, a creative network of contemporary Scottish art and design practitioners through a distributed and disruptive manner of collaboration. It uses a developing and robust digital/analogue multi-sensory process that promotes alternative environmental attunement to place. It does so through the consolidation of a small cohort of textile designer/makers into conversation and practice with a new collective of non-textile practitioners. In doing so, the project aims to explore what it means to be a practitioner in twenty-first century Scotland, including challenging the arts/crafts divide through collaborative interdisciplinary participation. Furthermore, this project questions existing ways of making and collaborating using digital/analogue avenues that augment, but do not replace the influence of the practitioner on the design process. It asks two key questions:

- How can multi-sensory digital/analogue processes influence contemporary Scottish maker/designer relationships?
- In what ways can these relationships develop a different attunement to the contemporary landscape and response to this?

This article will discuss the ongoing reflection, insights and challenges of this aural driven project. It will first provide a brief theoretical context in the provenance of the project alongside three key theoretical ideas of sound attunement, making and co-creation. This is followed by description and analysis of the first two research gatherings alongside participant reflections between those gatherings. Furthermore, we add a short component of ongoing work from the third digital gathering just before the onset of the pandemic. We finish with a developing critique of the work and a set of next steps for this project, which opens up dialogues of participatory design, collaborative making and a newly found perspective in sensory and place promoted within a twenty-first century Scottish context and through encouraging conversations between practitioners from different disciplines.
2. Context

This project builds upon the existing body of research and practice that took place with textile practitioners during a year-long research project called Aural Textiles, which explored the inputs of non-visual stimuli into textile production (Authors 2019). The bespoke sound-to-pattern process, developed through the project, involved listening and recording landscape sounds and transforming those sounds into textile patterns and designs. We evidenced that a novel set of contemporary textile patterns, across a range of textile disciplines, can be generated in response to the aural environment. Three key insights came out of that initial project:

1. Data-driven processes augmented but did not replace the role of the designer/maker. Each practitioner exerted control over the output that was generated that was dependent on (a) their pre-existing skill set and (b) engagement with the other project participants.

2. A digital/analog approach to working enabled practitioners to experiment with their process and technique, and the novelty of a data-driven design approach enabled them to be creative in new ways.

3. The use of digital platforms and ease of open source ways of processing and moving information allowed for the practitioners to share sounds between each other, as well as ask and answer questions or provide reflections on their own working practice within a private forum.

Therefore, the impact has been not only new entanglements between practitioner and their landscape and with each other, but an overall democratisation of the design and creation process. It is these new entanglements that this Distributed Capabilities project builds upon through a proposed design collective that promotes distributed and disruptive collaboration, including and extending beyond the original cohort of textile practitioners. Before moving towards the gathering, we briefly explore the three key theories that ground our research.

Sound Attunement

The sense of hearing is a key component of living things. In humans, the sense of hearing comes from the interaction between small air vibrations received within our ears and transmitted to auditory areas of the brain. This ‘sonorous presence’ (Nancy 2007) is always around, present in the landscapes and places humans inhabit. Listening or sound attunement ‘makes us re-think our relation to power and in deep listening a deeper dialogue is understood’ (Back 2003: 274). This is further emphasized in the way that sound is ‘tendentially methexic’ (Nancy 2007:10) meaning that sound and the act of listening has a sense of sharing and participation, beyond what is viewed and seen (Johnson 2016). On the other hand, listening also becomes a ‘decentred, receptive state’ (Williams 2019: 648) allowing for a multiplicity of sounds to inform how we understand the world around us. Listening, therefore, is more than just one type of state and thus should be a nuanced practice engaging the maker of sound (e.g. human, animal, or a thing, like the siren sound, or...
the low hum of electricity) and the practice of receiving that sound, allowing time to move beyond immediate interpretation. Attuning to the sonorous landscape is important not only to challenge our visual bias, but to open new inspirational cues in creative practice. The sound-to-pattern process (Mennie & Jaramillo 2018) used in this project promotes this sound attunement by allowing participants the ability to not only pay attention to the sounds around them, but to use and manipulate them into a malleable intermediate and give physical form to the concept of sounds, enabling tangible interactions with them (Figure 1). These intermediates began as spectrograms but have, in the course of this project, taken the shape of a variety of emotional or haptic interpretations of sounds.

Figure 1: The initial process showing the phases of capturing, transforming and visualising the lapwing bird sound into pattern and test weave/knit. (Source: Authors 2018)
Hybrid ways of making

The requirements for new approaches of making continue to grow as our design and product understanding evolve beyond industrial processes. These industrial processes can be seen as the instigators of the division and separation of the fine arts and applied arts. Digital practices are beginning to show that these divisions need not be made and that links between artistry, designing and creating are possible through what is termed a hybrid way of making (O'Donovan et. al 2017). In our existing work this analogue-digital-analogue iteration allows for an experimental and easily prototyped approach to making. This idea parallels work of Andrew & Diamond (2018) that sees a broadening acceptance of digital tools into textile craft. In this sense, the collaboration happens not just between people but between people and the digital process thereby mutually augmenting each other. It is this mutual augmentation that we will explore in our network, extending into disciplines beyond textiles by inviting each textile practitioner to pair up with a practitioner from another discipline in order to disseminate and further explore the process of data-driven design.

Co-creation

The idea of building and designing together traditionally involved sharing skills, responsibilities and forms. As industrial procedures forced the separation of design from production and from consumption the notion of creating things together was relinquished to the designer and maker. Yet, from the 1950s onward the idea that people, user, participants, or stakeholders all could have a say into the design and decision-making processes was exemplified through participatory design (Sanders and Stappers 2008), user-centred design and the notion of co-creation. Co-creation describes a process of producing items of mutual value, allowing design and production to sit between multiple stakeholders and creator (Prahalad and Ramaswamy 2004). This, however, only answers a part of the evolving idea of co-creation where it is seen mainly as a connection between a creator and a group of users or consumers. The work of Ramaswamy and Ozcan (2018) further this discussion towards an interagencial socio-material assemblage of co-creation. Their value-in-interactional creation supports the agency between multiple actors within a collective of making. For the purpose of this project, we support the notion of co-creation ‘as a creative process that taps into the collective potential of groups to generate insights and innovation’ (Rill & Hämäläinen 2018: 24). This allows an understanding of thinking that is not only inclusive of the value making approach but also incorporating the multiple agencies inherent in this collaborative project. In the end, these three components of hybrid making, co-creation and sound attunement form the foundations of the ongoing research enabling a rich and strong area from which to develop the work.
3. Process

The six previous Aural Textiles participants, whose practices encompassed weaving, knitting and screen printing, enrolled in the Distributed Capabilities project. Six new creative practitioners were recruited to take part in the project, with disciplines spanning fashion, jewellery, ceramics and woodworking. The project was planned to take place over three phases spanning the course of 18 months: exploration, iteration, and curation. Each phase would allow the participants’ time to work with each other at a relatively longer pace, punctuated with three weekend gatherings, and culminating in a public exhibition. The gatherings use a participatory and design innovation methodology (Bannon & Ehn 2012; Dixon & Murphy 2017) that addresses complex challenges through new design practices and bespoke participant engagement. Through our creative and participatory design labs we collaborate with practitioners, addressing the research through creative approaches to co-create preferable futures. We brought this expertise to ensure an interactive session leading to positive and productive outcomes. Key areas for exploration included: engagement, partnerships, governance structures, as well as evidencing value and impact. In-between these gatherings, a digital platform enables continued support, knowledge exchange and reflection, maintaining momentum and presence whilst in a distributed manner.

Figure 2: The first gathering showing the collective group of participants (Source: Sambo 2019)
Gathering 1: Huntly

The first gathering in April 2019 allowed project participants to meet each other and share details of their respective practices. It also allowed researchers to share an overview of the sound-to-pattern process as a starting point for more detailed explorations between pairs of practitioners, as well as, allowing researcher to partake as participant (Chapman 2018). By the end of this gathering, the participants formed pairs comprising one member of the previous Aural Textiles group and one of the new practitioners, with some participants entering into more than one pairing. The intention for such pairings was to understand how insights gained by participants in the previous Aural Textiles project would be shared with the new group members (Figure 2). In the four months after this first gathering, each pair met in person and virtually a number of times to further explore their ideas and processes for sound-inspired collaborative creation of objects across their respective disciplines.

The gatherings were documented in our online blog and Instagram page as a way for all participants to share progress and thoughts with each other. Recorded interviews were conducted with all participants in order to establish each practitioner’s prior experience of data- or sound-inspired design and collaborative working; current working models (i.e. distribution of commercial work (retail, wholesale), research & development, residencies, exhibitions, teaching, other sources of income) and anticipated impacts of the project on their practice. Opportunities for future commercialisation were also discussed. The majority of participants indicated that they wanted the project to provide them an opportunity for creative exploration without a commercial focus, to “foster their artistry” (Wilckens 2019) but were interested to explore how outputs might be commercialised in the future. There was also a consensus among the practitioners that they wanted to challenge some of the expectations around “craft” – what it is; how we can use it to communicate and challenge ideas around identity in present-day Scotland; and how we value “making” (as individuals, groups, society).

After the initial meeting, the original members and the new participants paired up and agreed to meet for a six-month exploration phase, which they documented in reflective blog posts and on their business Instagram accounts. During this period, the pairs (and evolving trios) explored the connections between their distinctive disciplines, including between jewellery making and weaving and the connections of ceramics and surface printing. One collaboration in particular began to push the boundaries of sound exploration. As expressed in a blog post:

“One theme that we plan to develop is the idea of silence. Standing on the open moorland, Lewis stretches out as low rolling hills. Beyond that is a huge open expanse of sea and horizon. Apart from the roaring wind in your ears, the island is both visually and aurally quite quiet. Even the wind seems to turn to white noise after a while. This idea of silence relates back to the spectrograms – we’ll be looking at the negative space in the spectrograms – the background noise or silence as inspiration.” (Stevens 2019)
This brief description of a collaborative weekend between two of the practitioners evidences a new way of perceiving the wind. Rather than the sonorous presence it is the ‘sonorous absence’ or the negative capabilities of sound become the inspiration for further investigation. The gaps in-between the sounds form a new type of attunement to what is active in the landscape. These types of encounters carry on towards the second gathering in September 2019.

Gathering 2: Helmsdale

At the second gathering, participants brought materials and tools for hands-on sharing and creative experimentation; as well as samples of work created during the exploration phase. A group reflection on sound-inspired design and collaborative working practices also took place, as well as individual interviews with each participant. Participants were tasked to share with the rest of the group a particular component of their practice. This was done to support creative exchanges but also to consider how public engagement activities could be created and worked out. This developed into a series of ad hoc creative encounters (Figures 3 & 4), with practitioners all learning and experimenting from different creative practices and understanding the processes of each practitioners’ way of making: when handing tools and objects from one practice over to an individual from another, the participants were less constrained by technical boundaries or commercial viability. This certainly fed the experimentation in the room and delivered some practice-led surprises. “I had never
thought to do it that way before” was a common remark. (Prosser 2019). It also laid the foundation for our next gathering looking at how we can best enable people to share with each other this sound-to-making process.

Interestingly, some of the practitioners are starting to move away from the data-visualisation elements of sound inspiration and have started exploring their emotional and graphic responses directly to the sounds; while others have started to introduce additional datasets into their designs. Both approaches point to a more in-depth and multi-layered engagement by the practitioners with the soundscape. At the end of the gathering, there was further discussion around potential routes/opportunities to commercialise outcomes from this project. At this stage, it was felt that this distracted from the main aims of the project and negatively impacted the participants’ experiences of the project, and the researchers decided not to pursue this further with the group until after the project was completed. Also emerging from this gathering was a clear sense that many participants desire greater input into the direction of the project in terms of defining the research questions and devising ways to address these, suggesting that over the extended period of this project the practitioners have shifted their perceptions of themselves from “practitioners” to “practitioner researchers”.

Gathering Three: Digital Gathering

The plans for a third gathering in March 2020 had initially been planned for a public engagement weekend at the UNESCO World Heritage site of New Lanark in south-central Scotland. Participants would have shared and critiqued their ideas of collaborative work and finalised their plans for creating objects for what was then an exhibition in autumn 2020. This, however, was not to be the case. The COVID-19 pandemic caused a massive halt to everyone’s lives and with it the project. This gathering though marked a period of rethinking and reworking and a point to pause upon the work up to the beginning of the lockdown. One of the collaborative pairs began to express their work not through the sound but rather...
through their own technical process (Figure 5). Through their online and in-person discussions they chose to find ‘a common vocabulary to make together, where our practices can meet—that had to come first’ (Prosser 2020). Another collaborative pair has shown a developing connecting between knitting and ceramics. Inspired by aspects of memory, dance and movement the knitting incorporates dropped-stitches and other ‘imperfections’ to attune to ideas of dementia and memory loss. These knitted fabrics are then used to make impressions into clay and fired. This creates two unique interactions, the first is the loss of the fabric, and the second the permanence of the stitches embedded into the finished glazed piece (Figure 6). This has brought about what one of the participants states as ‘playing at the edge of what the materials can do conceptually’ (Prosser 2020). The fusion of knitted fabric and vitreous nature of ceramics create a new and exciting hybrid connection.
As with any type of research involving people, inter and intra-personal challenges arise within the collective. In particular as the collective has grown the necessity for ongoing reinforcement is needed from the researchers. The use of various social platforms allows the necessity for collective sharing, though does not maintain a strong level of connection if it is not continuously used or updated. This and other challenges are ongoing and will require further investigation and review towards the end of the project. Alongside these developing insights are ongoing reflections by the practitioners whose developing understanding of sound attunement has expanded form the initial research space. One participant states, regarding her exploration of call and response to dances and songs, ‘I’m fascinated by the

Figure 6: The experimental artefacts between the knitted fabric and the clay imprints (Source: Hopcroft and Sinclair 2020)
idea that sound doesn't just originate from the performer, and that an active audience contribution becomes a vital element in the overall musical experience’ (Hopcroft 2020). This notion that sound is decentralized from the soundmaker reflects back upon the earlier aspects of listening, taking into account that sound making and listening require multiple way of interacting and interpreting.

4. Next Steps

This article has explored the varying stages of an ongoing design research project. It focuses on the collaborative developments of cross-disciplinary and sound-inspired making between a group of practitioners across a distributed network in Scotland. Since March 2019, this collective has encountered new approaches to aurally engaging place as well as working through a growing collective. Its needs and challenges have provided much needed discussion around the tools used, and the needs and desires of the making community.

It has also provided a small window into the developing work to a point at which the COVID pandemic would impact the wider creative community. The next stages of this project will look towards consolidating the collective work, working through pandemic related issues of collaboration, and moving towards curation of the co-created objects in the Spring 2021 for a final exhibition. It is hoped that we will deliver public workshops on sound-inspired design/making as a way to develop the understanding of and storytelling around sound-inspired making and objects. In the end, this project has undergone a series of key transformations from small collaborative network focused around textiles to an evolving assemblage of practitioners. It has opened up dialogues between making and listening, providing the practitioners with new tools not only for their own practice but new ways of working (together).

References


Collaborative Capabilities: Aural Encounters in digital/analogue co-creative making


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Acknowledgements: This work would not be possible without the ongoing and active participation of Cally Booker, Laura Lightbody, Carol Sinclair, Beth Farmer, Dwynwen Hopcroft, Marie Melnyczuk, Isabelle Moore, Olive Pearson, Netty Sopata, Orla Stevens, and Jen Stewart. We thank Zöe Prosser, Lina Wilckens, and Daniele Sambo for assistance with documenting and analysing the gatherings.

This work was funded by a Network Grant from the Royal Society of Edinburgh to Dr. George S. Jaramillo and Dr. Lynne J. Hocking-Mennie.
Collaborative ontology design for Open Hardware and Open Design

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Abstract | The integration of ICT, open source software and practices, digital fabrication and online marketplaces has enabled designers, engineers, and makers to independently design, distribute and manufacture the physical replication of tangible Open Hardware and Open Design artifacts. Orchestrating these distributed chains, actors and technologies requires comprehensive documentation of elements and across multiple domains and applications. The goal of this paper is to explore how an ontology of Open Hardware and Open Design artifacts could be collaboratively designed and what could be its main elements. In this paper, we present the results from a workshop that explored the prioritisation of domain concepts through a game of card sorting/generation to classify the elements of an ontology. Furthermore, we elaborate insights and Research through Design strategies towards integrating the design of ontologies with the participation of users and their communities, bringing Community-Centred Design to ontology engineering as both Meta-Design and Ontological Design.

KEYWORDS | OPEN DESIGN, OPEN HARDWARE, ONTOLOGY, DOCUMENTATION, META-DESIGN
1. Introduction

The integration of ICT, open source software and practices, digital fabrication and online marketplaces has enabled designers, engineers and makers to independently design, distribute and manufacture the physical replication of tangible artifacts. This possibility has been reinforced with the increasing ease of organising both local and global supply chains connecting local manufacturers, manufacturers in China and the distributed network of makerspaces. These elements constitute the Open Hardware (Ackerman, 2009; Gibb, 2014) and Open Design phenomenon (Abel et al., 2011; Bakırloğlu & Kohtala, 2019; Cruickshank, 2014). This generates innumerable possibilities for design in practice, education, research, entrepreneurship and social innovation. Orchestrating these chains, actors and technologies can be a complex task, since its distributed nature renders even the discoverability of such documentation a critical issue. Distributing and sharing design projects over ad-hoc value chains requires a comprehensive documentation of elements beyond the mere tangibility of artifacts (processes, software, electronic design, ...) spanning across multiple domains and applications.

There is a gap in practice and research regarding how such documentation can be generated and managed, given its complexity in terms of elements (CAD files, video, images, code, schematics, bill of materials, ...) and technical and application-specific information (authorship, copyright, information architecture, code, patentability, function, application, ...) adopting different documentation formats and practices (Lena-Acebo & García-Ruiz, 2018; Menichinelli, 2018; Milara et al., 2019). The goal of this research is to fill this gap by exploring how an ontology of Open Hardware and Open Design could be collaboratively designed. In information and computer science, an ontology is the semantic level of abstraction of data models in a database: a formal representation that model a domain of knowledge or discourse designed as a digital artifact with specific purposes; it informs data structures and interfaces in digital environments, tools and platforms (Gruber, 1995, 2009). Therefore, in the context of this article we focus on ontologies as formal description of data formats for documenting Open Hardware and Open Design projects. Here the ontology by itself is not a complete system ready to be used, but a first prototype of a set of metadata that enables developers to build and integrate systems on top of it, in order to aggregate data from multiple platforms and sources that would be thus standardised and easily catalogued and discovered by users.

The main research question of this paper is: What could be the main entities of an ontology that describes Open Hardware and Open Design projects? The topic was assessed through a card sorting game workshop in which participants classified and prioritised the elements of an ontology, considering its domain concepts. This paper elaborates such experience by proposing some contributions about how the design of an ontology can be co-created, and ultimately also on how the design of design ontologies can be reconfigured as both Meta-Design and Ontological Design. By reflecting upon the results and limitations of the workshop, three Research through Design strategies are developed for three platforms in
order to integrate the practice and research of the design of ontologies with users and their communities’ participation towards a Community-Centred Design to ontology engineering.

The paper is organised in the following structure: this introduction (1) sets the context, goals, research questions and methods of the article. The next section (2) clarifies the relationships between the design of ontologies, ontologies of design and Ontological Design. The workshop and its results are then documented (3), and insights from them are discussed (4). The last section (5) summarises the main results and suggests approaches for overcoming the limitations of this research.

2. Ontologies and Design

The representation of artifacts and the processes for creating them has always been a central element of the design activity (Diaz-Kommonen, 2002); this is even more important with open projects, that are shared, collaboratively edited and enacted in a distributed way. Sharing the documentation necessary for the design and creation of artifacts is a key element: for this reason, the concept of access to the (open) source of a design has become the most popular approach to designing with and for open and peer-to-peer distributed systems (Menichinelli, 2016). This paper focuses on one specific foundational element of design representations: ontologies. The development of ontologies is a key aspect in developing the organisation of the information describing design artifacts and processes (Menichinelli, 2018; Svenonius, 2000).

Ontologies, however, cannot be considered only as the structure of the data for design artifacts and processes: the connections between design and ontologies are more profound. The concept of ontology has here a duality: “In philosophy, ontology is the study of the nature of reality and the categories of things that exist. In information science, an ontology is a formal representation of the universe of things that exist in a specific domain. What these two approaches to ontology share in common is that they both articulate a universe of entities and relationships between entities” (Pomerantz, 2015, pp. 46–47). Following this, the connections between design and ontology take place on at least three directions: 1) design of ontologies (ontology as a design material); 2) ontologies of design (design artifacts and processes described by an ontology); 3) Ontological Design (ontology as a worldview which is designed and which designs) (Menichinelli, 2020).

In design of ontologies (1), the adopted meaning of ontology is the one from information science and computer science. The role of ontologies is to enable the sharing, reuse and analysis of common understanding of the structure of information among people or software agents (Noy & McGuinness, 2001). Ontologies are also designed with a purpose: “formal ontologies are designed artifacts, formulated for specific purposes and evaluated against objective design criteria” (Gruber, 1995, p. 907). They are shared among agents and sustain their agency: “an ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents” and
“a specification used for making ontological commitments” (Gruber, 1992) by defining “the vocabulary with which queries and assertions are exchanged among agents” (Gruber, 1995, p. 909). In a database, an ontology is the semantic level of abstraction of data models, and enables the integration of heterogeneous data sources, enabling interoperability and specifying interfaces (Gruber, 2009).

Design practice and artifacts can be considered and therefore documented in several different ways (Menichinelli, 2018): design as (a) a process (“i.e. step by step instructions”); (b) as an organisation (“i.e. networks of interactions, work organisation’); (c) a documentation (“i.e. blueprints”); (d) as a production (“i.e. files ready for direct fabrication”); (e) as an artifact (“the artifact and its description”). In the direction of ontologies of design (2), designers adopt a Meta-Design perspective self-reflexively elaborating ontologies that describe all these aspects of the design practice, from processes (Green et al., 2014; Menichinelli, 2018) to design engineering activities (Sim & Duffy, 2003). For example, practitioners and researchers have proposed ontologies of open projects in Fab Labs (Määttä & Troxler, 2011; Troxler & Zijp, 2013). Other researchers proposed that, more generally, the role of designers in Open Design is to become meta-designers by being database and interface designers that create multidimensional design spaces based on a database ontology in order to enable users to become co-designers (de Mul, 2016).

Designing an ontology is a way of characterising the world and its entities through language by creating a classification system and vocabulary that provides the conditions for collaborative activities to emerge (Diaz-Kommonen, 2002; Svenonius, 2000). This leads to the third direction: in Ontological Design (3) the adopted meaning is from philosophy and about the human condition. Ontological Design “stems from a seemingly simple observation: that in designing tools (objects, structures, policies, expert systems, discourses, even narratives) we are creating ways of being, that we design our world, and our world designs us back— in short, design designs.” (Escobar, 2018, p. 4). Designing is fundamental to being human, and in turn we are designed by our designing, and in this aspect Ontological Design mainly works on the philosophical level of Meta-Design. And more broadly, with a conscious Ontological Designing we design not just artifacts but rather a new way of being, since they embed culturally specific intentions (functions) and therefore participate in agency. As a practice, Ontological Design can bring social change because by showing the possibility of multiple and complex worldviews not just for the design of artifacts, but also of material and immaterial infrastructure (management systems, communication systems, …) and systems of thought (Willis, 2006).
3. A workshop for collaboratively designing an Open Hardware and Design ontology

3.1. Goals and structure of the workshop

The inherent openness of Open Hardware and Open Design projects and the often DIY and empowering nature of the practices and principles of the Maker Movement give place to the centrality of how users interpret project documentation. The access to the documentation, infrastructure, and tools that enable potentially anybody to edit projects, also increase the amount of modifications, forking, duplicates and so on. If not well structured, project documentation can easily give way to misinterpretations and deviations from the intentions posed by the original or previous authors, creating the danger of an increasing degree of redundancy. This complicates the management of project documentation and therefore the development of the ontologies and tools it requires.

The flexibility and openness of such projects therefore require custom and proper ontologies so that their documentation can enable the participation of different actors and relevancy for different applications within coherent systems. In order to address this gap, the authors either organised or participated in a workshop in May 2019 that explored how makers could collaboratively develop an ontology for artifacts based on the analysis of the existing different types of documentation required for its replication. The “Ontology of the Open for Open Hardware” workshop took place on Friday 10th of May 2019 within the Creative Commons Global Summit 2019 in Lisbon, Portugal. The goal of the workshop was two-fold: 1) to evaluate the ontological integrity within the documentation of an artifact through the metadata present in its documentation, and 2) to collaboratively prioritise elements that help to unequivocally identify a single entity, that is, to draw a line between what can be considered a single artifact and its reproductions. Therefore, the workshop consisted of two main activities: 1) a group discussion where participants identified definitions described in open hardware documentation (Figure 1), and 2) a closed card sorting activity to determine the level of priority of all these elements (Figure 2). A two-fold set of definitions expressed in the documentation are being considered for defining elements (Svenonius, 2000):

- Conceptual definitions (which express the intentionality of the author towards the artifact). In this regard, conceptual factors refer to the purpose for which the artifact was created and documented. These factors may differ even for similar technological applications, for example, when two Arduino projects developed with similar technical requirements are used for different purposes.
- Operational definitions (in relation to the description of the artifact). Operational factors are related to the steps required for reproducing the artifacts. A change

1 https://ccglobalsummit2019lisbonportugal.sched.com/event/MiXg/ontology-of-the-open-for-open-hardware
in materials, dimensions or electrical components, for example, will define the manner in which the artifact will be assembled.

For the first activity of the workshop, participants were given the following items:

- A list of 25 metadata cards previously defined from examples of open hardware documentation.
- Open hardware project documentation examples for participants to discuss.

Organised in three groups, participants engaged in the discussion and evaluation of metadata elements that could be identified as more or less relevant for project documentation and were encouraged to write down missing fields that they considered important. Participants were able to quickly familiarise themselves with the documentation and the list of metadata, as well as how authors express some of these elements within the documentation of projects (Figure 1).

For the second activity of the workshop, participants took part in a card sorting game, where cards representing metadata elements were sorted by level of importance for the overall definition of an ontology while trying to avoid duplicate entities (Figure 2).

Figure 1. First activity of the workshop.
3.2. Results

As results of the workshops, participants elaborated a list of metadata elements that were ranked in terms of their relevance (Table 1). In a total of 28 elements, 17 are operational ones and 11 are conceptual ones: in terms of architecture, an ontology of Open Hardware mainly describes it as a technical effort through the elements, procedures and actors that enable its design, distribution and manufacturing. In terms of ranking, however, the perspective of the participants changes this approach: conceptual elements are generally considered more relevant: the average ranking is 12.9, and for conceptual elements it is 11.3 and for operational elements is 14.0. This disparity might point to a contradiction between the practice and ideals of Open Hardware, or an emerging change in them that it is not tracked yet. The main tension highlighted is between how artifacts are valued by users not only for their physical characteristics but for their intended purposes versus the type of technology, materials and procedures for developing them.
<table>
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<tr>
<th>Table 1. Ranking of metadata elements elaborated in the workshop.</th>
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<td>Metadata element</td>
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<td>----------------------------</td>
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<tr>
<td>Project name</td>
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<tr>
<td>Keywords</td>
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<tr>
<td>Problem that the artifact solves</td>
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<td>URI</td>
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<td>Description</td>
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<tr>
<td>Project type</td>
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<td>Date of publication</td>
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<td>Domain</td>
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<td>Manufacturing requirements</td>
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<td>Level of effort required</td>
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<td>Certifications</td>
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<td>Estimated cost</td>
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<tr>
<td>Stage of development</td>
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<tr>
<td>Estimated assembly time</td>
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<td>Interface</td>
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<td>Parts list/Build materials</td>
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<tr>
<td>License</td>
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<td>Usage description</td>
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<td>Version number</td>
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<td>Language</td>
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4. Discussion

4.1 Community-Centred Design of ontologies between practice and research, communities and meta-designers

The workshop described above was prepared by identifying the most common metadata elements of a selection of existing Open Hardware projects, then formatted as cards to be sorted. The aggregation/sorting exercise was done through a set of criteria proposed by the facilitator (for example: level of effort required, estimated costs, assembly time, manufacturing requirements, skills, tools, …) with three possible levels of priority. The idea of designing ontologies collaboratively and the specific methodology proposed was well received by the participants: it provided a good starting point for organizing, prioritising a collection of existing entities and for the discussion and addition of new ones to an ontology of Open Hardware projects.

More precisely, for the specific the audience of the workshop, the emerging ontology shows how Open Hardware is considered as a utility-oriented medium for designing and working, with a strong focus on problem solving, manufacturing and usage of the artifacts it describes. The ontology was designed by participants as the results of their thinking about how they would produce and use the artifacts. This utilitarian and problem-solving perspective can be considered as the result of cultural values of the Open Hardware movement or at least of the participants in the workshop, who thought about the ontology with their practice as a starting point.

A workshop like the one organised is, however not yet representative of a community: participants of the global Open Hardware and Maker Movement communities attended it, but more than a community of practice was a small sample of a community of interest in the Creative Commons licenses and their application. Their practice informed their view of the
ontology, the centrality of community-based organizations in such movements cannot be addressed and appreciated in such a context that was limited in time and space. We therefore propose that a collaborative approach can benefit the design the creation ontologies of open projects, with the active participation of the communities that will develop and adopt them so that their worldview can inform and support their practice and vice versa.

The discussions with the participants brought up how the definition of an ontology emerges from local practices. At the same time, we should also note the role of the facilitator, that by selecting entities and designing the cards and the dynamics of the workshops acted not just as a facilitatory but already as a meta-designer of the ontology, bringing design activities in the facilitation. From these two aspects we propose to consider that both practice and research, community and meta-designers should element of Community-Centred Design of ontologies.

Furthermore, we propose that the main results from the workshop are not a specific ontology tied to a limited audience and with a limited approach to design, but how the reflection on that experience could pave the way for more deep and complex design of ontologies together with communities. We then elaborate strategies for extending the experience, tools and methodology of the workshop to different communities, to be explored and researched in their practice. Given the importance of both design and research, and their ability to redefine ontologies, we suggest adopting Redström’s approach for building Research through Design frameworks (2017). Moving from the generic results of the workshop to concrete cases, the next section explores how the insights here elaborated GROUU, Make Works and Appropedia design and implement ontology with communities through its digital platform as an artifact towards meta-design. These three cases represent different approaches for addressing the issues of documentation and replicability of Open Hardware and Design projects in the Maker Movement: from a single project (GROUU) to a repository of projects (Appropedia) to a network of manufacturers of projects (Make Works). In all these three cases Community-Centred Ontology Design could be implemented especially in the product, project, program and practice.

4.2 GROUU

GROUU is a current doctoral research with a Research through Design approach, revolving around a set of networked sensors and actuation devices (IoT - Internet of Things) for precision agriculture to be used in diverse agricultural contexts. GROUU aims to democratise precision agriculture sensor networks and automation, addressing the effectiveness of knowledge transfer once tests and community implementations are valid and working. By

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3 https://make.works/
4 https://www.appropedia.org/Welcome_to_Appropedia
aiming to digitise Tacit Knowledge and transfer it between users, GROUU is also exploring the possibility of having IoT as a digitisation and knowledge transfer media. The goal is to extend the implicit knowledge conversion through the socialisation model proposed by Nonaka and Takeuchi (1995) to a digitally mediated data sharing and usage ecosystem. The design of standardised ontologies can achieve this for the Internet of Things, maintained through documentation and versioning protocols.

The Research through Design strategy (Figure 3) sees GROUU at the product level, consisting of multiple open hardware, software and design sources developed within a doctoral research (program) revolving around the redefinition of criteria for Open-Hardware-mediated knowledge transfer design and evaluation (project). These are connected with the practice of the doctoral candidate and experienced farmers involved in teaching each other best practices in farming. Finally, the paradigm connects all of these with the main trends of Pervasive Computing, Embodied Cognition and Tacit Knowledge conversion: this strategy would connect knowledge transfer to media digitisation; the research of new roles for existing technologies could democratize its access.

![Diagram of GROUU](image)

**Figure 3.** A Research through Design strategy for ontologies in GROUU.

### 4.3 Make Works

Make Works is an open source online directory for manufacturers, makers, material suppliers, and workshops to make local manufacturing openly accessible to anybody. The digital platform allows designers and makers to find manufacturers, material suppliers and workshop facilities in their local area to produce their artifacts in a distributed manner. Make Works operate in six regions: Scotland, Birmingham, Derby & Derbshire, UAE, Sweden, Catalonia. Ontologies in Make Works describe specific regions and their manufacturers in terms of industries, materials, processes and machines.

The Make Works team’s goal and, therefore of its Research through Design strategy is to explore with Action Research how to develop the platform by considering diversity,
inclusivity, and accessibility. The aim is to avoid reinforcing one single point of view to all the regions, enabling each community voice to be heard and agency with an approach inspired by Fraser’s social justice framework of representation, distribution and recognition (1998).

In its Research through Design strategy (Figure 4), the digital platform is the product part of a project made up of several platforms for connecting makerspaces, designers and manufacturers (who constitute the practice). The bottom-up factory listing process is guided by a specific Make Works Handbook that defines the program since it bridges practice and research and informs their workflows. The Handbook describes the starting, co-designing, operating and running of new regions with context-based contributions and suggestions. Finally, Social Justice, Distributed Design and Manufacturing represent the overall paradigm informing all of these. This strategy would then connect locally produced artifacts with designing networks of distributed design and production.

![Figure 4. A Research through Design strategy for ontologies in Make Works.](image)

4.4 Appropedia

Funded in 2006, Appropedia is one of the main wikis dedicated to sustainability and international development. Its community focuses on the documentation of open source appropriate technology (Pearce, 2012), and currently hosts hundreds of appropriate technology designs developed by its community. Ontologies in Appropedia comprise these categories: a) a description by the author of artifacts and tutorials, b) contextual applications of technologies in different conditions and through design decisions, and c) impact validation by users in terms of the Sustainable Development Goals or other domain-oriented impact frameworks. Appropedia aims to align its ontologies with the Open Know-How\(^5\) standard to reflect manufacturing capabilities and contextual aspects related to replication and impact to the ontologies.

In its Research through Design strategy (Figure 5), the platform’s documentation functionalities are the product to be developed, while the platform is the project. Open

\(^5\) [http://openknowhow.org/](http://openknowhow.org/)
research of appropriate technology is the program connected to and informing the work of design students, researchers, designers, makers and non-profits. Finally, Open Source, Open Design and Hardware and Appropriate Technologies represent the overall paradigm informing all of these. This strategy would then connect the documentation of the design and manufacturing of open artifacts with researching open source appropriate technologies.

![Figure 5](image)

**Figure 5.** A Research through Design strategy for ontologies in Appropedia.

### 5. Conclusions

The lack of standardised guidelines and ontologies for Open Design and Hardware create communication barriers and pose a problem for discovering these artifacts through machine-readable search engines and, therefore, ultimately to services and platforms for designers. This paper argues that a collaborative approach to the definition of ontologies could provide an exciting direction for creating documentation tools for developing and managing Open Hardware and Open Design projects and processes. Furthermore, exploring this direction could also improve our understanding of how a design approach could work with ontologies and digital technologies while enabling designers to reflect upon the nature of their practice and its impact on stakeholders’ cultures. Overall, this research points out how engaging communities in developing their technological infrastructure has far broader implications about design and its role in supporting collaboration and its practice, research and culture. This paper also contributes to the emerging approach of Community-Centred Design (Meroni & Manzini, 2014; Villari, 2013) by expanding its focus towards data ontologies and local worldviews. Through a focus on the community dimension, Community-Centred Design has extended the scale and complexity of the engagement of users in design processes and projects further beyond Participatory Design and Co-Design (through their engagement as individuals), User-Centred Design (through analyses of their needs) and User-Experience Design (through analyses of their experiences). This approach further adds a focus on the analysis of the communities’ worldview of how design processes and projects are structured (ontology as a worldview) by linking it directly to the development of digital tools and platforms that would support their engagement (ontology as a data format)
This approach enables designers to develop digital tools directly linked to how communities perceive and consider intangible entities such as design processes.

In this paper, we present the results from a workshop that explored the prioritisation of domain concepts through a game of card sorting/generation to classify the elements of an ontology. Furthermore, we elaborate insights and Research through Design strategies towards integrating the design of ontologies with the participation of users and their communities, bringing Community-Centred Design to ontology engineering as both Meta-Design and Ontological Design. The approach was well received by the workshop participants and provided content for the elaboration of several insights. However, such contents and insights are constrained by the limited context of the workshop. Further research should expand them by working directly with communities with an Action Research and Research through Design approach to give them an active role. For these reasons, the paper contains three Research through Design strategies for co-designing ontologies in three different examples of Open Hardware and Design projects within the Maker Movement: from a single project (GROUU) to a repository of projects (Appropedia) to a network of manufacturers of projects (Make Works). Thus, further research is important for improving the workshop structure and methods, extending to more elaborated methods and testing and implementing the Research through Design strategies in real life.

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Collaborative ontology design for Open Hardware and Open Design


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**Acknowledgements:** The authors would like to thank the participants of the “Ontology of the Open for Open Hardware” workshop, which took place on Friday 10th of May 2019 at the Creative Commons Global Summit 2019 in Lisbon. Likewise, they would like to thank the organisers of the Creative Commons Global Summit 2019 for hosting the workshop. Emilio Velis would like to thank Creative Commons for the scholarship support for attending the Creative Commons Global Summit 2019. André Rocha and Alessandra Schmidt received support from the Distributed Design Market Platform (591699-CREA-3-2019-1-ES-CULT-PLAT) Creative Europe project.
Contemporary Spaces of Apparel Design: Embracing both Digital and Physical Environments

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Abstract | The juxtaposition of digital technology with the physical environment has changed the way humanity moves through life, contributing to complex relationships with our surroundings. Spaces are no longer limited to the tangible as computer screens become portals to auxiliary environments, altering perceptions of distance and time. The relationship between the hand and material object has changed as the work of design blends virtual and physical spaces requiring agile design thinking. This article examines these digital and physical spaces through the lens of a reflective creative apparel design practice, specifically investigating the use of the digital textile printer alongside traditional garment-development methods. Craft and technology discourse provide a framework for using these spaces by analysing them as tools in the making arsenal. Here, by acknowledging the contemporary design environment and embracing the juxtaposed digital and physical spaces for design, an innovative workflow is established that encourages improved design and making systems.

KEYWORDS | DESIGN ENVIRONMENT, APPAREL DESIGN, DESIGN THINKING, TEXTILES, TEXTILE PRINTING
1. Introduction

The juxtaposition of digital processing devices with the tactile, physical environment has changed the way humans move through life, contributing to a more complex relationship with time and place. The time required to accomplish tasks, communicate overseas, or move across the globe has been shortened, and immediacy of results is celebrated. Life’s activities are now nearer each other in time, making the places these events occur nearer in thought, if not nearer physically. Because digital technology is a driving force behind this shift, product designers must consider how this affects the making process, the product being produced, and how the product will be used. Much design work is now conducted digitally, in a space where new hand and machine relationships are established. Working through a screen instead of manipulating physical objects allows for experimentation in design with the ability to “undo” actions or test multiple versions without committing to irreversible manipulation of materials. Design iterations are interconnected and virtually side by side for evaluation. This article looks at the digital design environment through the lens of a reflective creative design practice, uncovering how this environment operates as a space for innovative design thinking. Specifically, it investigates the use of the digital textile printer alongside traditional garment-development methods to seek out innovative processes through the development of a body of work using “making as a way of generating design knowledge.” (Loh, et al., 2016) It focuses on how both physical and digital design environments work as complementary tools that work in tandem rather than focusing on pre-programmed tool or computer program purposes; for as the more focused these purposes become, their range of creative use is limited. (Albers, 1971) Theoretical craft approaches to making provide a framework for using these digital and physical places by analyzing them as tools in the making arsenal; when these tools are combined with creative play, risk-taking, and design thinking established processes are challenged and pushed towards innovation.

Digital tools and processes are introducing significant changes to the way the apparel design industry operates, including the way clothes are produced. Traditionally, a skilled patternmaker using draped muslin and paper patterns would develop sewn samples that would allow direct evaluation of aesthetics, functionality, and material choice. Modification to the sample required additional versions, and unless a complete re-make is developed the original is lost. With the development of digital platforms, programs such as Adobe’s Illustrator and Photoshop, Optitex, Gerber, Browzwear, and CLO 3d provide both 2D and 3D spaces for apparel design and development. Within these constantly evolving technologies, the designer can save multiple versions, experiment with aesthetics and construction, and plan order of operations in the digital space before consuming physical materials for sampling. However, a design on a screen can only understand the nuances of physical material qualities as well as a person programming or using the machine understands them. (Albers, 1971; Edwards, 2000-2001; McCullough, 1996) This suggests that a relationship between processes would be more efficient and innovative.
To develop this relationship, the physical and digital design spaces can be organized and understood as tools. Through this lens we examine how designers might work to problem-solve by combining process and material knowledge with the use of the most appropriate tools. The impact of this designation of tools could be approached from several points of entry, but as it involves the work of designing itself a practice-based approach is taken here. Within this research framework, the development of a capsule collection of garments incorporating both digital and physical tools is evaluated. Current fashion design processes are often problematic, and instead of solutions that are merely “modifications of these undesirable practices and the status quo,” (Fletcher, 2014) this approach to the design process encourages the designer to experiment with new methods. In this work, using a practice-based methodology generated information from a maker perspective, supporting research of the design process; while this kind of research remains context-specific, it enables design research to operate as an “open system, one that is networked, responsive, and expanding.” (Vaughan, 2019)

2. Contextual Review

This research seeks to describe a progressive relationship between the digital and physical spaces of design by analyzing the design process, and it draws from previous research on design, making, and apparel design, with both long-standing sources as well as contemporary articles valuable knowledge contributors. Because using available resources as tools to manipulate materials frames this work, craft-based discourse is highly relevant; additionally, while today’s fashion and apparel field is a global, corporate industry the process of designing and assembling clothing has roots in craft as well. (Lou Taylor, 2004) Important to include here is the use of the terms “garment” or “clothing” instead of “fashion” in this article; Yuniwa Kawamura explains that “items of clothing must go through the process of transformation to be labeled as fashion” (2005), and here we will not be concerned with the sociological and semiotic transformation of the clothing object. Instead, we will focus on the designing and making process. Fiber artist Annie Albers’s text On Designing describes the dance between functional and aesthetic concerns, and how this affects the maker’s use of tools and materials; David Pye also writes about tools and the making process in The Nature and Art of Workmanship and The Nature of Design, providing a basis for making sense of balancing knowledge and skill with taking the risks needed to innovate. Bringing this into the contemporary lens, an article by Loh, Burry, and Wagenfeld is an example of how Pye’s theory on the complex relationship between tools forms a repertoire, one that includes both the digital and physical. Additionally, these sources are examples of how knowledge can be gained through the kind of practice-based design research executed here.

Sources affirming the validity of digital technology for creative use within craft and apparel applications is helpful for both theoretical and methodological purposes. David Pye and Annie Albers contribute perspective on the relationship between hand-crafted methods and
contemporary technology, while Malcolm McCullough describes how computers and software are virtual tools for developing and making. McCullough expounds on both of these concepts in Abstracting Craft. Taking this further, Dreyfus and Dreyfus explain the importance of human intuition and expert skill in the use of these tools in Mind Over Machine. While this text focuses on robotics and spends time addressing fears around the development of artificial intelligence, the debate between the power of computers versus the experience-led wisdom and intuitive understanding of a human mind provides a useful model to follow when balancing logistics and innovation. The 2001 Manus-Machina exhibition catalogue by Andrew Bolton showcases the use of digital technology in apparel design and is important to reference for perspective on using digital tools to make clothing. Because this work involved developing original textiles, sources such as Digital Textile Design and “Design Thinking for Textiles: Let’s Make it Meaningful” provided theoretical and methodological guidance.

3. Theoretical Framework

Textiles have long been used by humans to make garments that cover, adorn, and protect, and the garment manufacturing process has progressed along with advancements in better tools and new technologies such as the sewing machine. Additionally, social changes such as the industrial revolution and the rise of fashion houses at the turn of the century has led to the development of a complex, fast-paced industry that relies on digital design and communication to maintain. Before the current disruption from the coronavirus pandemic, this fashion system left little opportunity for the designer to think or work outside established systems of making clothes. The more regimented each step in the development and making process becomes, the less creativity or skill is necessary (Edwards, 2000-2001; McCullough, 1995); with regard to tools, the more focused they become, their range of creative use is limited (Albers). The fashion industry focuses on economies of time and money, and these processes settle at the most efficient balance of these with “best” ways of manufacturing generally evaluated in terms of their cheapness rather than ethical or environmental concerns. (Fletcher, 2016; Pye, 1964) Coping with the pandemic’s effects on supply-chain logistics and changing consumer buying habits is requiring a new perspective on these priorities, such as a re-connection of time between seasons and collections. (McAlpine, 2020) To help guide us towards the sustainable systems changes often called for in current fashion discourse (Bowles & Isaac, 2012; Fletcher, 2014; Gwilt, et al., 2011) as well as those demanded by the effects of the pandemic, we can look at theoretical models for working creatively outside previously established systems. This idea is supported in Pye’s (1968) theories on making, which acknowledge the safety in working within proven methods but also recognizes that taking risks is the only way to innovate, requiring a designer’s intuition and dexterity.

The digital environment of design, encompassing both 2D and 3D computer CAD programs, is itself a contemporary design and making tool allowing “Concepts [to] become things. We
can’t touch them yet, but we can look at them, point at them, and work on them as though with hand-held tools.” (McCullough, 1996) While this opens opportunities for innovation it also enables the simplification of complicated process and the automation of physical tasks – a capability that contributes to mental de-skilling as well. (Edwards, 2000-2001; McCullough, 1996) This defeats the exciting possibilities for creative risk-taking and innovation, converting the digital design environment into “a means to an end.” (Loh, et al., 2016) Dreyfuss and Dreyfuss explain that a computer is a logic machine that is an “ideal beginner,” and an expert is needed to use the tool in an innovative manner; with expertise and intuitive decision-making the user can challenge pre-programmed uses. McCullough supports this, stating that “masters respond to context, even when doing so means breaking the rules;” this also encompasses the “…exploration, improvisation, and, to use the simplest word, play.” (1996) When we simply collect processes to repeat, we do not construct new knowledge. (Albers, 1971)

The theoretical framework for this research is based on a craft approach to making, and by understanding the relationship between designer/maker, tools, materials, and end product we find a framework that encourages educated, creative, and methodical risks to open opportunities for innovative discovery. As Pye stated, “Tools of themselves make nothing,” (1964) and are limited to what they are used to accomplish. Without design thinking, or the “creative input and designing workflow from the practitioner… such toolsets remain outside the practice.” (Loh, et al., 2016) A designer with expertise in managing both digital and physical spaces of design in a symbiotic manner is needed to navigate the ever-evolving technologies that affect materials and tools. (Bye and Sohn, 2010; Carden, 2016; McCullough, 1996)

4. Process

The collection of garments completed for this work initially began as two separate tracks of design experimentation: one using traditional draping, patternmaking, and sewing methods, the other experimental prototyping using the digital design space. (Figure 1) Both directions sought to uncover design and making processes that would maximize the designer’s creativity, reduce material waste, improve emotional durability, and serve functional and aesthetic user needs. Open-ended experimentation and design “play” (Flanagan, 2009; McCullough, 1996) within these spaces soon merged, as intersections between processes began to surface and the capabilities of each environment benefited one another. The result was a larger body of creative design research exploring this relationship, primarily incorporating patternmaking and sewing skills with the use of Adobe Photoshop and Illustrator to develop original textile designs. The researcher’s twenty-plus years of patternmaking and sewing experience provided expertise in using textile materials and contributed an intuitive ability to manipulate shape and silhouette to minimize fabric waste. This was combined with dedicated research on the proper operation and capabilities of the digital textile printer. Use of textile printers began as early as the 1960s, and with
improvements in quality, speed, and accessibility these tools have contributed to connecting garment and textile design. (Bowles and Isaac, 2016) With these printers, designers can develop and design conceptually and aesthetically in a digital environment before committing to using actual resources. (Bowles and Isaac, 2016; Carden, 2016; McCullough, 1996) Furthermore, the digital printing process consumes far less water and energy, minimizing environmental impact. (Bowles and Isaac, 2016) In this way, the textile printer enables development and execution of creative, innovative, and less-wasteful garments; for these reasons, use of this particular technology became the fabrication tool spanning the digital and physical space.

Figure 1. The body of work completed in this practice-based research. The look in the far right uses the textured textile made from the motif components in the jacket.

The process of designing and constructing the garments integrated digital and physical spaces from the beginning. Garment patterns were physically developed using draping, flat patternmaking, and muslin sampling; simultaneously, textile print designs were developed digitally in Adobe photoshop. A snapshot of the Castilla coccinea wildflower provided the base motifs of the print; these were modified to adjust scale, contrast, and tone. By working in both spaces simultaneously, the textile and garment designs were developed in a complementary manner; volume and proportion created interest as well as highlighted the print designs. After developing the physical paper garment patterns and printing several successful 8”x 8” textile samples, the garment patterns were digitized and placed in photoshop to be joined with the textile print. Here, via the screen, the logistics and aesthetics of the project could be evaluated before moving forward. Several design problems presented themselves. First, the garment pattern pieces did not efficiently nest
within the printing area, leaving significant waste material. Second, the print scale was not appropriate for all applications on the garments. Additionally, the engineered prints and stripes did not match the intended pattern pieces perfectly.

Figure 2. The print layouts were completed in three- to five-yard increments. Tight nesting of the pieces was considered; filling in empty spaces are the smaller motif pieces.

To resolve these design problems, knowledge of the advantages of both digital and virtual places of design was employed concurrently; as a result, the plan for the printing process shifted from producing repeat print yardage to engineered printing. (Figure 2) This allowed the prints to be placed directly on the garment piece in the proper location, and the pieces from various garments could now be intermixed on the blank yardage to enable better nesting and create less waste. Correcting the textile print scale was easily done by digitally developing several versions to compare in relationship to the garment silhouette and body shape. Despite these modifications and a meticulous print layout, the printing process still left a significant amount of textile waste. Smaller pieces were needed to fit within the spaces of the layout, leading to the development of an additional garment that could utilize small,
repeatable components. Using the individual print motifs as component pieces, these were placed in every crevasse of the print layout, allowing significantly more of the raw textile to be used. (Figure 2) The yardage was printed, and the larger garments pieces were cut and sewn while the motif areas were arranged and placed in the laser-cutter to create hundreds of individual shapes. These were then attached to a base textile to create an entirely new textured fabric. (Figure 1) The resulting body of work represented a workflow incorporating physical and digital spaces as symbiotic tools enabling both resources and creativity to be maximized.

5. Analysis

Digital printing allows for flexibility in surface design through color, scale, and placement, and the juxtaposition of the physical and digital places of design using traditional knowledge alongside emerging technology created avenues for developing on-demand customization, accessible creative branding, and forward-thinking methods of making clothing. The open-minded view of incorporating these resources during the process is key, encouraging treating materials as a direct source of knowledge through direct material handling (Marr & Hoyes, 2016) and allowing the maker to respond intuitively when working in both physical and digital spaces. With this approach, they are used strategically as symbiotic tools and the space and time between tools is narrowed allowing design problems to be recognized quickly and resolved digitally. Logistics within the digital environment presented solution options, while knowledge of how the physical material would be sewn, constructed, and draped in the final printed textile material guided the final design solution. This illustrates how an agile, flexible, and resource-led attitude towards tools and materials enables the designer to understand and execute solutions. Risks were managed or worked out digitally before commitment to physical goods, and intuitive experience challenged the digital solutions to their fullest potential.

The designer is more capable of experimenting with methods that lie outside established systems and can develop ways of working that resolve problems such as those within the apparel industry. The challenges facing the industry include adjusting to significant changes in how products are produced, marketed, and purchased – an issue highlighted by the coronavirus pandemic – while resource-depletion, pollution, and ethical manufacturing remain problematic. A new perspective on the processes of design, including a holistic, resourceful view of materials and tools enables the designer to have greater impact through design thinking and incorporating solutions within the design, for “Change only begins to occur once practitioners come to understand the potential of new technology and are comfortable with it.” (Bowles & Isaac, 2012)
6. Conclusion

How we value and nurture the relationship between digital and physical spaces of design is critical to future innovation. Through applied design research and consequent reflection on that practice, a new workflow that shrinks the distance between the digital and physical environments emerged. Because this design research focuses on the tools and materials within each space, by framing these disparate design environments as tools or “toolchests,” the focus moves from an isolated or independent approach to an integrated one that allows the practitioner to use creativity and intuition to design a better workflow. (Loh, et al., 2016) This relationship between digital and physical tools assists the removal of limiting processes and tools for their intended purpose only, for “the more we learn how to do, the less we know what to do.” (McCullough, 1996) Guided by design thinking, the work of designing becomes an intentional, problem-solving activity as a result, and a more circular or responsive way of using materials and planning production occurs. Specifically related to this practice-based research we also see that “Design thinking is not a commodity, therefore the act of making textiles is more than a series of steps on the road to new product development and innovation.” (Valentine, et al., 2017) The work of designing using traditional garment-making methods alongside the digital textile development provides an example of how we can approach design in a contemporary manner.

A re-thinking of the apparel industry as a whole is often called for in discourse addressing concerns about resource sustainability, ethical manufacturing, and pollution (Fletcher, 2014; Gwilt, et al., 2011), yet recommended solutions are limited to modifying specific parts of the larger system or discussing larger theoretical approaches. However, these parts are interconnected, and focus on an isolated area limits effectiveness; furthermore, consumers expect both aesthetics and functionality, and both must be addressed. When either is highlighted, the designed object is limited, and this segmentation “arrive[s] at separate instead of at a single, all-inclusive form that embodies the whole of our needs.” (Albers, 1971) The designer is at the heart of this complex system, and “From the centralized position the designer can influence and impart new (sustainable) information that aids in the design and production of ‘better’ garments.” (Gwilt, et al., 2011) This places responsibility on the designer as a driver of systems change; with a contemporary perspective and understanding of the tools at their disposal they are better equipped and empowered to effect change. The industry is undergoing a seismic shift, and the various technologies being introduced are yet to be fully understood. But if we organize our perspective by considering the positive impact of condensing the space between these tools through physical and digital capabilities, the possibilities for developing innovative solutions to many of the challenges facing the fashion industry are reachable.

This suggests that we not simply look at what each place of design offers individually, and that we look beyond designing in a linear manner. This particular body of work began as disparate exploratory tracks, yet the contemporary design atmosphere requires collaborations of resources, including tools. The models of design and business planning are
undergoing an accelerated transformation requiring agility and progressive thinking. This requires organization of methods and tools, or the designing of a path to begin “mastering your means to the point they no longer interfere with attaining your ends.” (McCullough, 1996); brands and designers who embrace intentional, thoughtful incorporation of digitization within the entire the design development process will be equipped to survive the coronavirus pandemic and become part of a more sustainable, evolving new workflow. Considering environments or spaces of design as tools provides that organization, and by educating current and future designers, product developers, and makers how to harness the physical and digital places of design as tools in the making arsenal, they will be better equipped to balance the value of human understanding, empathy, and intuition with logistical, algorithmic, digital technologies to thrive in an increasingly virtual and data-driven world.

References


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Design Cultures of Making: Fashion thinking as creative process and pedagogy

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Abstract | This paper shares research being developed through an Art and Humanities Research Council, Creative Industries Cluster funded 5-year project, the aim of which is to transform the competitiveness, agility and creative output of the UK’s fashion industry. Its focus is to develop innovative, multidisciplinary STEAM+D based fashion designers, industry facing training, and education for post graduates fashion students, breaking down traditional fashion and technology silos. Through their work a group of researchers at the Royal College of Art attached to the Future Fashion Factory Project (FFF) propose fashion thinking as a new rational for fashion education that has three distinct strands – fashion thinking for social-change, fashion thinking for applied specialisation and fashion thinking through advanced manufacturing. Fashion thinking through advanced manufacturing is discussed here highlighting Discourse, a tool developed to enable investigation into current pedagogic models, and revealing the importance of developing new language competencies for fashion.

KEYWORDS | FASHION THINKING, DESIGN THINKING, INDUSTRY 4.0, DESIGN ANTHROPOLOGY, PRACTICE BASED, PRACTICE LED, STEAM+D.
1. Introduction. The Creative Industries and Manufacturing Landscape in the UK.

In the Executive Summary 2020, Manufacturing the Future Workforce, The High Value Manufacturing Catapult recognised that the overall contribution manufacturing made to the UK economy was in decline but the government wanted to make the UK more competitive in this field. The counter narrative developed through the Creative Industries Federation, the independent body which claims to represents, champion and support the UK’s creative industries, stated that the creative industries were growing at more than twice the rate of the UK economy. However, there was a recognition that UK creative industries were under-capitalised, suffered from skills shortages and were hampered by a lack of diversity and unequal access to opportunities. Agility, new skill sets and a younger workforce were seen as imperatives to greater success. The Creative Industries Manifesto (Creative Industries Federation Report 2020) proposed equipping the next generation of the workforce through returning creative education to the heart of the curriculum. Countering this, the Longitudinal Education Outcomes data (LEO, 2019) suggested studying for an arts and humanities degree did not enable graduates to earn significant salaries by age 29 when compared to economics or science graduates, with a sub narrative that undergraduate courses in art and design do not contribute significantly to GDP. The Creative Industries Manifesto suggested that metrics beyond salary were urgently needed to capture the true value of creative education. Wider measures such as social value, creative achievements, and civic contribution must be recognised they claimed.

A complex narrative and counter narrative are still developing in UK politics involving the creative industries, manufacturing and higher education. Post the UK leaving the European Union many policies will be rewritten and new strategies developed that will impact all 3 sectors and their relationship to each other. Recently published reports commissioned by the UK Government suggest a confusing picture of claim and counter claim focusing on the value of an arts and humanities education and its contribution to the UK economy. These include a new industrial strategy document and the Ten Point Plan for a Green Industrial Revolution Building back better, supporting green jobs, and accelerating our path to net zero (2020). The tide may even be turning, back in favour of the creative industries due to the devastation caused it in the UK by the pandemic. It is within this fraught landscape that UK art and design schools are being challenged for their relevance and may need redesigning for a more agile future.


In 2018 the Creative Industries Clusters Programme funded by the Arts and Humanities Research Council invested £80m in eight new creative research & development partnerships
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bringing together the UK’s creative industries with the university sector. This programme was proposed as a catalyst to further grow the creative economy unlocking emerging fields and adapting new technologies. Part of the UK Government’s Industrial Strategy Challenge Fund, the programme proposes to drive economic growth through the development of new products and services to address some of the problems of skill shortage, an aging workforce, lack of agility and so on.

The 5 year project funded through this programme and jointly held by RCA, the University of Huddersfield and the University of Leeds focuses on industry-led challenges in which designers are at the forefront of the creative process, applying, co-developing and implementing new textile and industrial digital technologies in collaboration with supply chain manufacturers and other technology experts, in the high value luxury textile and fashion sectors. Developing a new skillset for designers is central to the project as the research focuses on developing two key themes: Digitally Connected and Sustainable Processes and Digital Communication Systems. The RCA is tasked with developing research from both themes to address the identified skills gap in the industry where multidisciplinary designers trained in a unique combination of art, design, science and technology competencies linked to the STEAM+D agenda might answer the need for a newly skilled workforce.

Through FFF the RCA is working with multiple industry partners assessing, from a designer’s perspective, how new technologies might be configured and implemented as they are developed. The disruptive influence on the way that business in fashion design is done is being explored by RCA researchers who have received additional funding through the AHRC to be trained in design anthropology and ethnographic methods. Design Anthropology takes the future oriented nature of design and marries it to participant observation as a key component of anthropology, setting itself the challenge of developing tools and practices for collaborative future making. Design Anthropology integrates anthropology’s rich tradition of contextualisation and interpretation into the tasks of design, emphasising the generative role of theory in developing design concepts and critically examining existing, often implicit conceptual frameworks. (Ton, Otto and Smith 2013). This approach, married to an examination of Design Thinking and Textile Thinking, an engagement with Transition Design theory, Theory of Change protocols, practice based and practice led research methods will be developed over the course of 2021 and shared through a book sprint and podcast.

3. Fashion Education: Old & New Models of Pedagogy

Traditionally focused on training students in conceptualising, designing and making of their own collections, most undergraduate and postgraduate fashion courses in the UK have not significantly evolved over the past 25 years. They appear to be increasingly unsuccessful in training students to enter a world of advanced manufacturing, relying on machinery and manufacturing processes that have not changed significantly in over 100 years. Design
students are not trained to work with digital tools, leading manufacturing systems or engineering technologies or in the development of new models of entrepreneurship or circular economic models that now make up the fashion industry landscape. Nor are the students being equipped to address societal and environmental concerns in the rigorously informed way demanded by both industry and consumers.

Reports from Fashion Industry Journal Business of Fashion (State of the Industry Report McKinsey & Company/ Business of Fashion 2016) showed that students entering the jobs market were lacking knowledge specific to new technologies resulting in impaired ability to challenge current practice or develop new design-led roles. The future of the UK Fashion Design School may depend on these new insights. Multi-disciplinary universities in the UK have already understood design thinking, speculative design, and critical design methods (Rogers and Bremner 2019. p.5) as useful approaches to innovation and are leading the way in research for new economic models of values led entrepreneurialism and the design of ‘volume to value’ business models that are profitable without growth. As Rogers and Bremner (2019 p 4-5) suggest any repositioning of design education ‘must first acknowledge that it has been complicit in creating a world that nobody wants any more’. They recognise a shift in UK Design School approaches in a journey from an emphasis on design, to a desire to ‘gain academic legitimacy’ establishing dialogues with history and scientific and philosophical theory, then a ‘search for legitimacy through design science’ and finally a push towards interdisciplinarity ‘in an allegiance with technology’.

4. STEAM+D

STEAM as a new industry facing pedagogic model originated from Rhode Island School of Design (RISD). Researched over the course of 4 years from 2011, and driven by an understanding that design education fosters critical thinking and comfort with risk taking, RISD’s ambition was “to reach consensus among disciplines on the requirements of the 21st Century workforce” (Allina, 2019.pp 32). In the United States the understanding of the value of design to advanced manufacture is well established, where RSDI considers design to be a literacy, a capability and a specialism. The Design Council Report Designing a Future Economy- Developing Skills for Productivity and Innovation 2018 suggests that design skills are the fusion of creativity with technical ability and interpersonal competencies. They highlight moving from STEM to STEAM+D - that is, Science, Technology, Engineering, Art and Maths, to include D, the Design element, to ensure a resilient economy in the longer term. The report encourages policy makers and education providers to consider how they will develop the complex problem solving, critical and creative thinking abilities that are essential to innovation (Design Council 2018).

In their Leading Business by Design: High Value Manufacturing report the Design Council (2015) the policy recommendation was that young people at all stages of education require exposure to the multidisciplinary mix of science, technology, arts, humanities and enterprise
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that should underpin both creative and manufacturing success in the UK. They go on to say that government should provide incentives to universities to deliver an increased range of multidisciplinary design courses in partnership with expert bodies to enable engagement with the fourth industrial revolution. The RCA introduced the STEAM approach to its programme delivery in 2016 as part of its strategic plan announced in the Vice Chancellor’s report 2016/17. The report stated that developing new models of postgraduate, research-led design education are key to the delivery of a distinctive STEAM education at the RCA. The evolving pedagogical model adds research-driven enquiry, applied through knowledge exchange with industry and through dynamic and ‘live’ curriculum developments. This research is frequently inter- or multidisciplinary in character, the RCA being the UK’s most research-intensive art and design university.

The RCA’s 2016–21 Strategic Plan outlines the roadmap for the development of the university’s taught programmes. Over the planning period, it is developing new programmes to ensure that it remains at the forefront of art and design education. The RCA is supporting design development through an interface with three core scientific disciplines: computer science, materials science and robotics. Around 11% of the students hold a first degree in fields beyond art and design, for example medicine, finance, law or engineering. These students bring knowledge and expertise from previous careers, and find new, creative applications and solutions through studying at the RCA. The LEO data (2019) supports the proposition that it is through a mixed and interdisciplinary training, particularly an undergraduate degree in science and engineering, married to a post graduate design degree that enables graduate earnings to substantially increase. The Fashion Programme at RCA has seen many more students apply with first degrees in maths, biological sciences, architecture, and computing.

The basic principal of Industry 4.0 is that by connecting machines, work practices and systems, businesses are creating intelligent networks along the entire value chain that can control each other autonomously. UK fashion students have been trained to become micro businesses and then Small to Medium size Enterprises (SME’s) and UK Government research funding has targeted small-scale enterprises through research with UK universities like the Creative Clusters Programme. This strategy looks as if it may pay significant dividends in the new post pandemic business environment. McKinsey & Company/ Business of Fashion (2019) recognised a new role for small players where they might support R &D for larger brands in in-house labs, or attached to universities as Learning Factories designed as a simulation to enable experiential learning as happens in European technical universities. It is proposed this is where the RCA could lead the way, embracing new technical, economic and sustainable challenges. The linking of small designer business to offshored volume producers had been developing at speed through designers’ bench and desktop factory technologies - pattern cutting tools that enable digital development of pattern files that can be sent anywhere in the world via digital networks. An example of how fashion designers are needed to engage with these new industry paradigms can be demonstrated by the fact that these tools do not currently serve the industry well. They do not provide accurate enough fit, that
is, how the pattern fits together and then fits on the body. The systems have been designed by engineers, excluding fashion designers from the initial design process, and in the workplace, where the technology needs to be operated by a skilled technician. The systems serve lowest common denominator manufacturers where speed and cost over pattern accuracy had become the dominant metric over design and fit. This had led, it is argued, to the huge problem of too cheap, undervalued clothing ending up in landfill. Challenging a mindset that proposes “just about accurate” as good enough is where the designer/researcher’s value lies.

5. Fashion Thinking – A New Model

Initial FFF/RCA research reveals the necessity for training a new type of multidisciplinary fashion student/researcher/designer who can rise above existing “silod” training structures and who has the intellectual capacity to question, hold to account, and design within, emerging and evolving new industrial models. RCA Future Fashion Factory researchers have proposed and are developing three new directions which can be viewed as distinct, but also linked and coupled, to co-generate knowledge and form new propositions for designer led research and practice. Beyond Skov and Melchior’s (2010) identification of an object based/culture based/practice based and production-based approach this research supports the following positions:

Fashion thinking for social change proposes following a humanities trajectory, looking at systems for sustainability and bio design as well as user experience, informed by psychology and new economic models. The future of meaningful work, infrastructure change and workers’ rights fall within this remit. Neo colonialist perspectives are challenged.

Fashion thinking for applied speculation develops criticality, assessing movements within the industry to test fields of application contextualised by new textile and digital technologies, aesthetics, philosophy and science. Circular economic models, their ‘complex web of logistics’ and scalability problems (BoF 2020) are explored for long term solutions. The ethics of new technologies are also challenged within this paradigm.

Fashion thinking for advanced manufacturing encourages work that radically reimagines making processes, machines and systems from a designer led perspective within the context of Industry 4.0. Degrowth and just in time economic models, agility in manufacturing, scalability and adaptability, R technologies (Stahel 2017) and reverse logistics are developed here.

A series of ‘platforms’ designed to support engagement with these new perspectives were introduced by Zowie Broach, Head of the Fashion Programme at RCA in 2016. The platforms, Bio Design, Sports, Digital and Future Systems were developed and led by Helen Steiner Graeme Raeburn, Kath McGee, and myself and supported by scientists, engineers, and digital technologists during students’ first year at the RCA. The agile structuring of the
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platforms has evolved year on year and the content is developed to be future facing and provocative. The groups are taught in parallel with an understanding that there are shared rationales, areas of interest and synergies. Collaborations across Platforms are encouraged. This work is supported by a lecture series and a Work in Progress show.

Each of the platforms has proved to be positioned in exactly the right place to respond to the Covid crisis. According to BoF-McKinsey State of Fashion 2021 Survey (2020), the most fertile ground for new opportunities will be in the areas of digital technologies and sustainability. The casualisation trend that was already in motion before the pandemic is likely to emerge as a ‘dominant force’ in fashion in 2021. By October 2020, sportswear company stocks had exceeded their pre-crisis-levels by 7 percent according to BoF, while the non-sportswear clothing was down 18 percent and designers are experimenting with a pre-order selling and zero stock models.

Strand 3, Fashion Thinking through Advanced Manufacturing is being further developed in the context of the FFF research investigating the potential for reshoring UK manufacturing in Industry 4.0. In order to equip masters’ students with research skills for them to explore and critically examine Industry 4.0 it is proposed they will need both hard and soft skills. Skills that include an understanding of technologies, digital tools and engineering, married to critical thinking, collaboration and interdisciplinary working.

Vaughan (2017) claims that underpinning practitioner research is the understanding that the practitioner–researcher has the skills and expertise in the actions of the field to be able to undertake research within it. Citing Schon, Vaughan points to the transition from designer-practitioner to designer-practitioner–researcher in the course of academic study, as a shift from being able to understand and articulate the value or challenges of technical acts, to being able to place these in broader socio-cultural, technical and economic contexts.

Beyond Nixon and Blakely’s notion of Fashion Thinking as “adding meaning and value to the functional and experiential spheres of products and services,” (Nixon and Blakely 2012) that hints at the commercialisation of Fashion Thinking for use in business, just as criticism of Design Thinking proposed it as a branding exercise for a set of concepts (Curdale 2013, p 14) RCA research builds on the idea of Fashion Thinking as a “paradigm of critical thought and creative agency”. However, rather than proposing Fashion Thinking as a methodology to be incorporated by organizations beyond fashion, its first function as a mixed methods approach to designer led research can be to serve a new generation of leaders within the fashion industry. Fashion Thinking as a methodology draws from perspectives developed in Design Thinking, Textile Thinking and STEAM +D approaches in its collaborative methods and iterative prototyping. However, RCA FFF researchers propose that through training at Masters level students can take on the complexity of the wicked problems the fashion industry has generated. This also aligns fashion thinking with parts of Transition Design. The fashion thinker will be better able to critically appraise complex situations and propose new approaches, systems and economic models through design. Led by, and in combination with, a newly developing confidence in practice based and practice led research, and inclusive of a
more traditional and well-established humanities/consumption focused research, I propose engagement with, and designing of, new technological advances can lead to a more environmentally conscious fashion and textiles industry. The possibility to foster this change is through joint industry/academic/engineering engagement that is more investigative, critical and reflexive on both sides.

6. Discourse as provocation

Discourse: A Tool to Debate the Future of Fashion AS Design, designed by RCA Fashion graduate and Future Fashion Factory Research Associate Chelsea Franklin in 2018, was a card-based tool aimed at encouraging debate among fashion students on wider developments in education and industry and the scope of their responsibility. Franklin developed the tool over the course of two years with the support of Zowie Broach, the Future Systems Platform and the wider fashion team at RCA in response to her observation that the type of engagement seen in other design disciplines had not been fully represented in fashion education. Her background was as a designer for an international brand. Student engagement should, she proposed, include research around bottle necks in commercial opportunities, an in-depth understanding of material choices, understanding global context, competition, and collaboration in industry 4.0. Her design research included investigating design tools and games such as those produced by IDEO. The aim of the initial prototype was a means for Franklin to illustrate her place and intention amongst the fashion cohort.

Discourse was created in response to a perceived disconnect between the value systems within fashion education and industry. Franklin suggested that the fashion system struggles to produce value. Responsible for both fuelling and exploiting a growing consumer demand for a faster and cheaper product, she believed the fashion industry had educated consumers to understand that fashion had very little value. The workshop developed through Discourse began with the objective of generating dialogue and supporting debate on aspects of the fashion system. This was tested by Franklin with her graduating cohort and at her degree show and then as an FFF researcher in two key settings. The first was the International Association of Societies of Design Research conference (IASDR 2019) in Manchester titled Design Revolutions. The workshops were premised on the idea that other design disciplines have much to teach fashion through open dialogue around shared problem spaces. It was observed that participants were able to engage with Discourse at a high level, and given levels of expertise in a range of fields, the responses were often delivered using examples from disciplines outside fashion as well as personal (consumer) experience and opinion.

The second workshop setting was at RCA in a series of workshops with first year and second year Fashion MA students. Though the aim was to encourage debate, analysis from data collected (sound recordings, survey-based feedback, interviews) revealed that this was problematic for many participants due to lack of knowledge of specific industry terminology, conscious feelings of courtesy with peers and self-reported concern about ability to
understand the probing language of the questions. Although *Discourse* was designed to enable dialogue, interacting with it in a range of controlled settings revealed the wider challenges fashion students face in articulating and responding to the themes presented. Data collected from *Discourse* sessions with fashion students point to two major findings. Firstly, they appear to imply a lack of knowledge in certain aspects of the fashion system, in particular production and new technologies. Even if students had worked as designers, claims of being kept away from sites of production still persisted (Tham2008) Few if any students had worked in manufacturing settings. On the RCA fashion program, establishing means for language and skills acquisition through industry exposure, engaging in research projects as well as formal learning opportunities to develop meta-competencies aims to enable fashion students to critique, disrupt and innovate in the making, designing and fabrication processes, through and with the design of machines, new tools and systems.

Testing *Discourse* three sets of value were expressed: - students’ value to industry, industry’s value systems and consumers’ understanding of the value of fashion. The findings show that students can sometimes feel ill equipped to tackle the complexities for the fashion industry. It is proposed that until students understand existing systems, they will be unable to challenge them and this becomes crucial for a post pandemic industry where returning to old ways is not possible or desirable. The absence of industry, engineering and science from fashion education can mean insufficient specific insights of the field graduates are about to enter. This is a historic problem in the UK which will see a dramatic change in fortunes in the coming years as the UK Government is faced with the new economic landscape facing fashion design. Meanwhile the reshoring the UK fashion industry looks like a more and more viable option.

**Conclusion**

The situation for Art and Design training at undergraduate and post graduate level in the UK remains complex and uncertain particularly in light of the UK’s withdrawal from the European Union. If the UK government continues to support the development of an advanced manufacturing sector and the reshoring of UK manufacturing industry then UK fashion education can rise to meet this challenge developing the way fashion is taught to engage more fully with Industry 4.0. At RCA the STEAM+D focus aims to give masters students a critical advantage, shifting towards becoming designer-practitioner-researchers. Through industry facing projects, collaboration with science and engineering they will able to engage more fully with industry partners both nationally and internationally, co-developing industry facing projects and placements, initiating collaborative industry PhD studentships and MA business sponsorship, and the establishment of research labs, co-situated within academia and commercial settings, to foster radical change. The development of fashion thinking is predicated on this engagement with industry. Within the context of post graduate fashion education, engineering and industry collaborations can enable acquisition of Discourse, where the role of the university will be to provide space for
learning - establishing meta knowledge, criticism and reflection through academic research channels.

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Acknowledgements: I would like to acknowledge support from Kat Thiel, Chelsea Franklin, Doug Atkinson, Margot Vadderpass, Marion Lean, the Future Fashion Factory and RCA fashion teams.
Design culture of playing.
The musical instrument industry: an important culture of made in Italy

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Abstract | The production of musical instruments is an industry where Italy is one of the acknowledged world leaders. A musical instrument is a product with a high degree of technology and design, where historical tradition and cultural roots have been handed down, together with the necessary incremental innovations: it has all the features to be considered a very “Made in Italy” product.

In any book, conference, exhibition about Italian design it can be easy to find many small traditional companies that produce furniture, accessories, bathrooms, kitchens, tiles, handles, shoes, clothes, glasses, food, wine, and cars: Ferrari is immediately identified as Made in Italy; on the contrary, it could be very hard to find excellent products as a Fazioli piano, a violin from Cremona, an accordion from Castelfidardo, a Harp from Cuneo, cymbals from Pistoia. Why is the Italian musical industry still not present in the spotlight of Italian design?

KEYWORDS | MUSIC, MADE IN ITALY, PRODUCT, TECHNIQUE, TRADITION
1. Economic data

Some economic data can help to understand the importance of the Musical design industry in Italy. 1,021 enterprises are operating in the production of contemporary musical instruments with an export amount of 116 million euros (source: Registro Imprese and Istat, 2015). We are talking about micro and small enterprises and in some cases medium ones: 85% of active enterprises are of artisan production, 15% (144 enterprises) are industrial ones, with an average of 6 workers. Despite the dimension, the Italian musical instrument industry is important in international markets, and in some cases (Fazioli piano and other) it represents excellence. The export trend is increasing so that Italy is the 9th biggest exporter of musical instruments in the world. If we consider big countries like the USA and China and technological excellence like Japan, we can assume that it is a good position. Approximately 70% of Italian enterprises are located in 6 regions: Lombardy, Marche, Emilia Romagna, Veneto, Piedmont, and Trentino Alto Adige. This is mainly due to the deep connection between the artisan tradition, local materials, the history of music and the history of Italy in general. Districts and supply chains are fundamental in our musical production: some famous examples are the Recanati – Loreto – Castelfidardo district, with its keyboards and accordion (fisarmonica) production, the district of Cremona with one of the most important string instrument production, the North-Eastern part of Italy with its excellence in raw materials such as the red conifer of Val di Fiemme and Panaveggio forest (the one used by Stradivari for his violins). (Antoldi et al., 2016). It is curious that those 6 Regions with the highest concentration of musical industries also are the Italian Regions with the highest number of Design schools, universities, and academies. Many of the most important design congresses and exhibitions are held there, many times about “Made in Italy” but rarely about musical design.

2. Deep roots in the Italian culture

The contemporary “design made in Italy” has many opportunities in the field of musical production, starting from the very deep and ancient roots of the Italian musical culture.

The name which is currently in use for the seven notes was invented shortly after the year 1000 by Guido Monaco from Arezzo, by taking the initial syllables of a Latin ode to Saint John. During the following centuries, the study of music and acoustic phenomena from a mathematical point of view became a fundamental part in the work of great Italian thinkers like Leonardo and Galileo, who contributed to the birth of the scientific method. Moreover, until then, the basic education of the medieval scholar included Music in the Quadrivium, which is the area of mathematical disciplines (arithmetic, geometry, astronomy, music) and not in the Trivium of philosophical ones (grammar, rhetoric, dialectic). Music was science even prior to art.
In the 1700s, in Italy, the scientific aspect (related to study of acoustic and building of big theatres) and the artistic one (for example the great authors, musicians, and singers) were at a very high level. As a consequence, with the diffusion of opera and melodrama, not only the name of notes but also the standard reference lexicon of sheet music was in Italian, and it still is: dynamic (pianissimo, piano, forte, fortissimo, ...), pattern (allegretto, andante, adagio, moderato, ...), and, more in general, all the words related to agogics, that is the interpretation of a music sheet.\(^1\) Italian is known worldwide as the language of opera: to learn Italian is a fundamental step for any opera singer.

Therefore, the Italian musical cultural scenario, together with the Italian craftsmen’s ability to build musical instruments, could be an invaluable source of supply for storytelling, input, and idea in the field of Made in Italy musical-related products.

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\(^1\) Except some modern terms derived from black music, that are in English: Blues, Swing, Ballad, ...
product at the right time, such as the Vespa Piaggio that characterized the Italian boom-years after the second world war. In a similar way, in Italy, the atmosphere of great concern and ferment about music, musicians, operas, songs, authors, performers, theatres provided the right conditions for the development of extraordinary inventions in musical design.

The inventor of the piano was the Italian Bartolomeo Cristofori (Edwards, 2015): by changing the existing harpsichord (clavicembalo) to allow a dynamic modulation of the sound, he invented his arpicembalo, then pianoforte (his first recognizable piano can be dated at 1720) at the end of a decennial research and development path that took him from his native Padova to the Florentine court of Medici. This extraordinary invention allowed the introduction of the possibility to play gently and loudly on the same instrument as opposed to the harpsichord, lack of dynamic expressivity. Even today, the key feature of the contemporary piano industry, in Italy and abroad, is the same concept of dynamic sound modulation proposed by Cristofori. To focus on the importance of the piano, it is crucial to consider that, among all the musical instruments, the piano is one of the most popular and widespread and in every school, it is propaedeutic to the learning of other instruments.
Another fundamental Italian invention was the modern violin: the first preserved model, dated in 1564, was realized by Andrea Amati from Cremona. Starting from the 16th century in the triangle Cremona-Brescia-Venezia the lutherie art developed (Baroncini, 1994) whose construction techniques are still actual today.

The Italian input was fundamental in the development of another popular and diffused instrument, the guitar: the Neapolitan luthier families (Vinaccia, Fabbricatore, ...) started to release the first guitars with six single chords, instead of ‘cori’ (couples of chords) formerly used. Those gave origin to the modern concept of guitar (Ravalli, 2018).

4. Made in Italy: stories of territories, materials, and culture of technique.

4.1 Pure design

If we consider the perfect relationship between the function and the shape, between the engineering and the ergonomics, between the aesthetic value and the playability we can say a musical instrument is a pure design. Since many of them have an ancient history, they become archetypes in their use, sense, and meaning: this implies an optimization in their materials, technology, and usability. All the components must be optimized for a structural resistance or the transmission of the vibration, for this reason, industrial machinery is not always effective, often a manual working action is necessary: the typical sound of many acoustic musical instruments, especially the more complex ones, is due also to their production technique that, despite a company’s industrial structure, still requires craftsmanship expertise in many cases. (Mancini, 2019).

Design products, local materials, expert craftsmen, long-time tradition and attitude to innovation are important ingredient of what is called “Made in Italy” and, in the best tradition of “Made in Italy” products, the history of Italian musical instruments starts from craftsmen with fine technique deeply connected with the materials of their regions, where creativity and talent are important features, too.

4.2 The sound of materials

According to a study commissioned by CNA (Antoldi, et al., 2016), it appears that in Trento province there is a high export value (€ 8.66 million in 2015) due to enterprises that select, season and work the local red fir tree, a wood which is unique in the world for its sounding features, used in the production of soundboards and other resonance components of top-quality acoustic instruments. European, Asian, American luthiers are faithful purchasers of Val di Fiemme red fir (Picea Abies), known as “the music tree” or “the resonance tree”, the same used by Stradivari for his unique violins. Today, about 60.000 luthier instruments, 15.000 harps and 180.000 pianos in the world are made with some of these components.
The strong export-asset and the excellence level are the main reasons for the success of these enterprises, which apparently don’t know international crises.

Figure 3. The perfect structure of a Trentino “Resonance Tree” – source: Archivio fotografico della Camera di Commercio I.A.A. di Trento (legnotrentino.it).

As often happens in the production of objects in many industrial sectors, local materials give the input for the birth of artifacts (i.e.: the alabaster of Volterra, the travertine of Rapolano, ...). Also, in the musical field, many instruments are built according to the natural sound of local materials: for example, in Budrio (Bologna), the local terracotta (pottery clay) is used to produce ocarinas, an ancient Italian wind instrument whose origins are lost in time, improved in the 800s by the local musician Giuseppe Donati who started the “modern era” of ocarina production, for which Budrio is famous.

4.3 Materials and manufacturing

Many histories of design products are related to the ability of craftsmen to work a specific material, derived from a long-time technical tradition: i.e., the ability to work the leather and the famous made in Italy shoe enterprises. In the musical industry, an important Italian tradition is derived from the millenary art of metalwork. In Agnone (Isernia), the Pontificia Fonderia (exclusive pontifical foundry since 1924) Marinelli Snc has a long tradition in bells
production (on the factory website they say about 1000 years of tradition) and today is famous worldwide in this specific production field.

![Figure 4. UFIP – Est 1931 series cymbals. Courtesy UFIP – Pistoia, Italy](image)

Another common feature of many Italian enterprises is the small dimension. Sometimes factories are family-owned as is the case of Pistoia, where in the 18th century the family enterprises able to work metal started to build church organs. Then the ability in the lamination processes was successfully applied to the production of cymbals. During an economic crisis, in 1931 four of these small enterprises decided to join, establishing the Unione Fabbricanti Italiani di Piatti musicali e tam tam (Italian cymbals and tam-tam united factories), called UFIP. The deep connection with its origin, that is the ability to work metal, led UFIP to innovate the cymbals production by patenting the Rotocasting®, a unique centrifugal casting system that allows the elimination of all the impurities of the bronze alloy. Today UFIP is known worldwide for the top quality of its cymbals, an Italian made in Italy excellence of design.

4.4 Manufacturing and culture

The knowledge of a working process can be another important factor in the development of a specific industry, on a regional basis, as it happens in many industrial districts (as Udine and its production of chairs, Florence and its leather products, ...). In the musical field, the case study of accordion could be representative. The accordion is an instrument that was not invented in Italy and that is not necessarily built with local materials. The accordion probably was first built in Austria and from the mid-XIXth century was diffused in Italy, in the Marche region, above all by the work of Paolo Soprani. Today a great part of Italian popular musical culture is based on songs and rhythmic patterns played on the accordion. Especially in summer, there is no local festival (Sagra) without an accordion player in the live band. In the
Tuscan countryside until the 80s, the accordion could often be identified as “the” musical culture. This extraordinary diffusion, in Italy, of an instrument which is not native Italian (for materials or birth), was due above all to the great ability of Italian craftsmen: in 1924 93 accordion factories in the national territory were recorded. Today the most famous are produced in Marche (Castelfidardo and Macerata), Lombardy (Stradella, Cremona), Piedmont (Vercelli, Leini) and Tuscany.

As before reported about UFIP, an economic crisis was the occasion for a union of different factories: in 1946 the *Fabbriche riunite di fisarmoniche* (united accordion factories) was created, with the name FARFISA, an excellent company whose experience was based on the production of keyboard instruments (accordion, keyboards, electric organs, ...). It started the development of the Italian most important musical production district - the Marche district. A famous FARFISA product was the Compact, one of the first electric organ produced on an industrial basis, widely diffused in the 60s and co-responsible (together with the Vox Continental) of the sound of the rock and psychedelic music of those years. An electric organ is an instrument based on a simple concept: the pressure applied to a key generates a sound through electro-mechanical internal components. It is the same concept of an intercom: by taking advantage to its achieved know-how, today Farfisa is an internationally known company that produces intercom and videophone all over the world. Another story of made in Italy.

*Figure 5. Navini accordion. Courtesy G. Navini snc – Castiglion Fiorentino (AR), Italy*
Differently from other product categories, where industry replaces small artisan factories, in the musical field, this substitution is rarely possible because the quality of certain components can be guaranteed only by manual work. Moreover, a big industry is not often able to provide the possibility of fixing damaged instruments. This particular attitude of Italian small enterprises is important because in music there is no programmed or forced obsolescence as in other industrial sectors: a good instrument is expected to last for decades, so the maintenance service is still fundamental. This is both the reason of excellence of Italian musical instruments and the reason why small familiar companies still survive, as G. Navini snc, established in Tuscany in 1936 (Castiglion Fiorentino), which still today is a reference point for accordions and maintenance service for many musical instruments.

4.5 Highly skilled enterprises and craftsmen

Many small enterprises in Italy are famous for their musical instruments, thanks to the extraordinary ability of their craftsmen.

![Salvi harp – model Whitney, with white ebony veneer. Courtesy Salvi Harps – Piasco (CN), Italy](image)

Salvi harps is one of the most important harp producers in the world. Since the first appearance of a harp in an orchestra, thanks to the Italian composer Monteverdi (in the first year of XVIth century), the harp and its soundboard had to adapt the volume to the
increasing dimensions of orchestras and auditoriums: for this reason, the research for materials with the best resonance features was fundamental, together with the study of optimal shape for the sound boards. The use of the best resonance material (the red fir of Val di Fiemme, used as the main component of the soundboard) and the continuous search for innovation (the company has its R&D department inside) are some of the reasons why this company ubicated in Piasco (CN) exports its instruments worldwide. Its long tradition, started in the mid of the XIXth century, permitted them to train generations of artisans: today the high expertise of the workers makes the difference and Salvi can be considered as an excellent Italian company.

Rampone & Cazzani is an Italian company ubicated in Quarna Sotto (VB) that has produced saxophones since the invention of the instrument (by Adolph Sax in the second half of XIXth century). Today it is considered a niche market manufacturer, thanks to the great sound of its instruments, the perfection of details, the possibility of customization.

![Figure 7. Rampone & Cazzani – model R1 jazz. Courtesy Rampone & Cazzani – Quarna (VB), Italy](image)

5. Fazioli, a made in Italy brand of excellence

In New York, in September 2003, during the celebration for the victims of twin towers destruction, a concert for 21 grand-pianos was played: they were Fazioli pianos; at the White
House, in 2016, during the celebration for the International Jazz Day, Aretha Franklin and other international stars played a Fazioli grand-piano (AGI, 2016). Fazioli is an Italian piano factory whose concert grand pianos are famous worldwide and appreciated by many important pianists. The company was established in Sacile (Pordenone) nearly 40 years ago, from a spin-off of the main family factory, a wood working factory, and since then it shuns the production derived from an industrial nature but, on the contrary, it pursues a strategy that combines an absolute technical perfection – derived from in-depth studies of materials and sound engineering – with a traditional handicraft production. These factors combined with the choice of the best woods from the Val di Fiemme trees are the carriers of technological innovation and absolute quality. In a Fazioli piano, there are several patents: the exclusive three-layered soundboard, the unique fourth pedal, but beyond these innovations what matters is its recognizable sound, a strong brand value. The annual production is of about 140 pieces, 95% of which are exported all over the world: they are the numbers of a small company of excellence if we compare it with the biggest piano factory in the world, the Chinese Pearl River that produces 150,000 piano/year (Stefanato, 2018). The choice of the founder (Paolo Fazioli) was to create a high-level object with a special focus on a contemporary Italian sound that was different from the other famous brand (Steinway, Yamaha, ...).

![A Fazioli piano](https://example.com/fazioli_piano.jpg)

*Figure 8 – A Fazioli piano – Credits: © Fazioli Pianoforti spa - Foto Roberto Zava / Studio Step*
Today we can say that, if Fazioli is called the “Ferrari of pianos”, this ambitious goal was achieved (it is curious to notice that, similar to a car, a piano is a mechanical engineering product): many great pianists like Herbie Hancock or Angela Hewitt, in some interviews declared that they preferred Fazioli grand pianos instead of Steinway for their concerts.

6. The districts of the Italian musical production

In the field of design, the concepts of districts and supply chains are well studied. Even in the musical field the same features applicable to the definition of a district can be found: when companies use local materials, when they share competences, when they optimize their know-how, when they create a network for promotion and marketing, in these cases real sites of production born and music-related industries can develop. In Italy, two districts of musical production can be identified: Cremona and the Marche district.

In Cremona, the roots of the art of lutherie can be dated in the XVIth century with the products of the Amati family. Then, in the golden era of Italian music, the XVIIth century, Guarneri and Stradivari defined the archetype of arch instruments, today still in use worldwide. People in Cremona were able to take advantage of this long tradition of made in Italy, through structured actions regarding both the enhancement of existing asset (material and immaterial) and the promotion of “new”; actually in Cremona we can find: the Stradivari foundation, the international lutherie competition, the international lutherie school “A. Stradivari”, the Superior Institute of musical study “C. Monteverdi” and the academy “W. Stauffer”, the violinmakers and archmakers (liutai & archettai) consortium “A. Stradivari”, the international exhibition Cremona Mondomusica with more than 300 exhibitors per year, the innovative Violin museum, the “Laboratory of musical acoustics” by Politecnico of Milan, the Arvedi laboratory for non-invasive diagnostic analysis of University of Pavia. A strong component of innovation is the key to the enhancement of tradition. The institution of the “Cremona Liuteria” trademark based on a specific production regulation was set up to prevent industrial standardization and to preserve and guarantee the Cremonese musical instruments. In 2012 the “traditional violin know-how in Cremona” was declared Intangible Cultural Heritage by UNESCO. The result of this organic approach is a strong growth in the sales, above all in exports: in 2015 the export of musical instruments in Cremona was € 4.225.170,00, + 11,85% as compared to 2014, +553,23% as compared to 1995; those data demonstrates that the excellence market is still able to grow, despite international crises, even because it doesn’t follow temporary trends. An interesting fact is also that 42% of the total of 154 luthier artisan workshops have a foreign owner: the attractiveness of Cremona is very high especially outside Italy, not only towards students but also towards entrepreneurs (Antoldi, et al., 2016).

2 http://www.cremonamusica.com/en/
3 http://www.cremonaviolins.com/il-consorzio/il-marchio-il-regolamento-la-tutela/
The Marche musical district is the biggest area of musical production in Italy, with the highest value of turnover. While in Cremona the district is connected with the specific production of arch instruments and its related technologies, in Marche the district is hybrid and not focused on a specific kind of instrument. All started with the production of accordions (see above about FARFISA), an instrument with keys where the sound is generated by a blower; during the following years the local factories could adapt to new technologies and the market changes: by electrifying the harmonium (where keys and blower are the same components of the accordion) in the 60s the electric organ was introduced, then the first keyboards (electric piano) were produced together with the first Italian electric guitars (Eko). Today many fields of music production are active in the Marche district: keyboards, electronics, amplifiers, speakers, ... and many international industries such as Korg and Roland take advantage of the ability of local craftsmen and factories. Today Eko Music Group Spa, Fatar Srl, Korg Italy Spa are some of the enterprises with the highest turnover (ICRIBIS, 2020).

7. Some opportunities

The word design is paired with the word music in a very few cases, most of them referred to home acoustic speakers that are considered pieces of furniture to be put in a living room or in a bedroom: in this specific field, the good design seems to be considered a value for the product and is also used for advertising campaigns.

Among the musical instruments producers, few companies consider design as an essential feature of their products (on the contrary, in other market fields, in certain products the word design is shouted and exhibited, sometimes out of proportion, sometimes without any good reason). In musical instruments, Design seems to be an additional feature, that comes after all the main product qualities: tradition, materials, sound, prestige. Even amongst the companies mentioned in this paper, it is hard to find the word design in any of their websites. In the academic world, some books regarding design and music can be found (i.e. in Italy the recent book of Marano, 2019), but they are far too few to be considered as effective literature on the topic.

Another area with a lack of design-driven attention is the world of exhibitions or expo. In big design events as Salone del Mobile in Milan or 100% Design, visitors are not only operators, sellers, designers or entrepreneurs: a large part of public is made of curious people or people not directly involved in the topic of the expo; in those big fairs, however, musical products can rarely be found. In music fairs it is just the opposite, that is only a few are curious people amidst the majority of insiders.

Deep cultural roots, long-time tradition, fine materials, excellent craftsmanship, brand value, product durability, attention to innovation: many Italian musical industries possess all of the qualities usually related with the Made in Italy, a heritage that could represent a real opportunity to open new roads in the wide meanings of design.
Design related to musical instruments and accessories could be the topic for research projects, academic courses, workshops, conferences, fairs, and papers. Designers, professors, and students could be involved in this specific field and, for example, producing a structured survey of the Italian musical industries: each one of the factories, just mentioned in this paper, would deserve a wider discussion for the wealth of their technical know-how, their ability to work local materials, the durability of their products.

Italy always expresses high cultural value in music, both at an international level and at local and regional ones; this is another point of view to start from, for an inclusive approach to music design and its preserves.

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Digital encounters in the culture of textile making: developing a hybrid craftmanship for textile design by fusing additive methods of surface fabrication with knitting technology

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Abstract | Digital fabrication technology presents an unfamiliar territory for textile design, thus requiring exploration and analysis of the emergent forms of textile crafting and materiality. Through practice-based research methodology, this research examines the intersection of two fabrication methods: industrial knitting and 3D filament printing, with the aim of outlining a hybrid material territory for 3D textile composites. Accordingly, the research addresses the notion of textile as a multi-material system. The physical results are presented as a material library of samples which have been produced through two methods: i) the exploration of geometric tessellations to generate self-folding surfaces by direct printing on non-elastic knitted structures; ii) the exploration of pattern arrays to generate self-forming surfaces by direct printing on pre-stressed knitted structures. Using this hybrid approach to textile crafting the research discusses the aesthetic possibilities of the fusion of these two technologies, and the potential for development within the Industry 4.0 model.

KEYWORDS | TEXTILE DESIGN, HYBRID METHODS, MULTI-MATERIAL SYSTEMS
1. Introduction: textiles as culture of crafting

Being one of the few disciplines which has the material—the textile—as the resulting artefact of the design process, textile design complies with Risatti’s definition as a culture of crafting: one that is based on advanced technical knowledge and direct experience of the material in the creative process. Based on Pye’s distinction between the two notions of design and workmanship, the concept of craftsmanship emerges in Risatti’s definition as a unifying activity of the two rather than a separating one (Pye, 1968; Risatti, 2009). In this context the notion of crafting combines in its description the intellectual and creative nature of design activity, together with the proficiency of technique and material knowledge which is conveyed by the attributes of workmanship. Likewise, crafting as activity implies an integrated process between artistic expression, design, ideation, material and technical knowledge.

Consequently, artistic expression and technical proficiency are closely interrelated in the practice of textile design, as the culture of crafting and materialization have always been deeply rooted within it, even though the rise of industrialization has triggered major challenges for the textile design field by separating the designer from workmanship in the production process (Gale and Kaur, 2002). However, the value of craftsmanship and making through direct interaction with the textile has been preserved (Valentine et al., 2017). Likewise, knowledge of the material, together with the process of forming and making, define fundamental placeholders in the development of an intended design and desired textile quality. Another aspect resulting from the legacy of the culture of craftsmanship is that the development of technology and methods of making textiles are driven by the experience of the material as key to the design process, which then influences ways of creating expression in textile design (Ingold, 2009). Pye defines this process as “the workmanship at risk”, where the designer’s methods are not fully known, leaving a place for exploration and redefinition of the known technology by experience.

Today, the extended availability of digital tools and methods of fabrication have unlocked new design possibilities for the expression of textiles which rely on established textile techniques, e.g. weaving, knitting, screen-printing. In particular, the extended availability of 3D printing technology marks a complex material turn for the textile field (Smelik, 2018). Likewise, McCullough (2010) discusses the role of the digital tools in the design and crafting process; the digital has opened a hybrid territory of abstract forms of materiality which make the transition between tactile to haptic processes, and requires the development of novel forms of crafting.

Digitalization, in addition to enabling these novel material practices, has also influenced the development of new production processes and new models for co-locating industries: with reduced scale but with mixed competences and fabrication lines—Industry 4.0 (Lasi et al., 2014). Manzini envisioned this change of industrial models in the book The Material of Invention, published before the present turn to the digital in material and fabrication technologies:
“The boundaries between privileged sectors tend to break down. What it comes into being is the formative nucleus of a situation in which the vertical model is replaced by a model in which relations are established, as they are needed between manufacturers in the various fields with a view to a specific objective-to develop and market a new, partially processed composite or else to manufacture a finished object, created by multimeteral components.” (Manzini, 1986, p.43)

Hence, this territory is no longer defined by traditional technologies or mono-component identities; it is defined by cross-disciplinary practices and methods which stretch the borders of different design disciplines by fusing traditional and unconventional forms of making, e.g. shape-generative processes, composite materials, and novel fabrication methods, enabling the transition from bottom up to relational processes for the creation of textile artefacts.

2. On novel processes and hybrid craftsmanship in textile design

Similarly to specific material classes such as wood, glass, and steel, textiles form their own class. The fusion of textiles with other materials requires a new classification for the multi-material created. Conventionally, the term “composites”, however, introduces a mixed methodology and describes a broader cluster of materials which are formed through the fusion of different material identities and properties (Fernandez, 2006). Consequently, for the textile field, the term “textile composites” refers to a specific class of materials where the technology to fabricate them “implies fibre and resin matrix structures built from material laid up on a mold, and thermo-formed under heat and pressure.” (Pearson, 2016, pp.305). Here the characteristics of textiles, such as pliability, lightness, and structural integrity, are mixed with the stiff character of resin. The casting and molding process is employed to enable the creation of textile composites with stable surface behavior and which can exhibit stiffness and three-dimensional shape (Bonder et al., 2019).

Compared to the conventional method of molding when creating textile composites, the use of 3D filament printing technology as an additive method for altering textile surfaces introduces another perspective. This method presents a hybrid space for creating textile composites which places itself at the intersection of known methods of textile composites—by mixing textile structures with polymers—and traditional 2D screen-printing methods. The pliability of the textile is mixed with the geometry and rigid behavior of the additive printed pattern, enabling surface shaping capabilities. This intersection of two material domains underlines a hybrid territory where 3D shaping, material behavior, textile construction and 2D surface pattern design meet to define a composite material system comprised of two distinct material identities: textiles and plastic polymers.

This cross-disciplinary textile territory is illustrated by the research and design of Van Herpen (c.f. Thys, and Connellan, 2012): her work with additive processes defines new perspectives on material agency and positions the notion dress as an architectural form for the body.
Clopath and Guberan, researchers at MIT, have proposed another perspective on 3D printing by combining this technology with textiles in a shoe that adapts to the wearer’s patterns of movement (Active Shoe, 2020). Likewise, Moslemian (2016) further explores the principles of self-folding when 3D filament printing technology is applied on textile to design active textiles. By proposing and analysing different geometries her research presents methods to work with these hybrid materials in an architectural context, with the aim of designing lightweight structures.

Many other research examples that combine textiles and 3D printing come from the field of textile engineering, and examine the technical aspects of this combination, for example material bonding and interaction, or smart properties (Pei & al., 2015; Grimmelsmann & al., 2017). Consequently, the ubiquity of and increased interest in 3D printing technologies has resulted in expressive fabrics that present a visually attractive textile that is unfamiliar to us in its crafting. Here, the intricate geometry of shape and the combination of hard and soft material properties fuse attributes of the generative expression of form with the properties of the printed material and the qualities of the textile. The exemplary research discussed above outlines the research context by demonstrating different perspectives as to how these hybrid methods of multi-material systems can be approached through crafting design and technology. However, in most of these examples, textile base is used as background for the printing technology rather than foreground, thereby leaving an open question as to how the textile craftsmanship can be leveraged to a better advantage in this intersection of technologies. Subsequently, this research looks at the fusion between knitting technology and 3D filament printing, starting from the making of the textile structure in a bottom-up perspective of the knitted structure.

Using a practice-led research methodology, this research analyses the textile design possibilities resulting from the fusion of two methods of crafting and making: digital fabrication and knitting technology. What is crucial to this research is: i) to exemplify a hybrid method of designing textures and self-folding forms in knitting, and thus go beyond the current limitations of this textile technique with the help of digital fabrication; ii) to articulate a design vocabulary describing the textile qualities resulting from the fusion of the two techniques, and the advantages of doing so in terms of combining the properties of two distinct cultures of making—digital and textile fabrication—as a means of suggesting new possibilities for material design and to broaden perspectives on form-thinking in the textile design process.

### 3. Fusing methods

Knitting as a textile technique was primarily developed to enclose the body. In knitting the loop is the fundamental unit of construction (Black, 2012). Therefore, loop geometry, multiplication and arrangements decide the end design of the knitted surface and the geometry of the 3d shapes. Similarly to other textile construction techniques, in knitting
there are two perspectives that interact in the design process of a material: the microscale (near-field), which is defined by the construction unit and yarn dimensions; and macroscale (far-field), defined by the design of the overall surface and shape. Alongside the process of creating complex shapes, the character of the yarn as raw material for design, and the structural design, are equally as important in the process. These two elements determine the aesthetic and functional properties of the surface: the feel of the surface against the skin, the outline of the shape, and the folding behavior in relation to the body. The construction techniques specific for knitting allow designers to work with both the 2D surface and 3D shaping (Glazzard and Breedon, 2012). Compared to other textile structural techniques, the fundamental properties of knitted textiles are elasticity, pliability and self-folding. Thus, 3D printing as a fabrication technology introduces the opposite elements to knitting into the textile design process: working with 3D solid objects with contrasting qualities to textiles—stiffness, transparency, smooth surfaces—and crafting in a non-physical process. The result of joining together the two technologies proposes a series of textiles as a multi-material system (Grimmelsmann et al., 2017).

Similarly to textile yarns, there is a large variety of 3D printing filaments which vary in terms of materials, colors and stiffness, e.g. PLA, ABS, Nylon. These filaments may also vary from soft to hard. However, in this research the interest was to fuse textiles and 3D filament printing variables with contrasting properties in order to be able to generate a composite material system situated at the intersection of the two fields, and therefore [hard/stiff] filaments were used.

The experiments explored various possibilities for generating three-dimensional surfaces when the pliability of the knit is forced into shape by the rigidity of the 3D printed layer. Two strategies have been employed: the principle of self-folding by 3D printing geometric tessellations on non-elastic surfaces; and the principle of self-forming by 3D printing on elastic surfaces. Figure 1 presents a material library with selected expressions resulting from the fusion between the two technologies.

2.1 Material Set-up

The knitted textiles were fabricated using circular single-bed (gauge 12) and flat-bed (gauge 14) industrial knitting machines using simple typologies: for example, on the single-bed machine single jersey, three-thread fleece knitted fabric, and meshes, and on the double-bed machine 1x1 rib structures. These structure types provided a greater degree of control over the stretch directions of the fabric and ensured equal distribution of tension on the textile surfaces. The quality of the surface of the additive layer was also dependent on the uniformity of the textile surface, as a high level of variation would obstruct the smooth movement of the 3D printer’s nozzle, damaging the fabric. In order to be able to add colors and patterns to the textile surfaces without influencing the geometry of the knitted base, two plating methods were used. In order for the circular knitted textiles to have two distinct faces, yarns with different colors were knitted simultaneously on the front and rear of the
fabric. For the weft-knitted textiles, the colors were added as patterns on the front, and randomly mixed on the rear; this was achieved using the programming environment of the Stoll machine, which uses a color-arrangement system that allows simultaneous work with color, pattern, and structure using plating technology. The fabrics used for the final experiments were knitted using natural fibres, e.g. cotton, viscose and wool, along with elastane. The choice of yarns was the result of the intention to create a contrasting expression between the textile base and the printed filament. Previous experiments showed that these materials have the best adhesion to 3D-printed filaments, and that they do not melt when the hot extruder comes into direct contact with the textile surface.

With regard to the exploration of the variables of the 3D-printed layer, filaments made of different materials were tested as additive layers on the knit, e.g. PLA, ABS, and nylon. However, ABS, PLA and nylon were considered to have the best adhesion to the knitted fabrics and the best bending behavior with regard to the explorations of self-forming behavior. Previous experimentation showed that the thickness of the printing layer, along with the character of the filament used, influences the attributes and behavior of the additive pattern. The height of the 3D-printed layer is dependent on the size of the printed area and the outline of the two-dimensional pattern to be applied to the textiles. The experiments were undertaken using a 3D printer with a printing area of 220 x 220 mm. For the explorations of self-forming behavior the thickness of the printed layer was 1.5 mm; for the explorations of self-folding behavior the thickness of the printed layer was 2 mm.

2.2 Strategies for three-dimensional forming

The physical results of this research are a material library of samples, which were explored using two methods:

i. Geometrical tessellations that resulted in self-folding surfaces as a result of 3D printing directly on non-elastic knitted structures.

ii. Pattern arrays that resulted in self-forming surfaces as a result of direct printing on pre-stressed knitted structures.
Digital encounters in the culture of textile making

Figure 1. Samples that explored the self-folding behavior of three-dimensional prints on knitted objects.

i. The first method involved the creation of different geometries with self-folding behavior through 3D printing on knitted structures. The self-folding behavior of the surfaces was not dependent on the elastic property of the surface; this type of pattern can be applied to non-elastic surfaces as well. The self-folding expression of the 3D-printed textiles was dependent on the relationship between the 3D-printed facets and the textile creases (Saito et al., 2015). During the drawing of the pattern to be 3D-printed, the initial mesh was split into individual elements. Each cell was offset by 3 mm from the neighbouring cells, allowing the formation of creases on the textile surface after the fabrication process, and the cells as a whole constituted the surface of the textile.

Samples 2, 3 and 4 (Fig. 1) illustrate the design of quadrilateral meshes composed of regular and irregular cells. Sample 2 and 4 have a regular pattern. The pattern of Sample 2 was printed with a thermochromic filament which changed from green to yellow. Due to the plating methods used in the knitting process, the color of the textile base varied from green to beige to yellow. The sample was intended to explore how the three-dimensional perception of a surface could be enhanced when working with tone-on-tone using color combinations (Fig. 2).
Sample 3 was 3D-printed with an irregular quadrilateral mesh which restricted its self-folding behavior as compared to Sample 2. The printed mesh had a discrete expression due to the use of a transparent nylon filament. The folds of the surface were emphasised due to the textile substrate, which was knitted with a three-tread fleece pattern. The 3D-printed facets of the quadrilateral mesh of Sample 1 were narrow and high. The pattern was printed on a pre-stretched fabric (single jersey, gauge 12, cotton and elastane). When the textile was released from the printing bed, the filament formed a dense structure which maintained the softness of the textile; although the expression of the textile was two-dimensional, the surface was possible to shape in three dimensions by twisting the two ends in opposing directions (Fig. 3). Samples 5 and 6 illustrated ways of folding using the method of aligned curves (Mitani, 2019); this method facilitated the creation of less structured geometries with softer edges and smooth gradation of the sizes of the three-dimensional printed patterns. As compared to Sample 6, wherein the knitted textile is rather neutral being a single jersey fabric which was plated using a light blue front and white rear, the textile of Sample 5 merges in the foreground of the expression with the 3D-printed layer adding color and texture to the end design.
ii. The second method explored the potential of 3D-printing primary shapes, e.g. lines, squares, circles, and triangles, with the aim of creating three-dimensional self-forming fabrics. The edges of primary shapes printed on textiles have the potential to bend due to the tension of the textile surface; this method thus facilitated the creation of various curved three-dimensional shapes (Aldinger et al. 2018; Moslemian, 2016). Consequently, a good understanding of the bending behavior of primary shapes on pre-tensioned knitted structures would be a great support for the ways of working in textile design, as the simplicity of the 3D-printed pattern would allow for more freedom for the actual design of the textile base. Samples 7 and 8 (Fig. 4) show the effect produced by the alignment of fine 3D-printed lines on a fabric which is stretched in both directions. Sample 7 used a single-jersey fabric as a support material for the 3D-printed pattern. The fabric exhibited uniform elasticity because every row was knitted with elastic yarn and wool. The fabric was stretched in both directions, but more in one direction. When steamed, the flat fabric compressed more in one direction, causing the 3D-printed pattern lines to curve. The lines of the 3D-printed pattern became closer in the other direction, emphasising the regular folds of the emerging texture. In the image of Sample 8 shown in Figure 4, the 1x1 rib structure was stretched during the 3D-printing process such that the 3D-printed lines curved the diamond pattern. The lines of the 3D-printed pattern thus interacted with those of the pre-stretched rib forming an unified expression.

Sample 9 explored another way of forming a dome-like shape; by designing an array of triangular units that were printed on a fabric that was stretched in two directions. In this example, the complex outline of the 3D-printed shapes formed the elements of the textile surface design by distorting the lines of the fabric. The textile fabric of Sample 11 combined
an advanced textile design defined by variables, such as pattern, color and structure, and an array of curved shapes which changed the surface expression. As compared to Samples 7 and 8, wherein the design of the print comprised the foreground of the textile expression, the 3D-printed layer of Sample 11 became a background in the overall expression due to the design of the textile. Samples 10 and 12 utilised a method of partially printing the filament on the textile. In both examples, a secondary layer of three-dimensional patterns emerged due to the fact that the filament was partially attached to the knitted fabric. Whereas in Sample 10 the filament constituted the foreground of the textile expression due to its textured shape and color, in Sample 12 the three-dimensional print merged into the surface design of the textile. This textile was knitted using a 1x1 rib technique, onto which an abstract surface pattern was applied using plating.

4. Discussion

The result of this research presents a strategy for designing textile multi-material systems for 3-dimensional surface design when combining 3D filament printing as an additive technique with knitting technology. Accordingly, the research presents two methods: i. the first method uses patterns of geometric tessellations to generate self-folding surfaces by direct printing on non-elastic knitted textiles; ii. the second method uses geometric pattern arrays to generate self-forming surfaces by direct printing on pre-stressed knitted textiles. The material library illustrates some of the variety of expressions and surface behaviors that can be achieved with this fusion of technologies.

Similar 3D textural effects in textiles can also be achieved through conventional screen-printing methods, using materials such as flocking or printing foil, as the exemplary research of Philpott (2012) illustrates. However, the great advantage of using 3D filament printing is the robustness of the additive material on textile which allows the formation of 3D shapes without limitations of the layer’s thickness and scale. The effect of the character of the printed material—the transparency, translucency or smoothness of the plastic layer—gives the textile materials, e.g. wool or cotton, a hybrid tactility, altering the conventional textile expression. The pattern generation work in the digital space introduces a new form of textile crafting since it goes outside established 2D textile methods to create pattern repetitions—while being influenced by traditional textile craft techniques. Based on haptic processes, the digital space enables extended possibilities when working with complex 3D typlogies and for enhancing the perception of depth of the 3D surface by manipulating directly the pattern design on it.

By fusing contrasting material behaviors and merging two distinct technologies, the proposed method exemplifies an alternative way of approaching the design of complex knitted constructions with the aim of achieving post-fabrication formation of 3D textures and shapes. The method places itself at the intersection of textile technology and digital fabrication, outlining an alternative method for designing and fabricating textile multi-
material systems which may open new material functionalities and extend the limits of
textile design and crafting. This hybrid method relates to the perspective of textile as a
multi-material system, defined by changeable variables which can be modified according to
the function of the material in the object design process, rather than producing a unique
textile design. It is a textile system in which the digital—characterized by extended
possibilities to create 3D patterns and arrays—is merged with knitting technology in order to
re-design the materiality of the knit as a foundation for the design. If so far the role of the
material in the process of object-oriented design disciplines, such as fashion, product design
or architecture, has been described using linear models of design, e.g. bottom up or top
down, the notion of textile as multi-material system relates to Manzini’s description as a
“model of relations” or to Frayling’s(2011) New Bauhaus as model of “convergence” might
introduce an alternative perspective of a distinct nature from the previous ones; this
perspective can be defined by flexible boundaries capable of extending the synclastic model
of design(c.f. Ingold, 2009) to the object-oriented design disciplines—where the material and
object define each other in the design process.

Nowadays, due to a high interest in developing sustainable processes and products, the
structure and premises of the current industrial model are highly debated. The advanced
digitalization of fabrication tools and methods of communication are driving the textile
industry towards a new era: that of Industry 4.0, where product design and manufacturing
processes are not separated but become co-located, alongside the different disciplines
engaged in the process. The total re-definition of the industrial model also enables a re-
positioning of material in the product design process, towards finding new forms of
craftsmanship inside the established methods of each design discipline. Although Industry
4.0 is a relatively new concept, it presents novel possibilities for the role of material in design
processes and an opportunity for textile designers to work closer to technology and
fabrication, where textile digital crafting proficiency will be most beneficial.

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**Acknowledgements:** The author would like to thank the knitting technicians Kristian Rödbj and Stefan Gustafsson for their support in programming and producing the knitted fabrics. The work was funded by the Smart Textiles part of Science Park Borås and the University of Borås.
Distributed design and production for distributed care. Investigation on materializing bottom-up open and indie innovation in the field of healthcare.


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Abstract | The paper investigates the role of distributed design and digital fabrication in the materialization of open source healthcare solutions co-developed by designers, makers, and user innovators with or within enabling environments such as makerspaces. A participatory and experimental design-oriented approach allows to refine the nonlinear development path that characterizes new fields in which design, technological experimentation and medical research may find application possibilities can also be identified. With these premises, this work aims to explore the dynamics of designing products related to the emerging field of Distributed Care. Firstly, the paper defines the emerging field of distributed design for healthcare and analyses experimental initiatives exemplifying the field of Distributed Care. The second part of the paper interprets the results of the use case analysis to demonstrate how designers, makers and independent innovators interacting with care specialists, patients and caregivers – can design, produce and distribute solutions with a real market potential.

KEYWORDS | DISTRIBUTED DESIGN, DIGITAL FABRICATION, MAKING, OPEN SOURCE HEALTHCARE, FAB LAB
1. Designing (for) distributed systems: an introduction

Nowadays, terms such as "distribution" and "distributed systems" have become a common, constituent and characterizing part of the production, release and diffusion models of many goods and services on the market. Blockchain, cloud computing and manufacturing are examples of distributed technologies. It was not until the early 2000s that the theme of distributed systems crossed the discipline of design. The scientific literature on the design of distributed systems mainly refers to the world of computer science and in particular to the design of computer systems (software engineering). We speak of distributed systems design or distributed computing environment to define a system whose components are located in different networked objects (e.g. computers). These components act in a coordinated way by sharing information to achieve a common goal. A distributed system is basically a set of independent processors that enable the sharing of resources through the use of software and allows the system components to operate autonomously, independently and geographically spread. The distributed systems are characterized by certain properties: transparency in the access and use of its resources, openness that facilitates the configuration and modification of the system, greater flexibility and interoperability, reliability in the resolution of errors and problems, and the ability to concentrate performance capacity and to scale physically, geographically, organizationally (Wu, 1999).

Another strand of scientific literature on distributed systems comes from the world of industrial engineering and management, more specifically related to the concept of distributed manufacturing (Marsh, 2012; Künhle, 2010). Basically, distributed production is a decentralized and networked model to organize local manufacturing processes. Digital transformation, especially the development of digital fabrication, has empowered this model and its operability. Organisations and individuals (professional, citizen, and indie innovators) can use a network of production facilities and technologies geographically dispersed but connected and coordinated through ICT technologies (Seravalli, 2013; Wolf et al., 2014). The spread and the convergence of a growing number of small-scale production activities, which are fuelled by a plurality of subjects and organizations and characterized by a democratized access and use of manufacturing resources, fosters the growth of forms of Commons-based peer production based on distributed production (Gershenfeld, 2012; Rifkin, 2013). Open and distributed production refers to an emerging collaborative production model which may be web-based or in physical facilities such as makerspaces and Fab Labs. This form of production is going beyond the Maker movement (Anderson, 2013; Dougherty, 2016) and allows an open and close-to-the-user materialization of artifacts.

Distributed Design (DD) is a very recent concept that has a strong link with the two abovementioned domains of knowledge and practice. Essentially, DD connects participatory, open source and DiY design processes with parts of existing production and distribution models, digital manufacturing technologies, thanks to computational capability and systems.

Moreover, Distributed Design - intended as open design for distributed products, services and systems - (Diez, 2018; Armstrong et al., 2019) requires users and indie innovators to
question themselves, to overcome their limitations and to experiment with new ways of making and doing things. Creators and innovators make use of digital-enabling technologies as digital fabrication platforms, prototyping spaces and community-based labs to make tools and tech accessible. Personal and personalized solutions can be created on-demand, on-site, and then shared with others. Recently, the theme of innovation, as far as design disciplines are concerned, is increasingly linked to experimental practices directly related to the dimensions of open and distributed knowledge and production. According to Aleinikoff (2014), “innovation is a dynamic problem-solving among friends”. Innovation is a practice closely linked to the bottom-up experiential dimension, often coming from a group of users who seek to respond to design niches through the increasing accessibility to spaces, places, communities and technologies more widespread in cities. This aspect can be connected to a constant growth in the dimension of participatory design, intended not only as a methodological approach but also as a spontaneous practice, with the aim of developing design solutions together with or by the citizens-users.

2. Patient innovation and open care: an emerging scenario

Unquestionably, digital transformation increased innovation capabilities in designers but also in final users. When that kind of design-driven and user-driven innovation become mission-oriented (Mazzucato, 2018), it can be work support the autonomy and quality of life of people, especially those affected by diseases or disabilities, as well as their families and caregivers. According to Bertalan Mesko (2016), the development of new forms of care enabled and enhanced both socially and technologically, the increasing digitization of patient data, and the increased permeation of so-called disruptive technologies, acquire a meaning only if they put the person at the center of their action. This means, first of all, strengthening his or her personal knowledge, and making him or her an expert capable of autonomously managing the prevention, self-diagnosis, and collaboration with the doctor to actively participate in the development of his or her own care. It is precisely the emerging trend of active participation by patients - both individually and in the organized manner of associations and caregivers - that brings to light new levers and new ways of innovation.

What gradually emerges is the concept of patient innovation (Zejnilović, 2016; Maffei et al., 2017), a bottom-up and user innovation formula that is divided into four main dimensions: design, production-technological, social, regulatory and legislative (Maffei et al., 2019).

As far as the design dimension is concerned, there is an important need to aggregate different skills, professional and non-professional, in a collaborative dynamic through informal design practices. The productive-technological dimension of patient innovation is expressed in the choice and use of technologies - particularly digital technologies - which can also be modified by the patient himself or built ad hoc. The creation of communities united by the desire to solve specific needs, goes to perimeter the social and/or socializing dimension. Finally, patient innovation must necessarily confront (face of) the regulatory and
legislative aspect, which often slows down or blocks the production and diffusion of certain design solutions, as they are not part of the traditional certification chain.

Digital transformation allows patients to access and exchange data and information, create a dialogue with health services and ministries, organise and participate in associations, and raise funds to develop scientific research. The health system is becoming increasingly advanced when it comes to monitoring the body and its physical performance, with biometric data collected by interactive personal and environmental devices.

One of the areas in which this shared synergy can give concrete expression to relevant ground-breaking solutions is the open care (Day et al. 2017). Nowadays, types of products such as aids and prostheses can be designed using open source knowledge, software and hardware, and materialized within makerspaces combining makers’ skills with digital manufacturing technologies (DeMonaco et al., 2019). Starting from this logic, a multiplicity of different solutions can be conceived and implemented answering to personal or social needs related to diseases or disability conditions. The personal and collaborative dimension in the path of disease management is, probably, the main catalyst that has made possible a series of innovative open care projects.

Within this transformation framework, it is interesting to explore the role of distributed design and production for open healthcare that we go to define as Distributed Care (DC), investigating emerging design skills and the use of digital fabrication within makerspaces, distributed labs where bottom-up experimentations developed by communities of makers, professionals and users are recently condensed. In particular, after a preliminary introduction on the main dynamics of open and distributed design, we will try to trace areas of opportunity and criticality, points of convergence and difference that may emerge in designing solutions for DC. The methodology proposed is the analysis of two case studies related to experimental initiatives developed by designers, makers and user innovators, materialized within an Italian Fab Labs, Polifactory - the makerspace of the Politecnico di Milano, and released through a distributed design platform (distributeddesign.eu). The analysis of these experiences in the field will serve to reflect on the development of Distributed Care, an innovation area characterized by a design culture strongly hybridized with the maker culture (Bogers et al., 2010).

3. Distributed design for open healthcare: two stories

Thanks to the systemic interpretation of the main elements of the emerging healthcare scenarios, it has been possible to scale up the proposed interpretation within a funded design project, explicitly conceived to be open and distributed.
Distributed design and production for distributed care.

FabCare and Next Steps\(^1\) are two experimental initiatives part of Distributed Design Market Platform (DDMP, distributeddesign.eu), a project funded and supported by the Creative Europe Program of the European Commission to implement the global network of Fab Lab promoting and improving the connection between makers and designers with the European market. DDMP is an opportunity to consolidate this network, focusing on the development of a European Distributed Design Market Platform for makers and designers. It is particularly relevant as a specific case study in order to explore the dynamics of product design in the healthcare sector within the Fab Labs.

FabCare (2018) and Next Steps (2019) are experimental initiatives promoted and developed by the makerspace Polifactory in order to stimulate designers, makers and independent innovators to design open source products for healthcare that can be distributed through digital platforms and materialized in Fab Labs. Both these experiences aim to demonstrate how designers, makers and independent innovators – also interacting with patients, caregivers and their associations – can concretely design, produce and distribute open source healthcare solutions with a real market potential.

The reasons why this is a relevant case study can be properly traced back to the nature of distributed dissemination with which the project outputs were originally conceived. According to Armstrong et al. (2019), the distributed design idea is one outcome of the intersection of two global trends: the maker movement and the digitisation of the design discipline. The entire DDMP European project integrates design skills and the making approach to enable the development of new entrepreneurial types of professional producers and in the case of the FabCare and Next Steps initiatives, this has generated open and distributed healthcare projects.

The parameters adopted for the case studies analysis are:

- physical and virtual places where the design process become "distributed" (Fab Labs, makerspaces, digital manufacturing platforms, etc.);
- enabling tools and digital technologies used to materialize the solutions;
- kind of solutions developed (e.g. product, product-service, on-demand, customizable, shareable solution);
- actors and stakeholders involved in the design and materialization process (e.g. community of users, caregivers, patient associations, etc.);
- release of the solutions (e.g. marketplaces, open source form although not necessarily free).

\(^1\) Other interesting case studies that cannot be analyzed in this paper are: Hackability, Careables.org, Open Rampette. Detailed information on these cases have been published within the MakeToCare reports (see www.maketocare.it/report)
3.1 FabCare. Open devices for smart monitoring and care awareness

| Table 1. Synthetic overview of the FabCare initiative. |
|-----------------------------|-------------------------------------------------|
| **Level of analysis**       | **Short description**                           |
| Places (Physical and/or virtual) | Fab Lab, university, medical centre, online platform |
| Technologies and enabling tools | 3D printing, 4D printing, Laser cutting, CNC Milling machine, Electronics, Soldering station, |
| Kind of solutions developed | Electronic devices and analog products for monitoring and prevention |
| Actors and stakeholders involved | Designers, makers, researcher, doctors and specialists (CM Santagostino), users, patients |
| Distribution | Release of the solutions through CC-BY license; download available on the online platform distributeddesign.eu |

For the first year of DDMP research, Polifactory based on the experience gained in the healthcare field, thanks to the MaketoCare research initiative (makertocare.it). Nowadays, types of products such as aids and prostheses can be designed using open source knowledge, software and hardware, and then be materialized in Fab Labs combining makers’ skills with digital manufacturing technologies. Starting from this logic, a multiplicity of different solutions can be conceived, intertwined and implemented answering to the needs of prevention or care for everyone. The experimental initiative that has been developed has taken the name FabCare, with the purpose of stimulating designers, makers and independent innovators to design open source products for healthcare that can be distributed through digital platforms and materialized in Fab Labs. FabCare was developed by Polifactory, within the Distributed Design Market Platform project. Therefore, FabCare’s challenge aims to demonstrate how designers, makers and independent innovators – also interacting with patients, caregivers and their associations – can concretely design, produce and distribute open source healthcare solutions with a real market potential. Furthermore, Fabcare was technically and scientifically supported, as well as endorsed, by Centro Medico Santagostino, that is one of the first Italian network of specialist polyclinics managed by a social venture capital company, and it is aimed at experimenting healthcare service models economically sustainable and socially responsible.

The whole project lasted only a few months: from May to October 2018, FabCare has developed an intense mix of events and activities. The main milestones of the project were: (i.) the Open Call for Ideas, (ii.) the selection of ideas to prototype, (iii.) the projects’ implementation and materialization, (iv.) the projects distribution and promotion.
Distributed design and production for distributed care.

First the Open Call for Ideas (i.) was co-designed, launched and promoted. Polifactory and CM Santangostino have collaborated to define themes and design challenges, and participation rules for designers, makers and independent innovators. Then, FabCare’s Open Call for Ideas was officially released during the European Maker Week, and from May to July the it has been promoted to the Italian Fab Labs network and the main design schools and university in Italy. Afterwards the selection of ideas to prototype (ii.) was made. Starting from a list of twentyone projects submitted by a group of sixty designers and makers, in July 2018 a panel of experts in design, healthcare and digital fabrication have selected the five ideas to be developed and prototyped within Polifactory. The winning ideas were: DermAware, Dermap, Mole Mapper, Palpatine and Zero2. It is important to note that they are specifically defined as ideas, because they were mainly interesting intuitions and concepts, still far from the logic of open and distributed design and production. 

For this reason, the evolutions acquired during the phase of projects’ implementation and materialization (iii.). From July to October 2018, seventeen designers and makers have operated in Polifactory with the aim of developing the five selected projects. During the phases of executive design, experimental prototyping and digital fabrication they have been supported by a network of technicians, professors and researchers of the Politecnico di Milano. In the end the phase of distribution and promotion (iv.) was held. The five projects were published on the platform distributeddesign.eu and on Polifactory’s website, thus promoted and presented at European Maker Faire Rome through an exhibition and a talk.

Despite the fact that these are projects with very different complexities, it is important to emphasize that anyone can actually reproduce them, because for each project the documentation is still available online, which includes digital files for production, fab-instructions, and the user manual. It is important to point out that all projects developed
within FabCare are not medical devices. These are open source solutions at the first stage of release and development that can be freely implemented following the instructions provided by the CC-BY license. All FabCare solutions provide informative support and/or help with prevention or monitoring activities regarding the problem or pathology for which they were designed. In no case can these solutions replace a consultation or relationship with a doctor or a medical specialist.

Figure 2. From left to right and from top to bottom: “Dermap”, a device that supports people in measuring the evolution of their vitiligo, designed by Marianna Accorsi, Giulia Sala, Giuseppe Valentino; “DermAware”, a digital bracelet to educate people on the burden
associated with atopic dermatitis, designed by Nicolò Bisi, Nur Eral and Mattia Fantoni with the support of Angelo Geraci, Nicola Corna, Fabio Garzetti and Nicola Lusardi; "Mole Mapper", a small tool for your skin health. Keep your moles in check and share info with your doctor, designed by Ilaria Vitali, Patrizia Bolzan, Mila Stepanovic; “Zero2” a device for patients with respiratory deficiency used to monitor their blood oxygen levels, designed by Tommaso Brioschi, Lorenzo Lanzoni, Giovanni Luca Fidone; “Palpatine”, an analogue wearable educational device to learn the correct breast palpation techniques, designed by Francesca Poli, Daniel Sanchez, Benedetta Beltrami, Luca Sommariva, Chiara Parise.

3.2 Next Steps. Co-designing open source walking aids

Table 2. Synthetic overview of the Next Steps initiative.

<table>
<thead>
<tr>
<th>Level of analysis</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Places (Physical and or virtual)</td>
<td>Fab Lab, university, co-design workshop, online platform</td>
</tr>
<tr>
<td>Technologies and enabling tools</td>
<td>Available walking aids, 3D printing, Laser cutting, Electronics, Soldering station,</td>
</tr>
<tr>
<td>Kind of solutions developed</td>
<td>Aesthetic and/or functional solutions for the customization and reconfiguration of walking aids</td>
</tr>
<tr>
<td>Actors and stakeholders involved</td>
<td>Designers, makers, researcher, patient association (AIG), healthcare company (Sanofi Genzyme), lead users, patients</td>
</tr>
<tr>
<td>Distribution</td>
<td>Release of the solutions through CC-BY license; download available on the online platform distributeddesign.eu</td>
</tr>
</tbody>
</table>

In the second year of the DDMP project, Polifactory has once again proposed to work on the issue of healthcare, this time articulating differently the identification phase of the project areas of intervention. The new action, called Next Steps, started from the desire to stimulate designers, makers and patients (as user innovators) to co-design and prototype a collection of open source walking aids that can be distributed through digital platforms and materialized in Fab Labs. Next Steps was developed thanks to the collaboration with Italian Glycogenosis Association (AIG), a patient association that represents people affected by this rare and degenerative metabolic disease. AIG prompted the involvement of patients in the co-design and prototyping of walking aids and for that very reason, the whole project was built around the co-design phase. Thanks to Next Steps, patients were able to experience a real process of patient innovation. Next Steps was articulated in three steps: (i.) the Challenge assessment; (ii.) the Maker in Residence activity; (iii.) the projects distribution and promotion. During the Challenge phase (i.), from March to May 2019, the starting point was an open call to action that stimulates the engagement of a group of patients that will be involved in the co-design of walking aids together with a team of designers and makers of Politecnico di Milano. During the Challenge phase, the product ideas were presented and
shared with AIG, within one of more events. Patient innovators such as Antonella Ferrari\textsuperscript{2} caregiver innovators such as Fabio Gorrasi\textsuperscript{3} were able to participate in this phase.

From May to September 2019 the Makers in Residence phase (ii.) was held. In this phase patients interacted with the designers who supported them in the development and prototyping of open source walking aids, thanks to the technical and scientific support provided by Polifactory, and the medical and scientific support provided by Sanofi Genzyme.

The last step, the promotion and distribution of the projects (iii.), took place in September and October 2019. As for the previous edition of DDMP, the results of co-design and prototyping were published both on the distribuddesign.eu platform and on the Polifactory’s website, and were also presented in Rome during a speech at the European Maker Faire 2019, and in Milan during the Manifatture Aperte event. Reflecting on the previously established co-design phase, an in-depth examination of the type of information obtained by strengthening the involvement of patients and caregivers is reported.

The results of a first survey with the patients from AIG association, the suggestions received by the patient-innovators during the co-design workshop, and the feedback obtained interacting with patients and their families during the AIG meeting evidences aspects that influence the design phase. First of all, the aesthetic dimension of the walking aids is as important as working on functional aspects. Secondly, walking aids tents to become physical extensions of the people; personalization is an important issue because characterizes the identity of the walking aids in order to be tuned with that of their users. Then, Next Steps solutions must be adaptable to the walking aids already available on the market. Last but not least, the digital manufacturing processes and the digital technologies embedded in the walking aids have to be adaptable for DIY, makers and Fab Labs, craftsmanship but also industrial sector. The result was four projects, focusing on different aspects of walking aids.

The first project is Twistr, a parametric stick that has developed a design and digital fabrication method to materialize personal parametric sticks – with kinect and grasshopper – having a 3D printed structure. The stick is printed with the carbonium material. Another stick project, this time made with a generative logic is called Taylor. This is a project of a method to create generative sticks, which change according to the weight, height and gender of the user. Another result was the project of an IoT rollator named Wander3d. Thanks to this hacking it is possible to transform a traditional walker into a motorized and sensorized object. The user can activate or not the motors according to the needs. The last project dealt with the aesthetic dimension of walking aids. Clip Clap is a project that allows the personalization of your crutch. This project concerns the co-design of removable clips for all

\textsuperscript{2} Antonella Ferrari is an Italian actress suffering from multiple sclerosis who, acting as an innovative patient, has designed and developed her own collection of hand-decorated crutches.

\textsuperscript{3} Fabio Gorrasi is an Italian caregiver innovator who has designed and make a special brace for his daughter affected by Spinal Muscular Atrophy, in order to give her more movement and freedom.
kinds of crutches that can be easily personalized and digitally fabricated. The projects developed will have to be available in open source mode according to the Creative Common License (cc-by and cc-by-sa).

Figure 3. From left to right and from top to bottom: “Twistr”, the parametric stick designed by Angelo De Iesi, Andrea Ascani, Ewoud Westerduin, Aurélie Marie Glaser; “Taylor”, the generative stick designed by Alessandro Ceriani and Marco Ceruti; “Wander3D”, the IoT rollator designed by Leonardo Lucchetti and Silvia Meregalli; “Clip Clap”, the customization of crutches designed by Lorenzo Cereda, Nicola Colombo, Giovanni Cortellessa and Andrea Stefanelli.

4. Designing for Distributed Care. A new scalable model?

The literature review and the experiences analyzed stimulate two levels of reflection. The first level concerns the key elements of a distributed design and production process for the development of open source solutions in healthcare. The second level concerns the characteristics and properties that define Distributed Care as a possible area of innovation.

The analysis of project experiences in the field identify the following key elements previously highlighted in the summary tables of the initiatives:
• **Actors.** The importance of cooperation between heterogeneous subjects such as designers, makers, but also specialists in the institutional care sector, patients, caregivers and associations. Distributed design stimulates the creation of transversal project teams that participate with different contributions in the development of the final solutions, especially during the initial phase that range from needs analysis and development of the project brief.

• **Places.** The importance of the places where the project development process is materialized. From the initial idea to the final solution distributed design generates a progressive delocalization of the innovation process. In fact, the first phases generally need the support of different "physical" places that function as "facilitators" and aggregators of (Fab Labs, research labs, medical and rehabilitation centers, schools, etc.) where the different subjects involved in the project development have the opportunity to meet, confront each other, work together. The prototyping and design development phases generally take place thanks to the support of a Fab Lab network.

• **Technologies.** The importance of the access and use network of advanced digital manufacturing technologies thanks to which production can be customized, decentralized and potentially close-to-the-user.

• **Distribution/release.** The importance of the concept of "openness" applied to the distribution and release phase of the final solutions. Distributed design makes the solutions accessible and materialize everywhere by downloading digital files from peer-to-peer platforms (e.g. GitHub). The available documentation allows to elaborate subsequent customizations and implementations of the solution, opening the entire design process and connecting it to a distributed production network.

What can we learn from the promising direction of distributed care?

• **Not only medical devices:** Distributed design promotes and stimulates a biodiversity of solutions, exploring the theme of prosthetics, orthosis, medical devices and a new generation of personal objects. Many solutions – especially in the field of healthcare – are influenced by the regulatory system, which is fundamental to protect users and patients. This is a bottleneck for distributed design, but it is also an opportunity. The development of non-medical devices can be complementary to medical ones. Distributed design can support users and innovators to create solutions that demonstrate how existing rules, standards and market barriers could be reconsidered.

• **Not only functional solutions:** Many solutions are designed following functional and technical requirements, but their aesthetic dimensions can be as important. Healthcare objects and aids tend to become physical extensions of people. Aesthetic personalization is important, because it characterizes the identity of objects and establishes a personal or familiarity for users.

• **Not only complex and expensive solutions:** Many objects and devices are complex and expensive. Distributed design can design solutions that can be adapted from
Distributed design and production for distributed care.

objects already available on the market, taking into consideration open hardware and low-cost technologies that are easily accessible for the everyday user and disadvantaged or vulnerable people.

- Not only new products: Many objects are unique and irreplaceable owing to a relationship that is established with their users and owners. Distributed design perfectly fits with hacking, repairing and upgrading practices and is compatible with remanufacturing and refurbishing processes.

What’s next? We could be at the beginning of an augmented concept of ‘care’ where people can develop a distributed awareness, responsibility and participation in the design of innovative open source solutions that work to take care not only of people, but also other living beings and the environment. This can be Distributed Care.

References


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Acknowledgements: Thanks to Centro Medico Santagostino, Associazione Italiana Glicogenosi (AIG) for participating in the co-creation phase, and Sanofi Genzyme for supporting Polifactory and the projects’ authors in the promotion and showcase of the results.
Heterotopia of Space: How capitalism is alienating and controlling societies

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Abstract | Multimedia has historically been the tool of choice preferred by political capitalism to gain control over people. This has been massively aided by the upsurge in the political sector’s machinery and progressive technology. Governments, and the private sector control multimedia tools such as advertising, social media platforms and technology to control people. Cities have risen to become heterotopias; vast-growing high-tech infrastructure capitals that transform people’s behaviour. A marked change was visible in the 21st Century. Technological devices previously only available to governments and the military became commercialised, packaged and marketed to people. In our capitalist consumer societies, such private sector corporations take advantage of social media platforms to further control social groups largely influencing their politics. The private sector, through its multiple alliance to governments, moved to exploiting technological tools commercially. Thus, progress became a basic process solely for gaining power and control over people.

KEYWORDS | CAPITALISM, CONSUMERISM, IMAGERY, SPECTACLE
1. **Introduction**

This paper defines heterotopias as manufactured spaces that alter people’s behaviour. In this day and age, it is very easy for governments, together with the private sector to manipulate multimedia platforms to create spaces where human behaviour can be controlled, almost expected. This paper sheds light on these manipulative practices by governments taking examples some historical, some modern, to exemplify how people’s behaviour can be almost orchestrated. A consumer society relies heavily on progressing its technology. Accordingly, technology took the upper hand guiding mankind’s gaze. As Virilio noted, “one can only see instantaneous sections seized by the Cyclops eye of the lens” (Virilio, 1994, p.13). However, for Debord sight is “the most abstract of the senses, and the most easily deceived” (Debord, 1995, p.17). Thus, in a world that is mirrored by images, reality is lost to the point of being obscured and even non-existent.

Multimedia has historically been used exploitatively with large socio-political implications. Originally, advertisement has been manufactured to lull public opinion. This has been achieved through the use of attractive visuals. Images, then, have become the new norm used by governments, and the private sector to derive their legitimacy in societies armed with technology. Previously, the exploitation of people, particularly the proletariat, was made by normalizing societal conventions through a visual illusion of imagery. However, today, this can be achieved through different online platforms as images spread instantaneously. This maintains cultural and political sustainability and ensures governments and corporations stay in place through the ongoing argument that people need government protection as there is always a security threat and people will always need things to consume. Our behaviour is currently controlled by the images that we see online.

Online platforms provide us with an arena for interconnection as well as for discovering difference. While there is a high degree of homogenization, it is imperative to note that there is also forms of diversification.

Visual communication literature addressed topics relevant to the exploitive image and how it’s used for changing social perceptions. Government’s newest trend is creating a hybrid image that juxtaposes violence with refined spectacle. It becomes impossible for some spectators to identify this metamorphosis. This is an approach that rounds people collectively leading to a homogeneous society. This method is used by governments and the private sector to control people by manipulating codes and symbols. Ideologies of suppression and obeisance are hidden in imagery that are innocently absorbed. Although ideologies have been reconstructed over time reflecting democracy, across societies yet, democracy has been long dead. It is only the illusion of democracy that we find across countries and societies nowadays. Dictatorship is ever present but is concealed behind concepts and imagery. In *One-Dimensional Man*, Marcuse suggested that with “technical progress as its instrument, freedom-in the sense of man’s subjection in his productive apparatus-is perpetuated and intensified in the form of many liberties and comforts” (Marcuse, 2002, p.35). Voting, freedom of speech, debates, open arguments, advertisement
all reflect an image of a liberal, democratic, equal, representation society. By taking part of governmental decisions, the majority of individuals think they are free under totalitarian regimes.

As societies advance technologically so do corporations driven by capitalism. Private sector corporations used technological developments, to camouflage its exploitive tendencies. Governments and the private sector have become intertwined and synonymous due to their enmeshed interests. They hide behind a polished and mediated representation. Societies become more and more intertwined with the spectacle, but also alienated due to their experience with mediated representations. For Debord, “the spectacle is not a collection of images,” but a social relation among people mediated by images” (Debord, 1995, p.12). He considered that anything representative can alter reality and may be harmful.

Today, with these easily affordable devices, imagery and the spectacle that has been commercialised by the private sector people can be reached collectively, thus rendering images more dangerous and exploitive. The purpose and use of images with new technologies has highly affected image production. These technologies were able to copy the image of the actual in the virtual. It bred a duplicate, almost virtual, space within the actual where societies can move from one interactive space to another. “This act of cutting reality into a sign and nothingness simultaneously doubles the viewing subject, who now exists in two spaces: the familiar physical space of her body and the virtual space of an image within the screen” (Manovich, 2002, p.104).

Not only did these new devices change the way people communicate and interact but it changed their behaviour and perception as they continuously disappeared inside the virtual. Technology took control over the body as people are delving more inside the virtual. Virilio’s point of view on these new technological devices is that it will “colonize human behaviour, just as television and the computer are doing, but this last form of colonization is a much more intimate, and a much irresistible form” (Virilio, 2000, p.51). Since many people are equipped with these tools, such societies become intertwined inside webs of technologies that are communicative, interactive, mobile and more importantly monitored and observed.

2. Aestheticization and the image

Totalitarian Governments have historically exploited artists to camouflage and propagate messages aesthetically. Before the industrialization of the screen, images were passed on differently. For example, in his essay, The Work of Art in the Age of Mechanical Reproduction, Walter Benjamin argues how political regimes can exploit new machinery. Previously, with inventions like cameras, film and printers which can distribute messages equally leading to a collective response.

Historically skilled painters, sculptors, or craftsmen were commissioned by patrons. As churches grew in power, so did the development of its artistic flair. Artists created artwork
as truthfully as possible filling it with illusion through a dynamic display. That said, it was
designed to impress. In order to hone its message churches commissioned artists to spread
its holy image to the public. City streets, towns and public shrines were covered with art,
associated with the church’s influential power. This type of art was made to appeal visually
and emotionally to the public. Comparing this to the Nazi regime who exploited the use of
new emerging art media like films, newspapers, the radio, advertisement, symbols,
speakers, ceremonial events, exhibits and schools, which all exemplified as Nazi propaganda
and exploited the public opinion. This is when Benjamin differentiated between two poles,
exhibition and cult values. “Originally the contextual integration of art in tradition found its
expression in the cult. We know that the earliest art works originated in the service of a
ritual – first the magical, then the religious kind” (Durham G.M. & Kellner M. D. 2006, p.22).
He asserts that exhibition value had exceeded its dominance over cult value as the first can
be distributed faster. These inventions changed the functionality of art that was only used
for cult and religious ceremonies. Within the framework of Marxism, Adorno and
Horkheimer’s essay The Cultural Industry: Enlightenment as Mass Deception, inspects the
use of such media are propagated within the arts particularly during wars to gain control
over the people. “Culture today is infecting everything with sameness. Film, radio, and
magazines form a system” (Durham G.M. & Kellner M. D.,2006, p.41). This allowed political
regimes and governments to control and divert human behaviour and perception according
to the imposed system. “The basis on which technology is gaining power over society is the
power of those whose economic position in society is strongest”. (Durham G.M. & Kellner M.
D.,2006, p.42). Within these media of films, radio and magazines, propaganda becomes
harder to distinguish, for some, when it’s aestheticized and blended with art.

Another more recent example of governments manipulating public opinion through imagery
is the United States diverting public opinion by selling an image of a picture perfect life.
Picture-perfect America is known for its nation building, technological military advancement,
and financial means. Although the United States is also known for exploitation of slavery,
imperialism and racism yet any anti-humanitarian atrocities committed by this nation has
been camouflaged with a polished spectacle. Identified as “a visually striking performance or
display” (Spectacle, para 1), the spectacle of the United States was fed to its people by
advertisement and films. With the advancement of visual communication devices, the US as
Debord noted “It has invented a visual form of itself “(Debord,1995, p.14). As a
predominantly capitalist consumer society, some of its citizens are living the glamour of the
United States. Therefore, this psychedelic image was manufactured by media. Its beliefs and
values have been constructed through its Hollywood image where other societies struggled
maintaining their culture because they tried replicating a phantasmagoric image.

In a controversial title, The Gulf War Did Not Take Place, Jean Baudrillard argues that this
war was a virtual war produced by the media. The only access to the public to see the events
of this war was through the US media like CNN. “It is a masquerade of information. No
images of the field battle, but images of masks, of blind or defeated faces, images of
falsification. It is not war taking place over there but the disfiguration of the world”
Heterotopia of Space: How Capitalism is alienating and controlling societies

(Baudrillard, 1995, p.40). The real events of this warfare disappeared behind the curtain of simulated reality made by the media and images. “The build-up is unreal as though the fiction of an earthquake were created by manipulating the measuring instruments” (Baudrillard, 1995, p.26).

This was a modern speculative war promoted by the media in a form of global entertainment and suspense. It was a broadcasted war that took place on the screen. In an interview with Paul Virilio, he stated that the Gulf war was considered a live war. (Virilio, 2004, p.66). This war was taking place globally and on every screen. But because the United States controlled the media, the image of this war propagated globally, from the US point of view. Very little was revealed from the actual combat between the American and Iraqi armies. What was exposed about the reality of the combat to the public was one sided. The United States wanted to promote to its public a strong and heroic image in order to maintain a hierarchal dominance. Their audience was introduced to a new militarized media that depicts a spectacle image and patriotic illusion.

For Baudrillard’s explicit view about the United States is that “it is neither dream or reality. It’s a hyperreality” (Baudrillard,2010, p.28). “The whole country is cinematic” (Baudrillard, 2010, p.31). Through different media devices, the world of advertisement expanded. The placement of ads varied from billboards, to buildings with screens, or popping out randomly on different social media platforms. This excessive bombardment of advertisement is infused with multiple forms of ideologies. Directed by John Carpenter, They Live is a Hollywood film that illustrates a typical consumer society that is ruled by a Capitalist government and its private sector. The film exposes how advertisement can spread ideologies and things to consume that lay within its spectacle. The glasses in the film exemplifies living a hyperreality of the fake and real. For Zizek wearing the glasses is “you see the dictatorship within democracy” (Zizek,2012, 02:58). When Nada wore the glasses, he saw what lies beyond the ads. What seems to be innocent, is a spectacle of control, and regulation. Through the ads, there is a message that promotes reproduction, sleep, and consumption. Zizek explicitly illustrates the strange lengthy fight between the two characters which represents the fear of stepping out of societies’ norm. This shows how people crave the hypnosis of ideologies since it embodies a comfort zone. Frank’s character illustrates the majority of daydreaming individuals who refuse to wake up to the ugliness of its society and the evil of these corporations. Zizek identifies this rejection, associating it to fear and pain. “To step outside of it, it hurts, it is a painful experience” (Zizek,2012, 04:42).

3. The King and Queen’s Gaze

Methods of people control exerted by governments throughout history has always changed in ‘how’ it dominates people. Early on, societies normalize traditions in order to control the public’s views, tunnel sight, and behaviour. Overtime, methods of control obscured what was once visible into becoming invisible. Michel Foucault identified representation as a
process of symbolization or coding linking it to power. To this, he examines Diego Velázquez painting titled *Las Meninas* dated 1656 and how power and hierarchy is presented in this painting yet remains invisible to the spectator’s eyes. Velázquez painting captures a photographic picture of the Spanish court. The skilled artist steered the viewer to look at particular figures and angles in the painting. What is visible in the painting is what the artist gave emphasis on using light and dark contrast. Relatively, Velázquez directs the viewer’s gaze on specific subjects and hides those who are in power. Both figures of the king and queen are obscured in a mirror placed in the middle of the artwork who gaze back at the oblivious spectator.

In the Middle Ages, the image of power was made visible to the public gaze. The image of power was visible to the public through public executions. Those were purposely visible for implanting an image of power and control over people. Pain and torture were used as punishment applied on the physical body. This reminded people of the authoritative power commanded by rulers. Torture devices varied in their instruments and practice. They were exploited in accordance to the severity of the crime. “Skilled torturers would use methods that delayed death while inflicting agonizing pain” (Foucault, 1995, p.34). Therefore, the image of pain was key instrument used to exert control.

Public executions were somehow ceremonial and entertaining. “The tortured body is first inscribed in the legal ceremonial that must produce, open for all to see, the truth of the crime” (Foucault, 1995, p.35). It publicized a specific image of justice – that of cruelty. So, in order to restore peace, abolishing riotous behaviour is a must in societies. The convicted used to endure public humiliation and physical pain in the most indisputable abhorrent ways. Because this power exposed its barbaric methods in public spaces, to some extent it normalized its barbaric ways onto its subjects. This form of power controls the public through the implementation of violence on bodies.

In modern societies, public torture is no longer used as a means of public control. New forms of power have emerged and replaced older ones. Works of architecture such as prisons replaced public executions. Instruments of torture gradually disappeared from public spaces and punishment was concealed behind prison’s walls. Additionally, other forms of discipline were conducted by different institutions. These new forms of power are different from medieval ones. The new power wanted to create obedient bodies that self-regulate according to the laws. “For example, institutions as schools, hospitals, and military are places that train individuals to self-regulate” (Foucault, 1995, p.136). These institutions became the norm of societies and concealed the system of control behind its disciplinary and cultured methods making it almost invisible to the eyes of the public. With technologies, power becomes invisible. Similar to Velázquez painting, it also gazes at the spectator directly and from every angle. “This power had to be a faceless gaze that transformed the whole social body into a field of perception” (Foucault, 1995, p.214). These devices allowed visibility to be everywhere. Watching people from multiple angles can be seen in Jeremey Bentham’s architectural design, the panopticon. The panopticon is a central tower from which prisoners
could be observed. Because the tower is always lit; prisoners assumed that they are being watched at all times. Consequently, these devices function as Bentham’s panoptic tower and Velázquez mirror. The spread of these devices within societies in order to monitor people, from any point in space and time thus making everything visible. Today, many public spaces are equipped with machinery that monitor everything. However, the system of control and power is hidden and remains invisible from the eyes of the public. With the new technologies, the mirror from Velázquez painting is positioned in the heart of societies as Bentham’s panopticon. In consequence, totalitarian regimes become invisible to the naked eye and it’s “gaze is alert everywhere” (Foucault, 1995, p.195).

This illustrates how the structure of the panopticon and Velázquez mirror is reflected in tools such as the CCTV, global positioning systems, wireless internet, smart mobile phones, smart watches and many more which are employed everywhere in the physical space. This in turn creates an augmented space, identified by Lev Manovich as “a space of monitoring and control” (Manovich, 2002, p.5). Therefore, an augmented space is a space of surveillance because these technologies function as the panoptic tower and Velázquez mirror. Therefore, the invisible gaze of the king and queen had moved from center of the court to be everywhere because of these devices. The power of the capital is reflected behind the shiny screens of these devices, creating different levels of control. Today, both the actual and virtual are spaces of monitoring and control over the masses.

4. The Shift of Heterotopias

Currently we live in heterotopias, spaces created by the government and private sector that control the way we behave. A utopic society represents a perfect image of itself. It is identified in Oxford Dictionary as, “an imagined place or a state of things where everything is perfect (Utopia, para 1). On the other hand, heterotopias are other places, spaces that relatively carry several layered meanings and are characterized by juxtaposing different settings together. “We live inside a set of relations that delineates sites which are irreducible to one another and absolutely not superimposable on another” (Foucault, 2006, p.23).

Heterotopias subjugate people in several spaces. Because heterotopias are part of a social structure, people are unaware of their existence as they are naturalized within the social system. They become natural and part of societies norm. Heterotopias have many characteristics and are experienced within the frames of culture. The masses are unaware of the existence of such spaces that are used for reconstructing behaviour. These spaces are used as a form of control over the body. People in heterotopias behave according to the place they are in.

Some heterotopic examples can be relevant to urban spaces, as they are able to juxtapose different places and environments together. Moreover, they accumulate time, preserving the past such as Foucault’s example of museums, libraries or cemeteries where the body is persevered. Another characteristic is that they can create a non-existent imaginary place as
well as differentiate and categorize people within groups and identities. Since people are living in online landscapes, heterotopias then are experienced in the virtual realm. As Foucault had noted, the existence of heterotopias is to regulate, examine, and restructure societies and people, for example the prison is a heterotopia. Although they seem harmless, yet they can regulate and discipline society’s behaviour. Since mankind is currently swinging in spaces of virtual and actual, mankind is nevertheless living the heterotopic “placeless place” (Foucault, 2002, p. 4). Online landscapes reflect a “placeless place or a place without a place” in virtual reality. Going through the World Wide Web, social media, google earth and other spaces are all kinds of heterotopias.

The virtual has the ability to create heterotopias that originated from spaces of society. Since many societies are wired with virtual spaces, therefore they adapted their behaviour to virtual agreements. Today, the actual space relies heavily on the virtual as most of its daily operations are conducted online. Businesses, finances, finding locations, interactions, and money transactions are conducted virtually. Online landscapes are colonizing societies inside its cybernetic frames that are limitless with its boundless pot of networks that promises the manifestation of any human desire. The new maps of many civilizations become identical because of World Wide Web and social media.

Societies find themselves more immersed in these happier spaces. These spaces are considered the new heterotopias as they impact people’s behaviour and actions. What people experience within online heterotopias are different than the ones in the actual. They can regulate and control people’s behaviour targeting specific areas such as consumption of commodities. For example, virtually, people are engaged in images. The image of fame, identity, lifestyle, and youth stream everywhere within these spaces. Virtual heterotopias are prevailing over reality and over the actual space leading societies to fall inside its illusions and imagery. And while consumer societies aim for similarity through fashion and style, this is leading to mass-producing behaviour. This alternative reality may lead to dangerous delusions. Adapting in the virtual heterotopia meaning sustaining self-image but leading to loss of identity.

The image of delusion and loss of identity heads in the direction of plastic surgery. The art of modelling flesh becomes the trend of consumer societies. The obsessiveness of extending youth resorts to extreme reconstruction of the body in order to maintain the youthful look in the virtual. Not only fashion can print a specific look with clothes and accessories also plastic surgery can print bodies. Duplicates of bodies, and faces exist because of these surgeries. Societies are living in the delusion of these images inside the virtual. They are trying to mimic and look as their virtual image. The strains of the virtual is maintaining the fake identity that lives differently in the physical. This is how new heterotopias operate on regulating societies as the focus today is mostly on appearances. Instead of controlling behaviour with instruments of torture, people are going under the knife willingly through surgeries in order to enhance their self-image. Furthermore, controlling people’s behaviour goes further towards what they consume. Since heterotopias are known for merging sets of places
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Social media tools like Instagram and Facebook merge things together. The user can go live, play games, shop, promote, follow pages, create pages, watch the latest news, among other activities. These spaces offer new ways of living as users become more dependable on them. Whether food, clothes, shoes even sports, people behave in a specific way according to the language of the virtual. Opening businesses is possible and easy virtually. Everyone can go online and promote their commodities and goods. Instead of investing growth in real urban spaces, businesses now aim to grow virtually. More Instagram followers means product popularity. Investing in followers and fake social media accounts, is used to gain consumer trust and increasing product sales. These virtual businesses are their own advertisement agency in marketing and promoting themselves.

With easy and inexpensive strategies like following accounts casually, random discounts and shout outs, online challenges, collecting funds for a cause, and free give away. Seeking popular online bloggers with over a million followers to promote merchandise is essential. Virtual businesses implement regular strategies and the linguistic language of the virtual space, were consumers are swayed by these strategies falling into this trap of virtual spectacle. The new heterotopias of the virtual space controls societies to behave and consume in a specific way. In the current consumer societies, people are completely alienated from their actual space and have no sense of identity as they behave, dress, and look the same.

5. Conclusion

Images created by processes within a capitalist system: one that is controlled by both governments and the private sector due to their common interests, have created communication tools such as film, advertising, and online platforms reaching global destinations, crowding out place-specific identities. This capitalist modern system has succeeded in alienating societies stripping it from its identity, physical body, and urban spaces. “It’s the disappearance of the place and the individual at the same time. It’s now proven that this technique is spreading all over the world. It’s easier to make people disappear one by one, ten by ten, or thousands by thousands” (Virilio, 2008, p. 147). Although it might seem that these technologies had helped societies however, stipulated a specific way of living in a capitalist consumer society.

While we think we are living in enormously technologically sophisticated worlds governed by democracies and catered for by the private sector, this is nothing more than an illusion. As our lives became more virtual, politics and Capitalism resulted in exploiting the internet and social media for their own personal benefit. Methods of control vary from trending a cultural demand to distract people with the latest fashion and trends, to services and products, to abusing global information systems and bombarding populations with endless and useless information to the point of conditioning human response to it. As capitalist consumer
societies continue to grow, their individuals latch onto these technologies as if they are means of survival. Yet, these societies are failing to see the exploitive tendencies of these devices since their communication was made easier. Consumer societies directed by capitalism are alienated from the fact that to some extent behave, act, in the same manner. Moreover, they are monitored and observed from every single point by the panoptic gaze.

References


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**Acknowledgements:** I would like to express my gratitude to Dr. Hassan Choubassi, and Ms. Nadine Khayat for their continuous guidance and support for this paper.
I - D

(I – Design _ Idiosyncratic Meta Design)
Idiosyncratic Proceedings on Reading and Production Meta-Objects in Contemporary Industrial Design

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Abstract | This subject-object oriented research, in post-industrial socio-economic condition, refers to a protocol design on reading industrial objects and measuring how their "hyper value" increases. The term idiosyncratic design will be read as a logical protocol, to be transferred in its digital performance. At the same time, software and its projection on computational design will be read as a tank of instructions– created by subjects – that awaits a subject to schematize them and, eventually, construct his own map of expression. Therefore, idiosyncrasy as the evolution of the designer’s description language becomes an expressive medium to produce new predicaments (in the Aristotelian logic). The purpose of this paper is to present a relational epistemological map of “idiosyncratic software”.

KEYWORDS | IDIOSYCRATIC DESIGN, EPISTEMOLOGICAL MAP, LOGICAL PROTOCOL, SUBJECT-CENTRIC CULTURAL IMPRINT, POST-DESIGN
1. An ontological approach on the idiosyncratic object

1.1. Idiosyncrasy as a medium

According to Hippocrates, who first formulated the theory of the four peculiarities in his work "On the Nature of Man", idiosyncrasy is the particular/unique way a person reacts and expresses his feelings or his particular organic or psychological state and mood by which reacts to external stimuli. The etymological analysis of the word relates to "unique" - "plus" - "crassos", which in ancient Greek are interpreted as "unique blend". However, the English translation as "temperament" is also interesting; here, temperament, taken as a behaviour pattern, relates to a time condition from "Tempus" (Merriam-Webster, n.d.).

It is difficult to fully grasp the definition of idiosyncrasy. However, we can denote that it has a dynamic base through which it can be perceived as an open, “metabolic” process that expands in time. It is open because it cannot be set into a stable and concrete meaning, due to the multitude of the different perception frames each subject creates for every stimulation. These frames create properties-substances which enable metabolic reactions from the subject as they relate the logical and the emotional parts of humans’ behaviours. Additionally, timeliness can be perceived both as the human temporal perception in a given moment of time and in terms of a broader cultural evolution of the notion per se.

Figure 1. The conceptual evolution of brain-emotion relational behaviors.

According to the chronological line above, the emergence of humans’ cognitive processing is directed through the divergence and convergence of the soul-brain function. The term "knowledge" refers to all these processes through which sensory input is transformed, reduced, stored, retrieved, and used. Knowledge deals with all these even when operating without proper stimulation, like with images and hallucinations. It is a dynamic phenomenon
that is inherent in every individual personality but evolves alongside it. Also, however, there is an intermediate/hybrid behavioural condition, referring to the blending of brain and soul. This hybrid condition is the personal filter or medium, both as an in-between as well as an operational condition.

By examining the relation of reason-emotion we can recall references on a mechanism on the definition of the relation between Subject and Object. In that context, we cannot omit to mention Merleau-Ponty, Foucault and The Dispositive, Agamben and The Apparatus, the Gestalt theory, and Zizek with the Parallax view. Although their extensive analysis will not be examined in the present work, we could summarize them under the formula: “what I see relates”. Therefore, when the question "what is this" pops up, instantly a chain of relations emerges, which are defined by the properties the Subject embeds to the Object of question. The properties are placed into the context in which "this" is, transforming the Object into “it is”. Nevertheless, it is important to clarify that the concept of “this” is not related to a psychoanalytic framework of perception, analysis, and interpretation, but is closer to the concept of the “thing”.

Hence, the mechanism of idiosyncrasy is a method of perceiving and conceptualizing the Object (“it”), and we can say that it is linked to the notions of exhibiting and curating. As such, it extends to the construction of a collective thing as a real-time interpretation. Examples of such mechanisms are both Aby Warburg’s Mnemosyne Atlas (1930) and Herbert Bayer’s curatorial mechanism in the historical "Points of View" exhibition in 1930 (figure 2, 3). In the first example, Warburg's very personal aesthetics and philosophy can be interpreted as a whole that produces generalizations. These extensively mapped generalizations serve as his own insight of a (new) knowledge and have the potential of becoming collective. The second one proposed a visual mechanism through which the observers created their own perspective through multiple views about the exhibited items. What is common in both examples is the ability to relate hands-on cultural perception and memory. Although the senses, as receivers of idiosyncrasy, are the way that materiality provides reminiscence and forgetfulness, as Hamilakis points out in his work "Archeology and the Senses: Experience, Memory and Emotion", p. 25, the fact that the Subject becomes a part of a testimony process reveals an enhanced experience, where the dominant sense is vision.

Nevertheless, what is happening in the digital realm? How sensorial experience is amplified when the subject is isolated in front of a computer screen? The answer to both questions is associated also with vision. The “thing” is formed in a process of “becoming”, a design process, and it can be read and interpreted always in relation to the quintessential conceptual term required by the design tools; the request of obtaining presence through representation (figure). An interesting example is the work of Lionel March, mainly in the context of the link between instruction and interpretation. Typically, March attempted to render interpretations to the built architecture through acts of the Boolean Operations Binary System 1-0. (March, 2010).
Hence, idiosyncrasy enables understanding of common principles and rationales within a given time and cultural context and helps us to synthesize trends and theories, which describe forms and "spatial productions" of the main elements used to characterize them. Forty years after J. Habermas's theory of communicative action and N. Luhmann's systemic theory, A. Reckwitz formulates an original theory of late modernity referring to the distinction between particular and general in culture, digital technique, and lifestyles, introducing the notion of uniqueness. In this society of uniqueness, which is described as the modern society that revolves around the pursuit of uniqueness both in objects, in subjects, both in space and in time, idiosyncrasy can become a tool to construct collectivity. To be able to properly describe this constructing process we introduce a digital idiosyncratic methodology, which will record, archive, categorize and interpret the subject's idiosyncratic expressions during a real-time design process, within a digital design software/environment. This methodology allows a “dissection” in the design process itself, while at the same time offers the possibility to redefine the design and its implementing instrument; the design program.

1.2. I (eye) – valuate

Although idiosyncrasy is enabled by desires, fantasies, and immaterial interpretations of the real, it leaves traces that can be read and measured. Thus, the triggering object of
Idiosyncrasy, which we name “idiosyncratic object” is an unattainable object; an object that escapes perception. Our goal is to try to create a system of understandings for the idiosyncratic object. This object, which we name ID-Object, can be grasped by reconstructing the many different frameworks to which it can be exposed, displayed, and exhibited. When exposed, the ID-Object is viewed in a raw state of/for use. When displayed it requests the condition of a filter between the ID-Object and the Subject-Viewer. While exhibited it becomes an Object-of-Value. Through all these states a new system of relationships emerges; relationships of transition are released by the narratives that the Subject uses to “dress” the ID-Object so that it becomes attractive. To describe this complexity, we focus on the tool of the diagram, which becomes a medium of presentation for the relations that arise. Hence, the ID-Object is converted into a field of interpretations that reveals the idiosyncratic imprints of the Subject.

Via this context, we can extract the value of the idiosyncratic object, and, subsequently, we obtain the possibility of detecting and describing its characteristics. Thus, there are three modules of value in the design process: theological materiality, the everyday object, and the time(less) cultural object. These modules of value re-establish the conceptualization of the framework of the idiosyncratic object; it shifts towards historical materialism and closer to an idealistic/fantastic/imaginary approach to the idea of history.

Therefore, idiosyncrasy obtains a functional role as it produces an intermediate space within the relationship of Subject and Object. Therefore, as the Object gains a multitude of interpretations and facets, at the same time the Subject gets endowed with multiple roles through its socialization, becomes multiple, and is transformed into a field. This multiplicity affects the empirical process of understanding the system of objects that comprises its environment, in a way that differs from previously established theories. Hence, idiosyncrasy works in a subconscious way that contrasts with the systems of perception and the rational methods of the Gestalt theory.

Here’s an example: I see a director’s chair or a mug or every-day object, in a warehouse, in my home, in a museum, in an online shop, and so on. As I attempt to describe the subject as a whole, experiential associations are created (Hamilakis, 2014, p. 29). Images are retrieved from multisensory memory forming a web. The relationships between them also create meaning - the hyper value of the object itself. Thus, perception with its multiple views, associations, and metaphors creates a system of interpretation, which enables a process of interaction. I see a stimulus, I perceive it and interact with it (buying, using, and designing) and eventually, I am led to a meaningful construction of multiple subjective views and idiosyncratic associations. All these metaphors create an idiosyncratic value system. Moreover, the tools used in the process of perception can be also used as tools for interaction, where understanding manifests the minimum expression of interaction.

Back to the design process, an important field to study is the transition from engraving to the design process and from drawing to design production. In other words, the study of
communication and description, through the process of material-immaterial translation, and how it yields the expression of the subjective "vision" of the designer. At the same time, the process described above is also involved in the transmission of design knowledge through different regions, epochs, and cultural backgrounds.

Figure 4. The four senses of Paper as an interpretation of Paper according to M. Frascari.

Marco Frascari, studying paper as such a condition, and at the same time in conjunction with the invention of typography (Frascari, 2017, pp. 23–32), uncovers the four senses of design (Figure 4). If we extend these senses to digital design, during the transition from analogue to digital the reduction is lost (anagogia). Anagogia can be traced back if we “capture” the relationship between a designer (user of the program) and the creator of a design program in an imaginary piece of paper. Via the medium of the tracing paper, the architect prepared a "sotto Lucido", that is, an underdrawing, where one can then draw the Lucido on top of it. One way that the concept of transparency as an intermediate space could be applied to digital design is a research area for the present work and will be further discussed below, as well as the design of the very transparency itself. Therefore, we understand that the design of an intermediate space is also a practice of meta-evaluation. What follows next is a series of other practices: the creation of uniqueness and the creation of intimacy. Uniqueness is experienced emotionally, as a sense of the sublime, of harmony, enjoyment, admiration, fear, pride, and so on, either bi-subjectively or solitarily (Τάσης, 2019, pp. 159-175).

2. The Unseen in Design

What is the value of idiosyncrasy for the Subject-Designer? Is this value constant both in an analogue and digital process? Diagrams as interpretations, introduce tools for measuring value?
In the synthetic phase of design, we refer to a "hypertextual" process that attributes the basic properties of the logical description of the design (in-port). When an object is interpreted performatively in an in-display condition, it is destabilized and transformed (ex-port) into a cultural symbol. But how can these two readings be correlated? The terms "import" and "export" are transferred into a new conceptual spectrum as "in-port" and "export". The reason is that we are trying to examine in depth the two fundamental processes of (digital) design, namely its start and completion.

The question of why architects choose programs (ready-made interface environments) to create, instead of choosing to design spatial relationships, conditions, and constants in a single programming language is a starting point. This question underlies the problem that we are planning by evaluating one export rather than a multi-export network. We see the representation/form of what we want to draw in a frame, in a picture instead. So what we design is constantly modified one-dimensionally by the image through the interface. But what is it that we do not see when designing? In Figure 5 we can see the "space" in which "what" we are designing is conceptualized by monitoring the invisible by-products of a digital design process. (Figure 5)

According to the diagram below, it is understood that there is a "latent" design in the design process itself. There are a basis and a system that allows us to "enter" and add our expressions. So, going back to the ratio of tracing paper, the design program is a Lucido on which our temperament carves out its own sotto Lucido, but which we can explicitly identify and highlight. To do this, the digital measurement methods of design temperament we propose are the following:

1. A Digital Interview, through the creation of a pop-up plugin, which will appear on the user's screen with a short questionnaire asking the reason of choice of the action-section made while designing.
2. Recording and interpreting those elements that are not immediately visible in (digital) design by:
   • The use of the MouseTracker program to create a heat map of the subject's designing paths.
   • Recording (quantitatively and statistically) not only the number of errors (via the Delete and Undo commands), but also the multitude of copies and alternative versions of files and designed-objects the user creates.

Thus, what we propose is a monitor device that captures the logic of the program, by supervising how it establishes and transforms the invisible space between the user-designer and the in-design object.
2.1. Inter – View in Design

The first step of our study refers to a recording of the design context a Subject-Designer creates in actual design software. The testimony of such recordings derives from highlighting the subject's uniqueness. Uniqueness enables singularity which can be defined as the merge of biological and technical evolution (Τάσης, 2019, p. 28). This process reconstitutes a different understanding of the idea of an interview. In our research interview becomes performative; it provides and surpasses general identification data (such as sex, age, etc), by focusing closely to design preferences that are highlighted through technical evidence (geometries, materials, processes of assembly).

What we observed is that etymologically "interview" withholds a performative and collective vector. It brings together Subjects in a meeting/festive/happening condition to create (new) knowledge. We emphasize that the importance of the interview allows the quantification of user-designer data, from which we can draw - through repeatability - qualitative conclusions about their modality; the way designers design. Thus, it gives us a more penetrative view
into the soul of the designer. However, it is important to note that we are not talking about an interview in the traditional way, where the journalist asks questions to an interviewer and expects answers that are recorded or documented. In our research a “translation” takes place. On one hand, the role of the journalist is replaced by that of the investigator, and on the other, harvesting of the temporal moods of the designer becomes palpable and accessible.

If we further elaborate on the performative side of this interview we can gain access to “pre-positions” of the Subject-Designer. These pre-positions refer to all these genetic principles that establish and institutionalize the manifestation of a design act, and they serve as a key to gaining access to the idiosyncratic status of the designer. Therefore, a dual nature is detected in the designer himself; in addition to being a designer he is also a user, and as such he can be examined for the causality of his actions while using the specific syntax of actions that legislates the design software. Consequently, what is permitted and enhanced is the gain of knowledge of idiosyncratic design methods produced during the real-time design process. In particular, by asking a question, while designing and not after or during a break, a kind of “shock” is created in the quality of the interviewee’s response. It is a form of “epiphany” not in its theological complexion, but the anthropogenic and deeply intrinsic aspect of the subject.

Therefore, the randomness of the interview turns into an “idiosyncratic snapshot”, which aims to elicit answers from one or more users of a design program. It is an infiltration into the subconscious, inner thoughts of the subject-during-design; those thoughts that only an immediate "why?" can shock and respond with both immediacy and "purity".

These interviews, to be real-time, must have some trigger (triggering actions). These activators are characterized as cut-outs because they stand out from all other operations that are repetitive, purely mechanical, or have to do with improving the productivity or modes of displaying objects in their digital dimension.

From the example of Autodesk AutoCAD and how its interface commands-acts are categorized, we can immediately conclude that over the whole range of this program, fundamental genetic design acts are summed up in a set of 50 commands, which are called "operations-cutting points", because they produce something new, by transforming the existing under-design object through idiosyncratic intentions that push the subject to perform. These are just two subcategories with about 20 Draw commands and another 30 Modify commands. In our research, we are interested in establishing the primary definition of the designer’s idiosyncrasy-measuring program and distinguish all idiosyncratic answers from the ones that have legislative or other technical constraints. The purpose is to comprehend the questions in detail and to determine when and how they will appear in a small window on the interface of the program used by the designer (pop-up window with feedback). (Figures 6, 7)

An example would be:
Q: Why did you choose to make this Fillet? (Note that for example, this fillet may have a very large radius)

A. Aesthetic Answer: I want spherical outlines that do not have sharp and aggressive angles. I want the shape to soften and become more organic so it can blend with the environment.

B. Technocratic Answer: I want all corners of my plot to allow large objects to rotate.

2.2 Design the value of MEmory

Beyond the speed of computing, interconnectivity, openness to knowledge, and many others, one of the greatest and probably the most important virtues that the computer has brought to our daily lives, but especially in our way of thinking, is that of "going back in time; recalling and correcting an error. In a computational environment, it is possible to press the undo button and erase an action without having to bear any consequences. This allows us to try and experiment up to the point where the program can write in its memory the history of the actions of the user. In our case, our interest focuses on identifying if and to what extent it is possible to operate alongside other programs that will be able to collect design-related data in digital design software. What interests us is data that refers to the way and to the duration of usage of the design software, as well as data that indicate repetitions and "errors" in the design process.

An example of this ability, to export real-time usage data, is the program\(^1\) "MouseTracker" developed by Jon Freeman (Freenan, 2020). Through the transition from the non-descriptive of the unseen side of the design to the descriptive one, through the designers’ footprints in real-time, the design in its entirety produces a multiple-subject (subject-designer-user) tank. Thus, a whole new world opens up in how we can recognize and study the uniqueness of each individual, simply by measuring how he designs, molds, and archives. However, this is an undergoing process of our research and it will be developed in the future.

\(^1\) Indicatively, we mention other similar programs, such as Mouse Monitor, MouseFlow and MouseTrap-os. On the latter, see (Kieslich & Henninger, 2017).
Figure 6. Digital Design Viewport as a framework for applying the idiosyncratic performance in design. Classification of commands and their signification as realization processes. Processes that embed properties into “That” that is under the design process.

Figure 7. The main menu of Morphological processes. Their interpretation as objectification processes. Procedures for the emergence and application of “idiosyncratic” logic.
3. From ontology to ontological form

If we think back to what our mechanism ultimately produces, we could probably say that it captures, transforms, and expands the Subject-Object interface in digital design environments. We map the intermediate and bring out the uniqueness of each subject by extracting memory from the physical (digital) evidence, not only from their actions but mainly from their intentions. Such a proposal, an algorithm recording unseen parameters during design, is a development of the design language vocabulary within the existing digital design environments.

Therefore, an ontological identification map of the post-designed object is produced. The user has the choice to intervene on this map without the actual object being visible, drawing it in an ontological context. And then there is the command that transforms the ontological map into an image. These images are the reflection fields on the original object. So, what is produced? A time gap or otherwise a dialogue between the designer and the object.

Moreover, one result is the design of the framework in which our temperament is more freely expressed. We do not define freedom as an arbitrary and meaningful concept that comes to fill gaps in our study. This freedom depends on the degree to which we can narrow the boundaries of design software to do things out of context. The result of such a process will be to create a new structure in the hub of forums that the design software already has, and where the users are looking for solutions to problems or improvements to existing and incomplete commands. Such a forum will not only send analytics and feedback to the design software provider/company but will be essential for further conceptualizing the Subject-User. In other words, it is a meta-forum, more immediate, personal, and practical.

Finally, a reflecting point of the outcome of this idiosyncratic plugin is the importance of ethics in such a software, which is based on the sincerity and validity of the subject’s responses. This is certainly its “Achilles heel”, but not a manufacturing mistake. This condition is the "necessary evil" to grasp the importance of the outcome of this software in design. The inability to create social meaning and the introduction of new values have contributed to the emergence of the life-craft industry (Σάκης, 2017, pp. 83–117), where the question of meaning arises in individual terms. Guided towards a narcissistic collectivity (a reflection of society), self-realization, and the acquisition of design confidence through exposure to and acceptance by design collectivity, this specific plugin, by giving the choice of true/untrue answer, ultimately might work reflectively on the Subjects themselves, as a view of emancipation.
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Acknowledgements: Special acknowledgements to Professor Mr. George Parmenidis, Prof. of the dep. of Architecture NTUA, for his lifelong companionship and mentoring. "This research is carried out / funded in the context of the project “I-D (I – Design, Idiosyncratic Meta Design) Idiosyncratic Proceeding on Reading and Production Meta-Objects in Contemporary Industrial Design” (MIS 5049532) under the call for proposals “Researchers’ support with an emphasis on young researchers- 2nd Cycle”. The project is co-financed by Greece and the European Union (European Social Fund- ESF) by the Operational Programme Human Resources Development, Education and Lifelong Learning 2014-2020."
If we can’t make it together, we won’t make it alone. The challenge and potential of collective making

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Abstract | The culture of making has always been seen as an inseparable part of design. Still in recent years we have witnessed that “making” gets less and less attention (i.e. time and resources) in our design education. The reasons for this are manifold. Among others, it reflects developments within the evolving field of design, as described by Bremner and Rodgers (2013). In contrast to this development, we argue that the action of making remains an utterly valuable part of design education – a valuable linkage of knowing and doing (Ingold, 2013). As an alternative, we propose to advance the culture of making, its inherent focus and assumptions instead of neglecting them. This essay presents insights and reflections of a collective exploration into making by four design educators and practitioners. The collaboration happened in different settings, sometimes with other local actors, was always guided by constraints. During the research, questions of how design education can facilitate meaningful learning processes around making, while not ignoring the evolving field of design were explored. The result addresses the complexity of co-creation, dialogue and practical knowledge in the setting of a contemporary design education.

KEYWORDS | COLLECTIVE MAKING, CREATIVITY, PRACTICE BASED KNOWLEDGE, CHANGE
1. Introduction

The culture of making has always been seen as an inseparable part of design. Still in recent years we have witnessed that “making” gets less and less attention (i.e. time and resources) in the design education we teach at. The reasons for this are manifold, but we don’t think they are unique. In our particular case, the driving force has been a concern to orientate design towards a less materialistic, and in result less wasteful practice (Findeli, 2001; Tonkinwise, 2003) and to focus on the role of designers as researchers and facilitators. In addition, the aim to develop a critical view on designing, to explore dissolving disciplinary and conceptual boundaries which paved the way for new and multiple ways of practicing design (Bremner & Rodgers, 2013) as well as the effect of establishing design education within academia and its rather logocentric knowledge traditions have all played their part in this development. At the same time, the rise of ‘design thinking’, too often highlighting only ‘thinking’, has also enhanced the distinction between thinking and practicing design, instead of “acknowledging the situated, embodied work of design thinking in practice” (Kimbell, 2011).

In contrast to this development, but not in ignorance to it, we argue that the action of making remains an utterly valuable part of design and design education – a valuable linkage of knowing and doing (Ingold, 2013) – that deserves to be cared for. As an alternative, we propose to advance the culture of making, its inherent focus and assumptions instead of neglecting it. This essay presents reflections of a collective exploration into making by four design educators and practitioners. Our goal was to explore “making” in an explorative research project, addressing the complexity of co-creation, dialogue and practical knowledge within the setting of a contemporary design education in reaction to situations we experienced as the “theoretical turn”, allowing theory to dominate practice – or even render it irrelevant. Our work was inspired by the idea to create a form of seminar series around making. Instead of focusing on a theoretical piece of work, and exploring it through discussion and dialogue, we focused on recurring meetings around a particular task or material and explored it through practical work.

2. The making of our worlds

2.1 Our context

Our self-initiated research project was set up in the context of a rather broad design education that abandoned disciplinary boundaries a long time ago. As a consequence, our educational situation differs from design educations with an outspoken focus on a particular discipline or material. But at the same time, our education is based in one of the few state-funded educational higher institutions in Sweden that are allowed to award a degree of Fine Arts at both bachelor and master level. For this degree, the Higher Education Ordinance defines that students need to show evidence of both practical and theoretical foundation, to
demonstrate the ability to create, realise and express their own ideas and to undertake artistic tasks. Artistic education, like artistic research, has artistic practice as method and as knowledge object (Lilja, 2015) and assessment is closely tied to the idea of artistic quality, which can be summarized as technical craftsmanship, material skills, personal expression and a relevant process methodology (Karlsson Häikiö & Olsson, 2015). As teachers, we therefore have to strive for a balance between the theoretical and abstract and the practical, concrete dimensions in a way that supports this development.

Our project was an attempt to explore and develop making not from an individualistic point of view (how to improve one’s individual skills), but from the perspective of educators and collaborators in a wider context of making. It was meant as a challenge to reflect on our own knowledge around making and to test new things – before we bring them into the classroom. Last but not least, we hoped it might offer a dialogue around making and its role in the curriculum. Contemporary demands on designers differ widely from the traditional ideal of being a skilful craftsman. Still the ability to make something real remains essential and as influential as creativity in the world of design (Nelson & Stolterman, 2014).

2.2 Making

“I want to think of making instead, as a process of growth. This is to place the maker from the outset as a participant in amongst a world of active material. These materials are what he has to work with, and in the process of making he ‘joins forces’ with them, bringing them together or splitting them apart, synthesising and distilling, in anticipation of what might emerge.” (Ingold, 2013)

Making has been central to our project. In design and craft, making can be defined as the skill, experience, and mastery of working with material and/ or processes (Design dictionary, 2008). “Making” as a verb refers to action and process and is more than producing an artefact. It can be a teacher, a process of growth and an inquiry into the world (Ingold, 2013) or “thinking” (Sennett, 2008), supporting exploration, understanding and discovery.

The field of making has changed and expanded its role in society during the last decade. In the agricultural society people used making and crafting in their everyday life to make the objects they needed – for their homes, for cooking or farming. During the industrialization in the 18th and 19th centuries, making became something a craftsman did. Artisans or industries made objects for everyday use, or exclusive items of very good quality. Crafted pieces could also be seen as art (Bringéus, 2005). From the 1990’s onwards status of making became low as people started to work digitally. Craft seemed boring, unnecessary, and unfavourable in the process of establishing academic and professional legitimacy for design (Design dictionary, 2008).

Today we can find making again in many contexts. The maker movement has grown widely (Anderson, 2013), craft bars and craft clubs with the aim to make craft together and socialize with others have become popular, as well as knitting cafés and craft pods. Their aim is rather to make, learn and have fun together, than to craft high quality objects. As an offspring to
this development, making is also seen as useful for people's wellbeing and as a kind of stress relief activity (Davidson & Tahsin, 2019).

Another field of the maker movement is craftivism. People use craft as a form of activism to make a statement on political and social topics. By making embroidery and showing them in public spaces, people try to affect and change societal development of society (Corbett, 2013; Aronqvist Engström, 2014; Greer, 2014). On the other end of this spectrum are handmade objects of high quality with a comparable status to art, that are shown in shows and fairs like for example Collect, a gallery-presented art fair dedicated to modern craft and design. The handmade object is valued as more authentic, more real, than machine made or digitalized work (Design dictionary, 2008).

The culture of making has always been seen as an inseparable part of design, but both in society and in education the role of making has changed. The authors Press and Cusworth (1997) fear that in the general opinion craft has little or no educational value in our post-industrial, information centred age. It seems to embody all those qualities that are considered irrelevant or inappropriate: individualistic, self-centred, low on technology, and with little contextual or critical context (Press & Cusworth, 1997). In addition, concerns regarding designs damaging and wasteful practice have questioned the need to make (Fry, 2009; Tonkinwise, 2003; Findeli, 2001).

"This, in turn, yields to the end of the "product as work of art" paradigm in design, and of the design act as a heroic gesture; in short, the end of the fetishism of the artifact." (Findeli, 2001)

But the criticism against making often refers to what is brought into existence, and is less concerned with what the activity entails. Design education can still view making as a useful tool for exploration, visualisation and finished objects. Making workshops are organised for different reasons, either as introductions to new fields of making, or to give people with different backgrounds possibilities to explore and work together. In the field of speculative design, crafted objects of high quality are used to convince the audience that the design proposal is realistic.

In our research project we have used collaborative, artistic making. Each member of the research group has contributed to the research with their professional knowledge around making as designers, artists and artisans and shared their knowledge in different materials, methods, techniques and processes. In an exploratory form, we have tried materials and contexts new to the individual, by using the whole group's practice based knowledge. We have tried our working method in different projects for more than two years.

2.3 Design and the nature of knowledge

There is no simple or ultimate answer to what design is. As a field it is constantly evolving and boundaries of what were once recognised as individual design disciplines (such as product, graphic, textile, and fashion design) change, dissolve and expand (Wilson &
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Zamberlan, 2015; Bremner & Rodgers, 2013). As a consequence, it is impossible to speak about design education as a unified or even static concept. Still the design researchers Nelson and Stolterman (2014) suggest that the learning outcomes of design education are a set of interrelated competencies (mindsets, knowledge sets, skill sets, and tool sets) that relate the abstract epistemological (thinking/knowing) with the ontological concrete (doing/acting/making). While there is definitely a general understanding that shaping and making are part of design, questions regarding content, focus and importance remain. The activities of making, shaping, doing and even acting are as multifaceted and evolving as design itself.

Many things that could be said about design education. One aspect relevant to our work, is the intuitive nature of knowledge. A study by Karlsson Häikiö and Olsson (2015) suggests that the academic demand to formulate practical knowledge within academia clashes with the fact that artistic knowledge often develops through the unknown, undefined, and varying (Bauman, 2002, as cited in Karlsson Häikiö & Olsson, 2015). As a consequence, design teachers in their study experienced the assessment of artistic processes within the academic setting as antithetic and conflicting.

“Within art and design education intuitive modes of learning and doing are very important ... under various labels (tacit knowledge, implicit knowledge, non-verbal learning, learning-by-doing etc.) these intuitive modes may be very resistant to analysis or conscious awareness but are central features of practice and learning in the arts and in design.” (Danvers, 2003)

But the conflict goes deeper than that. A logocentric culture sees knowledge as something that can and needs to be articulated in precise words. In extension, it doubts other forms of knowledge which affects how education is shaped.

“Current theories of learning typically emphasize cognition and the mind, rather than embodiment of mind and self. A consequence of seeing mind, body and world as separate entities is that the significance of our entwinement with the world of practice is overlooked.” (Dall’Alba, 2009, as cited in Adams et al., 2011)

Especially in design those different knowledge traditions collide - the practical knowledge tradition with its roots in experience and practical work and the theoretical knowledge tradition with its roots in research, concepts and theory. Nelson and Stolterman (2014) emphasis that the integration of thought and action in design sets it apart from other disciplines. And the authors Press and Cusworth (1997) suggest that intelligent making “a mix of formal and tacit knowledge, physical and mental skill, theoretical and contextual awareness, innovation and personal creative autonomy” is able to convey new styles of thinking, acting and problem solving, which might be more suited to our changing world. All in all, making connects back to a dimension that should not be given up on easily.
3. Our Research

This essay focuses on two years of seminars and work around making. Two particular design tasks were done in collaboration with local actors; the design of an insects shelter for a local urban farming initiative and an artistic project around industrial waste. Especially in this project we looked in depths into the waste materials origin, their journey, related issues and used making as our research methodology during the course of roughly one year. In between those tasks, we engaged in smaller projects in which we explored different materials and techniques, and reflected on our experience afterwards.

Our research can be described as practice-based (Candy & Ernest, 2018), an investigation in order to gain new knowledge partly by means of practice and its outcomes. We embarked on it in a collaborative way, emphasising our professional development rather than hoping to generate new theory or knowledge (Clark et al., 1996).

Our research was organized in the following way: One-day workshops started always by the presentation of the task though one member of the group, followed by approximately 6 hours of working time. The reflection happened several days apart, in the form of conversations and a written documentation. The larger projects started by on-site and industry visits and material explorations through one-day workshops. Subsequently we tried to find a story in the material or place. In the idea generating and sketch phase the practical work was interwoven with reflection and discussion meetings. The methods used to document the work were photography, individual notes and sketches as well as all three-dimensional traces of the process like mockups, material experiments and moodboards. In order to evaluate our work and to identify the learning outcomes of the entire project, we summarized individually we felt we had learned and experienced during the project. The goal was to relate those findings to the educational situations we find ourselves in and if possible to develop ideas on how to advance it.

Our most time-consuming part was a project that resulted in an art installation called “Waste camp”. The installation consists of a tent, a fireplace as well as relevant equipment. We chose camping as a theme as it represents both the aim to be close to nature as well as shows how this is choreographed by numerous artefacts that rather reinforce our separation. This duality was also present in the waste we had at our disposal. All materials had once thrived as part of nature; still humans had spared no effort to transform them into an artificial state. While our work was always guided by constraints, it was most dominant in this project. We allowed us only use waste material from three local industries. One producing high-end furniture, one matches and one manufactured everything from gaskets, sound absorbers to insulation and furniture components to supply various industries. The majority of the material would usually get discarded and most likely burned. We tried to develop a concept that was true to the origin of the material. Our aim was to create a new and different context for industrial waste in which its value is emphasized by treating the material with care.
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The result gives on one hand tangible form to our collective knowledge around material and making. It is characterised by what we already knew, what we learnt and what the material made us do. As a material result it is left to the mercy of the spectator and the question if it qualifies to the standards of creativity, ingenuity and aesthetics, as well as if it as a symbolic representation of an idea affords to “be interpreted within the hierarchy of constructs and degrees of abstractness imposed by its cultural context” (Press & Cusworth, 1997). At the same time, the entire project is a document of a process and a conversation around collective making. In the process we had to articulate and discuss our making in order to collaborate, and to drive the process further. We had time to elaborate about how our work could translate into an educational context and what would be important to consider. Reflections we will try to share in the following text.

4. Reflections – a manifesto for making

4.1 Glue guns and post-it notes are not enough.

“A conceptual idea is not worth much if it is not made manifest in the world.”
(Nelson & Stolterman, 2014)

Making is the ability to translate ideas into this world. As this, it is a highly complex activity
that connects materials, skills, tools and methods to a reality. In our projects we needed to respond to limitations, show resourcefulness and the ability to improvise, understand complex realities and networks and work with care towards materials and tools. We had no idea about the final result before we started, and despite sketches and models, the work developed constantly throughout the process. Much of the discoveries and learning happened physically and through tangible interaction. As Nelson & Stolterman (2014) highlight ‘wise crafting’ nurtures and matures a design idea and is also characterised by the carefulness of the process itself.

Figure 2. The process of preparing the floor. September 2019.

In education we nowadays engage often rather in forms of “speed making” – with post-it notes and glue guns as main ingredients. “Speed making” is quite often similar to brainstorming and works well to start or to swiftly focus in a longer process, but is deprived of knowledge about material, construction and production and other constraints that eventually need to be addressed in order to make something real. Still all making is a good beginning, if it is communicated to the students on what kind of level the making is happening and what other levels could be there.

4.2 Material carries a narrative.

We do not ignore the criticism against making. The industrial waste we worked with was brutal and real proof. To see material turned into objects that people use is one thing, to see it turned into useless waste another. Waste has consumed natural resources, energy and water for nothing. But the waste we encountered was not solely an unavoidable part of industrial production, it was also the result of rigid quality assurance and fashion. Within high-quality products, insect bites, butcher mistakes and small changes in structure can for example render large parts of leather useless. We also received large quantities of spotless
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material which only fault was an unpopular colour.

From this experience, we draw the conclusion that making is always part of complex systems and should be taught like this. Making is not only the skill of creating something with a certain level of expertise, but an array of knowledge connecting it to entire systems and a context in which the making takes place, including values and norms. By avoiding to work with making in education, we avoid the chance to evoke reflection and a deeper understanding for this. Instead we foster consumers by impairing the ability to create by oneself.

4.3 We create in order to understand.

As a research group we got the opportunity to work collaboratively on artistic, practice-based projects. The projects developed in a way that none one of us could have achieved alone. In the end, all skills and efforts were needed to connect to the industries, to collect the material, to explore and create and to articulate the concept and the project in its entirety. The group multiplied our possibilities. To take part in a creative process can be fun but also challenging, not at least when you are working in a group. The most prominent in our own evaluations are reflections regarding the group process and how it had affected the process and result. Did we actually make the best use of our abilities? Several aspects of the artistic process, the idea of an individual voice, individual interpretation, creativity, trusting the process, intuition do not lend themselves perfectly to group processes. Conflicts do not only arise to push for one’s own idea, but to make an idea coherent. Moments of ‘flow’ and ‘anti-flow’ appeared at different stages, caused by different opinions on the process or expected outcome, but also by stress and different working methods. "... we all know how tough a conversation among peers - particular designers - can be, each one defending his/her culture, experience and belief" (Devecchi & Guerrini, 2019). We realized that clearer communication in all stages would have made the creative process more enjoyable.

4.4 Experience, our own and others’, is the basis for innovative practice.

Working in groups is becoming more relevant for designers (Wilson & Zamberlan, 2015, Sanders & Stappers, 2013) and as a result it becomes important to address collaboration and collaborative skills in education. So far, we often underestimated the demand for facilitation that group work places on teachers and students. How can we prepare students and support group processes in the best possible way? How can we balance individual artistic development and skills that benefit group work? How can we evolve values and methods that are still influenced by design as an individual activity?

This research has had a transformative approach as it sharpened our awareness and made us critically reflect on our assumptions and ways of teaching. In the project we used our knowledge about material and practice in different ways than we usually do as educators, which helped to illuminate our habitual ways of working, communicating and making
judgment. We experienced the competences and skills of colleagues in new ways and subsequently developed an understanding of our own skills and took responsibility for being a good collaborator. While the dissonance between practical and theoretical; situated, embodied and abstract will persist for a while, we need to continue the dialogue, as not speaking about its value is damaging our own situation. “Inarticulacy gets mistaken for a lack of knowledge and an inability to rationalise actions.” (Press & Cusworth, 1997)

4.5 It takes time.
And finally, making and refining skills takes time. Due to an increasing complexity of the design field, this of course raises many questions. Within the education we teach, it was never an official strategy to eliminate making and practical work, rather making was taken for granted, while in reality other tasks demanded more and more time and attention. At the beginning of our research, we often accepted that making received less and less time. By the end of it, we had managed to make this an issue within the department and achieved partly to halt this development. Still, in the future, we will need a continued dialogue around making and its relevance.

5. Conclusion
We still believe that the action of making remains an utterly valuable part of design education and culture – a valuable linkage of knowing and doing (Ingold, 2013). Making is a way of understanding and exploring the world with all senses, as well as a mode of action in dialogue with the world, but making, as an activity beyond post-it notes and short workshops will continue to be a time-consuming, exhausting and complex activity, always in danger of being rationalised away.

Our collaborative journey has deepened our own understanding and given us time to explore making in various ways. The times we live in demand us to discuss what we see as the material of design - physical as well as abstract - and what the craft involved in the production process actually is, from a broader perspective than the traditional practice of material design (Nelson & Stolterman, 2014). But nevertheless, if we act through making, doing or acting – as they all are of relevance for design – we should treat them with the same care, ingenuity and skilfulness as wise makers always have. If we can’t make it together, we won’t make it alone.

References
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Inter-Weaving Culture and Crafts in Design Education

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Abstract | Knowledge of Culture and History is a very important component that dictates Design and it is from our past that we learn and create for the present and the future. The question facing Design educators today is how to align the present generation of millennials with the sensitivity and appreciation of our rich cultural heritage? The paper is focused towards the Future of Design Education, by stressing the need for the knowledge of Culture and Crafts as an integral part of Design Education that will help the Designers of tomorrow to be prepared for the Future. According to the authors, simply sitting in the classroom or searching online cannot help students learn about Culture and Heritage. To experience culture one has to actually go out into the field, dirty their hands and gather first-hand experiences. This will, in turn lead to a better understanding of the issues and challenges that present themselves to a Designer in the course of their Design journey.

This paper examines ways in which these qualities and skills/knowledge can be nurtured, with a specific example of an Interior Design course in India. Based on literature study and their findings from student assignments, the authors believe that Design Education should aim at sensitizing students about the cultural heritage and provide them with avenues and exposure to explore their cultural and contextual backgrounds as they are the future custodians of their culture.

KEYWORDS | TRADITIONAL CRAFTS, DESIGN EDUCATION, EMPATHY, HERITAGE, CULTURE
1. Introduction

“Without culture, and the relative freedom it implies, society, even when perfect, is but a jungle. This is why any authentic creation is a gift to the future.” (Albert Camus)

Knowledge of Culture and History is a very important factor that dictates Design and it is from our past that we learn and create for the present and the future. Cultural traditions and crafts along with the knowledge/skills form the cultural identity of a people.

In India, Traditional crafts have been an inherent part of the process of making. Such processes are organic and involve traditional knowledge of socio-cultural and religious needs, climate response, geography, local materials and the particular context in which they are located. All this collective wisdom has been handed over from one generation to the next as a legacy. It is seen that culture has an important place in the psyche of a community, in fact, a reflection of their identity and their histories, forming a composite whole that has many facets: social customs and mores, religious practices, language, food, shared histories and memories. India has a vast storehouse of traditional crafts, and almost each one of these crafts comes with a deep sense of history, and inherent stories, motifs, myths and rituals. The living crafts (and the ones that are already lost, or the ones that are dying) are practiced over generations, passed on as a legacy, and imbued with familial and societal stories.


Design education is a complicated process where inculcating skills of creativity and design knowledge is obviously aimed towards the users/consumers, keeping in mind their needs. However, this process must also be balanced with engendering empathy and respect towards the actual creator/maker and the society in general. The authors believe that this awareness about Culture and traditional crafts, especially in design education, engenders opportunities for growth and revival of our rich cultural heritage and traditions, and this further allows students to explore their milieu and its antecedents, and this fosters creativity. Culture therefore plays an important role to play in education.

The authors believe that in the context of globalization, the understanding of culture, crafts, indigenous knowledge and systems has a very important role to play in design education. The authors aver that awareness of culture is almost a necessity for urban lifestyles. As more and more people are moving away from their hometowns, migrating to urban centres in search of employment opportunities that exist in these cities, they are increasingly coming in contact with people from different backgrounds, both at the workplace and where they live. Awareness and respect for culture, one’s own as well as others, leads to fostering tolerance and harmony in a society, and helps that embraces diversity.

“Cultural awareness refers to the developing consciousness of culture and the ways in which culture shapes values and beliefs” (Burchum, 2002, p.7).
The question facing Design educators today is how to align the present generation of millennials with the sensitivity and appreciation of our rich cultural heritage? Thanks to the interconnected world that they inhabit, today’s students, although well-informed and more aware, are still living in a protective bubble, inured from the harshness of reality in many cases.

India is a nation with diverse cultures and traditions, and this paper looks at ways and effects of incorporating culture and understanding of crafts and traditions in design education from an Indian perspective. The paper is focused towards the Future of Design Education, and by stressing the need for the knowledge of Culture and Crafts as an integral part of Design Education, the authors feel that this will help the Designers of tomorrow to be prepared for the Future. According to the authors, simply sitting in the classroom or searching online cannot help students learn about Culture and Heritage. To experience culture one has to actually go out into the field, dirty their hands and gather first-hand experiences. This will, in turn lead to a better understanding of the issues and challenges that present themselves to a Designer in the course of their Design journey.

2. Background

“Culture is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society.” (Tyler, 1870 as cited by Avruch 1998).

The United Nations agency UNESCO defines Culture as the "set of distinctive spiritual, material, intellectual, and emotional features of society or a social group, and that it encompasses, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs."

Cultural traits and patterns are transmitted from generation to generation and this is an ongoing process. At the same time, culture is also dynamic in nature and it evolves and adapts to the stimuli from what is happening around us. According to Burchum (2002), cultural awareness begins with understanding the influences of one’s own culture.

It has been amply seen that Culture and Design are interlinked and each complements the other. They are both influenced by and influence each other, mirroring and echoing and also acting as sounding-boards for each other.

Design education, also known as creative education is the teaching of theory and application in the design of products, services and environments, and it involves problem-solving by applying prior knowledge, practical methods and native intelligence to solve the problems.
2.1 Impact of Globalization on Design Education

The modern education system that is prevalent today is primarily influenced by Western ideas, and Post-Industrialization thought process has come to dictate educational process, much to the detriment of indigenous knowledge, traditional lifestyles and cultures. Globalization is the prevailing force today, and it is impossible to not be influenced by it in the march for progress but this suppresses cultural heritage. The authors believe that it is necessary to move with the times, but still keeping the cultural identities in sight through ways and means to adapt to a globalized world-view, tempered with respecting and placing value to the traditional cultures can be a way to achieve this balance. Such measures to make Globalization more inclusive of traditional cultures can lead to a richer experience where the modern coexists in harmony with tradition. Design Education is one important means by which this can be achieved.

Design; like any other facet of the act of creating/producing evolves with times, getting influenced by whatever is happening around us. Advances in technology being an important part of Globalization, have a great impact on Design too. With Globalization generating newer market demands and producers/manufacturers and economies finding ways to cater to these demands, the Design community has also been partly responsible for catering and supporting these burgeoning demands. More and more developing and under-developed nations are trying to emulate the Western ways of life, as these are seen as aspirational, but in this process these nations are abandoning their traditional ways of life that had served them well in the past.

It cannot be denied that cultural and traditional knowledge is a unique response to the local context and have evolved to create a distinct identity for a people. However, this aspirational pursuit of something perceived to be superior (Western ideas) harms what was good in the past in a particular community.

Therefore, these market-driven exigencies ultimately affect Design, and by corollary, Design Education as well. Globalization has meant the rise of a universal mono-culture, and losing sight of the unique identities of traditional ways of life.

A culture based education is defined by Assembly of Alaska Native Educators (1998) as one which reflects, validates and promotes the values, world views and languages that form the culture of a community.

Design is a continuum between the past and the future. Learning from tradition and innovating at the same time, it acts as a connector between creativity and technique, serves to connect creativity, techniques and skills with traditional knowledge.

Culture and craft plays an important role in education and particularly in design education. At all levels of education, essence of culture should be imparted to students’ to make them aware about their roots.
2.1 Why it is important for India in the present scenario of globalisation to have knowledge of Culture, Traditions and Crafts incorporated in design Education?

Interweaving culture in design education can be reinforced by engaging students directly with crafts, culture, history, background research and analysing so that the students can gain a deep understanding and awareness of their own roots. This further inculcates knowledge of the deep sensitivity and tenuous bonds between a craft and its practitioner, and how the lifestyle of the craftsmen of a particular community is linked to, and directly influenced by the craft itself.

Such interactions with culture and crafts can provide the students with first-hand experiences and further enable them to develop skills and understanding that will help them to explore and experiment with materials, techniques and technologies, and this will lead to creating better self-awareness and critical thought processes.

As cultural heritage has a very important role in forming national identity, therefore the tangible and intangible aspects of this cultural heritage must be preserved and nurtured, and this can be achieved by incorporating the respect and understanding of cultural heritage in Design Education.

According to the International Indigenous Design Charter, designers must make sure that any representation of the indigenous cultures must reflect the cultural values of the community; respects and protects the environment and honors the values enshrined in the traditional lifestyle of indigenous cultures; such works must also be an authentic reflection of indigenous knowledge. In addition to this, and equally important is the need for the designers to ensure that representation must also empower as well as positively impact Indigenous peoples: from the past, in the present, and the future.

As mentioned by Purnima Rai (2016, pp. 27-28), in the present era of technology where everything is mechanized and digitized, India is fortunate that there is an unparalleled resource of hand skills that gives us a distinct edge over any other country in the world.

This rich storehouse provides an opportunity area for young designers to tap into, and create newer synergies. It is the authors’ belief that inclusion of Craft education in design curriculums can lead to enhanced creativity, better communication, the spirit of collaboration, problem-solving and resilience, qualities that are expected to be possessed by employees.

During an interview (conducted by authors) on 5 July, 2019, Usha Nehru Patel, a design educationist, Dean IIAD, New Delhi, stated that she strongly feels that being aware of their heritage and culture is very important for the present generation, thus exposure to culture in design courses is essential for the students to develop a clearer understanding of their own milieu and background. Usha also feels that this gives rise to an interesting dichotomy; if one needs to have one’s own identity, they need to have something that is different and
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Original and in the global context this means something that nobody else knows, but only they have an experience of. How a student reacts (embraces or rejects) the cultural aspect would depend on the individual, but it is essential that design institutes provide exposure to traditional crafts and culture to the students. This exposure brings a newer dimension to the whole cultural ethos, with everyone bringing in their original bits, their embodied understanding of their embedded culture to the table. Usha believes that exposure to crafts is important, and it is not only just exposure to craft techniques or a material, but also deeply rooted beliefs and a way of life. Another facet discussed was that while keeping culture intact is not possible since it is not static, but it has to evolve and redefine itself. In this process, some of the old ways would be still embedded in the new.

During a discussion on 5 July, 2019 with Pankaj Narain, a practicing designer and academician mentions that Globalization has had positive and negative effects as well. The good part has been that it has led to a boost in the economy, which has translated into increased opportunities for designers and craftsmen alike but the biggest fear is the dilution or even loss of culture. This is an effect of the current generation getting attracted to things foreign, and ending up losing touch with their own cultures due to availability of too many choices and an overload of distraction. During the interview, it emerged that in his experience, not every student would be interested in crafts and culture, and only a few would genuinely be keen on pursuing more knowledge about crafts and culture. The approach followed by Pankaj means that the craftsman is brought to the classroom as well as students going out in the field to crafts clusters and getting their hands dirty, thus gaining better understanding of these crafts. Thus, empathy is created in the mind of the students toward crafts and culture. Therefore, he feels that in spite of waning interest today, providing a platform to students to explore culture and heritage is still very important.

As the younger generation is rapidly embracing modern technology and increasingly being influenced by globalization, the indigenous and traditional technologies and skills are almost being forgotten and shall soon disappear for want of any patrons. According to the authors, simply sitting in the classroom or searching online cannot help students learn about Culture and Heritage. To experience culture one has to actually go out into the field, dirty their hands and gather first-hand experiences. This will, in turn lead to a better understanding of the issues and challenges that present themselves to a Designer in the course of their Design journey.

According to Darlie Koshy (2017, pp. 1-4) crafts provide differential advantage to design by providing sense & sensitivity. With values, stories and aesthetics all embedded within them, crafts can provide a connection to the heart unlike any other expression. As crafts have both tangible and intangible aspects, they provide a sense of realism and continuity in a globalized world, where a single, standard identity is slowly emerging, with everyone striving to conform to this global identity.
The authors suggest that Design education should aim for the following:

- To create a balanced curriculum that includes the vast repertoire of traditional knowledge that exists with the craftsmen.
- To develop empathy and respect in the minds of the students for culture, crafts and crafts practitioners. This can be achieved by interacting and collaborating with the craftsmen.
- To create design practitioners who can think local and act global at the same time.
- To create and shape designers who can think beyond stereotypical expectations of industrial design.

3 Incorporating Cultures and Crafts in design Education (A Case Study)

The curriculum of the Post Graduate Diploma in Interior Design & Styling department in the School of Design, Pearl Academy attempts to address the issues and possible ways forward for students to develop an understanding of the cultural and crafts aspect, and this is done through assignments and design projects that teach self-awareness, empathy, cultural awareness, and ultimately a global view. The projects are hypothetical in nature, and the project brief includes research, case studies, design and documentation.

3.1 Semester One: Familiar to Unfamiliar: Project 1: The Familiar

The cultural and self-awareness aspect is introduced to the students in semester 1 under the Interior Theory Module. As part of this module, 2 projects/assignments are assigned and completed during the course of 10 weeks. Each assignment/project builds upon the learning established in the previous project. Projects also progressively increases in size and complexity.

The first project is very personal, focusing on the individual student’s family history—where each student reflects on their family culture, their backgrounds, history, rituals and traditions followed in their family. The teaching and learning strategy in this assignment is based on learning through one’s own self experiences and the experiences of their peers. The students are encouraged to discuss on their own experiences of their family culture, and this is designed to encourage cultural awareness.

They talk about their family tree and family backgrounds, their surnames and how surnames generally are markers of community, traditional family occupations, region of origin etc. As a first step, the students gather information from their family members through interviews; discussions etc. and after data collection share their stories with the class in the form of a piece of reflective writing followed by presentation to the class. The students also reflect on the interior design/space planning aspects of their own house. For example: How spaces...
were used in their own houses as per their family culture; the concept of purity and impurity in kitchen or in entire house; family shrines and sacred space within the household; the practice of removing shoes outside while entering the house.

The project is important for the student to become aware of the history that has made them who they are, to realize that there is so much similarity yet lot of differences in the way spaces are used in each other’s family (for example, most Gujarati families will have a culture of removing shoes outside their house near the entrance). In many cases the students also discover that their family traditions are no longer practiced nowadays due to living in modern houses /dwelling designed keeping in mind global trends. This process of enquiry and exchange of ideas helps students to identify practices unique to a culture/community, and sometimes there are situations where similarities are also seen in diverse cultures.

This sharing of cultural practices and family traditions by the students in a studio setting creates a lively exchange of ideas and thus leads to increased awareness about culture.

3.2 Project 2: Familiar to Unfamiliar

The second project in the module is a group project under the name Design project 1 where the students move to an unfamiliar context i.e. a semi urban scenario/setup. They are asked to do a background research to understand the location/area and then they are taken to the site where each group is assigned one area or scenario and asked to collect data related to background, history, culture from past to present. The students observe in detail how people are interacting with the space, with each other and understand the culture and context. For research and data collection, various tools are used: interviews, surveys, recordings, sketches etc. After a detailed research for 2 days, students are asked to present a visual scenario of the present culture/trend/pattern. After the second day, the students work in their studios and brainstorm on opportunity areas for design – they have to go back to the background data collected and the scenario to understand the problem/design opportunity in terms of contextual; cultural, social influences. In their final presentation to the class, the students present their design solutions and explain how these solutions will benefit the users, the location and the context and all the stakeholders.

The faculties try to ensure that this particular design project is done in the older parts of the city (Delhi) where some cultural aspects are still alive and where modernity is rubbing shoulders with tradition.
3.3 Semester Two: Craft Techniques for Interiors

This project is designed with the aim of engendering interaction between design students and craftsmen for design and product development for the contemporary Interiors market. The objectives of this project are: To encourage students to engage with traditional craftsmen; To create areas of shared opportunities for the designers and the craftsmen, within a collaborative process; To foster a two-way learning process along with the spirit of cooperation; To develop a sense of empathy in the students towards the act of creating/making and the maker.

After giving basic input on crafts, meaning of crafts, Indian crafts, the students are explained the importance of crafts in the globalized world, this also includes interaction with designers who are already working in crafts sector. Students are made aware about ‘crafting of the spaces’; incorporating crafts- surface making crafts and surface finished crafts in interior spaces. Crafts of all kinds: architectural, functional, decorative are used to enhance and accent these places, which are incorporated on walls, ceiling, floor, furniture, paneling/partitions etc.

The students are asked to choose a craft that they would like to work on, and do a background research on the chosen craft and its context, community practicing the craft, to the present status and then identifying a craftsman with whom they can work with to
develop a product (with application of craft on a contemporary product that can be used in modern interiors)

This module not only helps the students in terms of understanding how design intervention works, but the craftsmen also benefits by getting new ideas for products. As part of an informal survey conducted by the students with their chosen craftsman, it was found that these new products did have acceptance and value in the market. This collaboration develops more confidence in both the students and the craftsmen.
Figure 10, 11: Pattachitra Lamp depicting the Traditional Fish story (Designer + Craftsmen)

Figure 12: Space Divider with Chamba Rumal Craft (Designer + Craftsmen)

Figure 1 to 12 showcase different Interior Products Developed as part of Craft Techniques for Interiors (Designer + Craftsmen) using different craft from India. These products are designed by semester 2 students of PG Interior Design & Styling course at Pearl Academy.

3.4 Semester Three: Hospitality Project: Boutique Hotel

Building on the learnings from the earlier semester, where the students are sensitized towards the understanding of craft and culture in a broader sense: (after incorporating craft in products, another aspect of incorporating craft in ‘crafting of spaces’ is introduced), In this semester the students work on hospitality space - a boutique hotel, and are given a choice to select one from two typologies, i.e. Contemporary or Heritage. They develop their
understanding about the culture of that region (here culture plays a vital role that dictates
the design, and the demographics, climatic response, geographic considerations, local
materials, motifs, patterns, colors, styles, crafts etc. all form part of that cultural context).

Figure 13: Mood board for “PadharoMarheDes”- Heritage Boutique Hotel on concept of
celebrating different aspect of Jodhpur’s, varied culture and exquisite beauty.

Figure 14: View of Bedroom

Figure 15: View of Dining Area for Heritage Boutique Hotel
The student’s study how traditional crafts and techniques and indigenous process of construction are used to the best advantage and can also be contemporized without losing their essence. The study of old buildings and their interiors as case study like Neemrana fort resort, Tijara fort resort etc., can give us a glimpse of crafts that imbue such habitats with their characteristic regional and cultural flavor, which are missing from modern buildings.

3.5 Semester Four: Final Project

In the last semester of the course, the students work on a project of their choice, and it can be based on any Interiors related topic or space to design. As part of the thesis project, some students tend to choose topics that related to Indian culture and its application in Interiors. It has been seen that exposure to culture in the earlier semesters, does whet the appetites of some students towards the cultural and heritage aspects, and some projects that emerge from this are focused on heritage and culture issues. A few examples:

- The Central Maharani (A Luxury Train that showcase the cultural heritage of Central India).
- Experience Centre for handicrafts of Varanasi, Experience cum Research Centre for Traditional Surface crafts of India at Varanasi for handicrafts of that region.

*Figure 16: Interior of a Luxury Train depicting crafts, textiles and culture of Madhya Pradesh, India in Interior elements like upholstery, furniture etc.*
As part of these projects students undergo a detailed research that involves studying the cultural and historical aspects relevant to the topic of their study. In the two year PG course, an attempt has been made to make students connected with an aspect of culture in order to sensitize them towards our rich heritage and cultural background. All these assignments and projects help student to explore ways in which traditional crafts and cultural heritage can be incorporated into our present day built environments, forming an evolutionary response to the changing times, and maintaining our own cultural identity in the face of the onslaught from globalization and not just following a bland aesthetic that eschews all individuality. Students also learn about unfamiliar culture and how culture can be incorporated in a public space. Focus is also placed on application of traditional crafts and local materials in its own traditional essence or contemporized.

4 Conclusions

Design as a formal discipline has emerged after the mid-20th Century, an era that has been dominated by modernist thought and ideas. Therefore, traditional art and craft have not been considered worthy of inclusion in Design and design research. The Euro-centric models have thus coloured enquiries in design and design education, and relegating a majority of traditional crafts under the umbrella of Ethnic.

However, an increasing call for understanding of issues related to diversity in today’s world has also triggered a need for re-examining the Euro-centric ideas and be more inclusive of the indigenous knowledge and skills. According to Alain Findeli (2001, pp. 5-17) twenty first century design must “open up the scope of enquiry”. The decline of crafts as seen in today’s
scenario has many reasons, few of them is due to globalisation. According to Laila Tyabji (2017, pp. 115-124) one of the reasons is due to the saturation of ideas, not a saturation of demands, the authors feel that integrating crafts and culture in design education can help in filling this gap.

As seen above in the preceding paragraphs, Design bolstered by tradition oversees the transitions from the past to contemporary values. Therefore, the changes wrought by Globalization are not confrontational with the past; instead, it can be integrated with the past to help perpetuate traditional ideas and sensibilities and prepare them for a new world. Thus, the future can be shaped by the past.

The authors strongly feel that understanding about ones roots, and learning through action must be an integral part of the curriculum for Design education.

The authors believe that Design Education should aim at sensitizing students about the cultural heritage and provide them with avenues and exposure to explore their cultural and contextual backgrounds as they are the future custodians of their culture. Going by current global trends: “Handmade is the new Luxury”, and as we hurtle towards a more technology driven modern world, leaving behind our heritage in oblivion, it becomes imperative to take stock of the value of Heritage and finding ways to keep the traditional knowledge alive. And as mentioned by Purnima Rai (2016, pp. 27-28) in one of her papers that In an increasingly mechanized and digitized world, our unique good fortune in being able to access an unparalleled resource of hand skills gives us a distinct edge over any other country in the world.

“Whoever wishes to foresee the future must consult the past; for human events ever resemble those of preceding times. This arises from the fact that they are produced by men who ever have been, and ever will be, animated by the same passions, and thus they necessarily have the same result.” (Niccolo Machiavelli, 2017, p.222).

**Referencing**


Learning through codesign toolkits.
A case study on codesigning the cinema of the future.

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Abstract | Codesign includes end-users in the design process. Ideally codesign occurs at many points in the design process however, in an education setting often only one codesign workshop is arranged. This study investigates teaching design students the value of codesign through a long-term funded project aiming to reinvent the future of the cinema for millennials. We involved non-designers, in codesign activities with mixed disciplined design students. The projects favoured by the end-users intertwined the ritual of going to the cinema, with the culture of sharing experiences with friends, with modern digital services. We argue a minimum of two codesign workshops are needed to generate valid ideas and maintain an ongoing voice of end-users in the process. Codesign materials needed to be carefully chosen for end-users to articulate their ideas and for design students to trial this new language, translating end-user views into innovative designs for the cinema sector.

KEYWORDS | CODESIGN, USER-CENTRED DESIGN, DESIGN METHOD(S), DESIGN EDUCATION, PARTICIPATORY DESIGN
1. Introduction

Design has been characterised as an intuitive, inward-looking process that ends when designers arrive at an aesthetically pleasing concept, they consider fits the client’s brief. Traditionally, in design practice, clients provide the content and designers create the form. The view that designers owe their allegiance to clients rather than end-users is still prominent in practice however, with the rise of participatory and user-centred design approaches, designers want to know how to engage with end-users and what the benefits are. Codesign includes end-users as design partners in the process with the aim of harnessing their contextual knowledge and creative ideas. Ideally codesign occurs at many points in the design process however, in an education setting often only one codesign workshop is arranged, making it easy for designers to ignore or misunderstand end-user voices, extracting ideas using intuitive idea generation processes. The main challenge is choosing codesign materials suitable to give end-users a strong voice and enable idea generation that informs innovative design at several points along the design pathway.

This study specifically looks into teaching the next generation of design students the value of a codesign process on a long-term funded project aiming to reinvent the cinema of the future for millennials. The authors of this paper led and taught and the codesign process to mixed disciplined Master of Design students, at Swinburne University of Technology inviting non-designer end-users into our classes. Each year, for four years we arranged two codesign workshops to understand the current cinema context and why cinema attendance is declining in Australia, following a global trend. The design students and non-designers then co-created future cinema scenarios suiting millennials’ preferences. The codesign processes included games, card sorting, think aloud, probes, and superhero toolkits. A thematic analysis of the barriers to cinema attendance across the four years showed that millennials regularly choose to watch movies at home alone or in social settings with food. They reported barriers such as getting dressed up, finding a friend who liked the same movie choice, the high price of cinema and travel to the cinema, and surprisingly leaving pets at home after a day at work or study. The codesigned project solutions presented in this paper centre on reviving cinema attendance through, personalised collectable tickets, making memories with friends, enhancing the cinema atmosphere by digitally lighting the corridors and combining going to the movies with treasure hunt gaming experiences.

2. Understanding codesign and the cinema experience

2.1 The stages of codesign

Codesign is growing as a design method, however debate continues about when and how many times to include end-users in codesign workshops. A design project typically involves three stages, each presenting an opportunity to include end-users, the exploratory,
generative and evaluative design stages (Hanington, 2007). In codesign, the exploratory stage
aims to understand the project goals and context and reviews past design concepts; in the
generative stage designers and end-users redefine goals and co-create a range of design
options and prototypes, in the evaluative stage, designers and end-users iteratively shape
the designed concepts into final design prototypes continually checking they suit end-user
needs (Spinuzzi, 2005).

Most of the research literature agrees, incorporating end-user ideas early in the design
process is vital to ensure project goals are sound (Hanington 2007; Lofthouse & Lilley, 2006).
Research shows that eighty percent of decisions are made in the first twenty percent of
project time, showing the importance of planning a codesign workshop early in the project
duration (Kleinsmann et al., 2007). Some argue typically the largest proportion of codesign
activity happens in the early phases of design, called the “fuzzy front end” (Sanders &
Stappers, 2008). Planning a second codesign workshop in the generative stages of design is
shown to help to reduce the number of unworkable ideas (Hoonhout, 2007).

Authors claim codesign workshops should occur at many points in a project duration, in the
pre-design, generative, evaluative and post-design stages (Sanders & Stappers, 2014). If
designers can develop an ongoing relationship with end-users then all stakeholders become
invested in the project (Honnhout 2007; Visser et al., 2005). Working with end-users has
been described as “a cascading process” suggesting better designs will result from a
continual cycle of end-user research (Reich et al., 1996). By listening to end-users’ views,
drawing on end-users’ expertise and understanding end-users’ goals at all stages of the
design process researchers advocate the end product will more likely suit end-users’ needs
and preferences.

Generative toolkits in the context of codesign workshops are a means to uncover the needs
and preferences of end-users, allowing hidden project issues to surface (Sanders & Stappers,
2014). Generative toolkits are design-led activities where designers create the toolkit to suit
a project context and support end-users to give creative input. Previous authors have
designed maps of when generative toolkits should be employed across the various stages of
codesign workshops (Sanders & Stappers, 2014).

Teaching design students end-user research methods has in the past revolved around
techniques such as focus group, observation, questionnaire and interview, where end-users
are observed for insights and information is extracted for a designer’s brief. This review
shows that understanding how and when to invite end-users into the classroom to
participate in codesign workshops with generative toolkits with real world clients is little
known. The study presented in this paper began with the broad aim to understand how
codesign processes benefit design student learning.

2.2 Challenges of cinema design: Why do people go to the cinema?

Cinemas are sites of cultural significance and there is a renewed interest in studying the
social and spatial dimension of cinema attendance (Bowles, 2011). This is relevant as the
design of the theatre spaces reflects social practices such as “getting together with strangers
in a darkened public venue” (Bowles, 2011, p. 854). The architecture of the theatre has been
designed so that patrons may forget the outside world and become immersed in an
environment free of reminders of ‘reality’. The notion of escaping reality is common in
cinema marketing strategies. The design of the lobby, screen, lighting, room proportions,
sightlines and seating are used to create this phenomenon (Muffoletto, 2011).

Part of the positive experience of going to the cinema is explained by its quality to escape
from everyday life (Addis & Holbrook, 2010; Katz et al., 1973). According to Muffoletto:
“People go to the movies to be emotionally immersed in an environment that excludes
reminders of their daily routine” (2011, p.1). In times of stress, such as war, movie theatres
sell escapism, contributing to their success and longevity (Jeacle, 2009; Ratner, 2003).
However, Muffoletto (2011) proposes that the escapist quality of the movie theatres has
deprecated due to increased contact with the outside world whilst being in the theatre. He
suggests the use of smartphones to text, social media and access to movie reviews or
trailers, is responsible. He also suggests that for the younger generation “letting it be known
what they are doing” has become a part of the shared social experience as much as the film
viewing itself. According to Lee and Ma (2012) the value of any form of media entertainment
lies in an ability to satisfy users’ needs of which one can be escapism.

The cinema industry has a history of success due to its longevity, its financial success and
cultural significance. Despite millennials spending more time watching movies at home via
evolving technology, the time spent watching movies in a movie theatre has remained
consistent since 1970 (Sedgwick, 2004). Traditionally, cultural theory and the importance of
the film script itself have been areas of research in the film industry (Sedgwick, 2004).
Research has been conducted into film form and content over other factors (Bowles, 2011),
however there is a gap for designers to reinvent the cinema as a space, service and desired
experience.

Research supports the theory that consumers use media such as film, online gaming and
social media as a form of escapism. There is evidence that providing patrons a sense of
escapism through the movie theatre experience is a key element of cinemas’ ongoing
success. While some research into how the design of the physical space of a theatre creates
a sense of escapism exists, service design, and the overall cinema experience (including
before and after the film) are neglected topics. With progressing technological
advancements, the underlying traditional desires of escaping and new trends of sharing the
experience should be catered for in innovative ways. This is what this codesign project aims
for.
3. Method

This study sought to understand how codesign processes benefit design student learning in regards to the future cinema experience. The spirit of entering into the codesign process was positioned according to Cross (2004), that anyone can be taught designerly ways of knowing. Each year, over a four-year period, two codesign workshops were arranged during a twelve-week semester, involving an iterative process of exploring, designing and reviewing ideas. First the designers undertook a literature review, then they conducted site visits to the cinema to understand the design context. After this, a variety of generative toolkits were trialled in the codesign workshops for a large cinema retailer in Australia. The workshops were each two hours long and held in large open space rooms in the university.

The designer participants were from the Bachelor of Design and Master of Design programs in an Australian university, ranging in ages from 22 to 40 years. They were all from different design discipline backgrounds including architecture, interior design, communication design, digital design, product design and fine art, most with previous design industry experience. The non-design participants were family and friends of the designers, other university students and staff, representing lead end-users of the millennial age group. By inviting non-designers into a series of codesign workshops, the designers were challenged to create generative toolkits to build ideas together with non-designers, which they had never experienced before. Here, the study built on Sander’s call for designers to create spaces that she terms “scaffolds” where everyday people express their creativity (2002).

Experienced university lecturers art directed the design work each year and this paper’s authors supported the design students to facilitate the codesign workshops themselves. Other student designers took notes of their general observations of the codesign workshops, participant survey question answers and they wrote their own reflections immediately after each workshop. The informal nature of notetaking was important to allow transparency and continuous checking to occur (Lincoln & Guba, 1985). This paper’s authors photographed the workshop process and the design outcomes.

The data sources used in this case study included existing marketing material provided by the client, site visits, workshop photographs, design prototypes and ideas used before during and after the workshops, design outcomes, observer notes and survey reflections. For analysis, all the data sources were organised chronologically under activity headings into a large case report. The analysis was organised in colour coded themes answering the broad question: “What are the lessons learnt from trialling codesign workshops in design education?” Following are the findings, outlining what students discovered from trialling two codesign workshops and the overall lessons learnt.

4. A case study: Codesigning the future of cinema

The client had undertaken previous market research to understand the barriers to cinema
attendance and the strategies to attract millennials out of their homes, bars, restaurants and into the cinema. The authors of this paper focused on two issues: teaching the students codesign skills and codesigning novel solutions to attract millennials back to the cinema.

Before embarking on the first codesign workshop the majority of students admitted they had not heard of codesign as a design method. There was confusion about who they would be working with. Some said they thought codesign would be about engaging with clients, others said they imagined engaging with different designers or people with different backgrounds. Others said they were excited to learn a new method that they could use in their jobs. One student commented: “I didn’t know too much about it, however I knew it would be a good skill to develop as a designer.” Several students were nervous for example one student said: “I’m unsure about codesign, it sounds messy and scary because you have to deal with strangers.” However, on the whole, comments were positive such as: “It sounds like a really interesting area that I would like to be more involved in and learn more about.”

4.1 Co-design workshop one

Students were encouraged to create activities with inspiring materials that would help them find out about moviegoers needs and preferences and the barriers to cinema attendance. The codesign activities ranged from model making with beach, forest and outer space themes, Lego play, creating mood boards, journey maps and card games aiming to find out what end-users would like as an ideal cinema-going experience and about their nostalgic memories of past experiences. One student’s activity was to create a future mood board about the experience of waiting for the movie to start. This student used a pop-up stage moodboard where non-designers pegged images onto the string (Figure 1). Another student used superheroes in the corridors to prompt discussion about how the corridors could be lit up after an initial finding that they were dark and depressing. One student was to create a personal cinematic profile card. Another activity was to map positive and negative experiences in the cinema on a mood board. One student asked the user to imagine themselves as a superhero either in the café, foyer, or entrance of the cinema (Figure 1). He wanted to find out what characters they liked. One activity asked participants to view images of a specific movie, and then pick out given words to describe what they were feeling. Finally, one student created a ‘cinema experience’ journey map. She provided printouts of different items (popcorn, wallet, tickets and emotion icons) to facilitate a creative conversation.

When analysing the success of the codesign toolkits, the authors discovered that games were the most engaging form of toolkit activity. Games provided the opportunity for participants to chat about their ideas while playing. The students were delighted with how much conversation they had with the participants while playing games, gaining great insights, information and opinions from the participants. Students were pleased that their codesign toolkits prompted many ideas: “It was really engaging and a lot of brainstorming was done”; “It was quite engaging and straight to the point”; “The users liked it and we got a lot of suggestions”; “People were very interested to participate in the activity because they said it
was very creative.” The toolkits acted as prompts for quick engagement as one student said: “Because my fortune wheel was very attractive, it was a good excuse to get them engaged.” Another said: “I not only gathered the information I needed but I also found other concerns and possible solutions related to the cinema experience”.

Figure 1. Top row shows the trivia hunt toolkit investigating options for the game. Bottom row shows three toolkits: a cinema mood board on a stage with pegs; a superhero dress-up game, and a build your ideal cinema with Lego activity.

After the first codesign workshop, we discussed ways of improving the students’ codesign toolkits in preparation for the second workshop. Students commented in the future they would make their toolkit more fun and more flexible. Students realised, if a non-designer participant wasn’t comfortable sketching, then their toolkit was wasted on them. Overall, the students concluded that most of their toolkits in the first workshop were far too complicated while others needed to be more varied to prompt conversations without requiring a lot of explanation. The students reflected that group toolkits save time where more people can listen and record ideas on the spot. One student said: “It was hard to capture ideas quickly – have two people, one can scribe”. Students realised the benefit of having attractively designed toolkits to create interest. At the same time, they realised a lot of money didn’t need to be spent to make the activity still worthwhile which was a relief for international students without a lot of access to resources. Some realised activities can be too open ended, where it would be better to ask more specific questions. Many decided for the second workshop a game would be the best to allow for fun interaction. One student reflected: “The activity was so fast, so I think I can make it a little longer and deeper to explore more information”.
The students all agreed in the second workshop, it would be better to include more visual materials such as images, cartoons (for example movies scenes and characters) and have less text, words, rules and descriptions as part of the activity. One student said: “Next time I need a toolkit where people don’t have to write a lot”. The students realised in the future they would sit back and allow the end-users to take over creating artefacts and models themselves. One student admitted he was not very good at facilitating but learnt a lot by listening to the discussion of the group. Another student said it would be better to: “personalise the experience more, for example having a photo that shows you as the principal character”. This student went on to design a personalised collectable cinema ticket with a photo of the person buying the ticket embedded on a printed ticket. Many of the participants said collectable tickets would be something they would put on the fridge or share with friends or hold onto as a keepsake (Figure 2).

![Figure 2. A student design proposal showing how cinemas could use a photobooth or an app to create personalised, collectable tickets.](image)

### 4.2 Co-design workshop two

The aim of the second workshop was to trial refined codesign toolkits to further understand the barriers and preferences of cinema-going millennials. The students were challenged to propose a design solution to refine with non-designer participants. The second codesign
Learning through codesign toolkits. A case study on codesigning the cinema of the future.

workshop was an important chance to gather end-user insights to help shape their design outcomes for enhancing the youth’s movie-going experience. One student thought the entry hall was the key area to focus on, as he discovered that participants thought the corridors were dark and depressing which was an opportunity to redesign. He codesigned a corridor with projectors installed to light up the corridors with images of the next blockbuster movie and lights to lead people into the cinema where the next movie would be shown (Figure 3).

One student said: “Users are more creative than I thought”. She discovered, that: “People like the idea of a game that makes you walk around the cinema”. It was one of the end-users who came up with the idea of augmented reality for a treasure hunt game she called a “Trivia Hunt”, showing how the codesign activity directly influenced her design concept. She explored a scavenger hunt idea, combined with trivia creating the Trivia Hunt concept (Figure 4). The idea was that trivia questions based on a film represented in a poster would be hidden in locations around the cinema for patrons to search for. Once patrons find the answer to the question, they enter it into their phone linked to a QR code for the chance of winning a prize, such as a movie ticket or a free popcorn.

Figure 3. A student design proposal showing how the cinema corridors could light up with projections of movie images and show the path to the cinema door.
The designers’ rule “form follows function” was stressed by a non-designer when one student said: “I found that cinema goers valued function above all... for example expense was an issue”. Millennials repeatedly discussed the price of the movie as a major barrier to attending the movies. The social aspects of going to the cinema was also repeatedly discussed. Debriefing and chatting with friends after the movies, was something that all participants wanted a design solution to cater for. One student found: “The obstacle of deciding on when to go [to the cinema], with who and what to see is much bigger than I anticipated”. In response to this, the student recommended the cinema team up with a dating app to find a friend to invite on a first date to watch a film together. Another student found: “People really want to bring their home to the movie theatre.” So the interior design students got working on comfortable seating like couches with rugs and cushions. Others worked on solutions where a dog salon would see their pets being pampered in the foyer while they relaxed watching a movie as leaving pets at home after a day at work was another barrier to going to the movies.

4.3 Lessons learnt

At the end of the semester after conducting two codesign workshops, the authors of this paper asked the students about their experiences. The students used the words ‘fun’ and ‘engaging’ to describe their experiences with codesign toolkits and real-world participants. One said: “it was fun, I gained practical and new perspectives” another said: “I got lots more insight than I imagined.” Another said: “People talked more after fun activities, and they felt more comfortable in this kind of atmosphere.” Several students acknowledged the importance for final design outcomes to include end-users’ perspectives. For example: “It’s a
very unique way to shape your design development with solid information from the real users” and “it is a very good tool to design not only products but experiences as it is important to know the thoughts and opinions of end user.” One student acknowledged that in the end the designer needs to make a decision to move the design forward, stating: “It can be very fun and creative ... designers still need to make a call”. In order to get feedback whether the final design proposals were suitable from a business perspective, the client was invited to the final student presentations to give feedback on the fit of the ideas for their business. The feedback was overwhelmingly positive – in particular on the ideas presented.

5. Conclusion

We found codesign to be a useful method when applied twice in a twelve-week university semester: the first workshops uncovered barriers to cinema attendance and the second suggested suitable prototype ideas. Two codesign workshops are sufficient to give designers a taste of working with rich data, where final designs are not based on intuitive assumptions. We found a codesign process trialling toolkits became a language facilitating ideas between different disciplines and stakeholders. We suggest a new important role for designers is to find their voice in orchestrating this language. We argue a minimum of two codesign workshops are needed in design education to generate validate student ideas and keep an ongoing voice of end-users in the process. The codesign materials need to be carefully chosen for end-users to articulate their ideas and for design students to trial this new language, translating end-user views into appropriate designs. The projects favoured by the end-users intertwine the ritual of going to the cinema, with the culture of sharing experiences with friends, with modern digital services. Revisiting past social connection behaviours such as going to the cinema can benefit future generations. This study reveals the potential of codesigning a cinema attendance strategy, moving beyond pure entertainment into concepts that contribute to improving society’s isolation and loneliness concerns. We suggest that codesign processes rather than traditional designer-client processes, offer novel solutions for clients looking to come up with innovative concepts for enhancing their existing business models.

References


Learning through codesign toolkits. A case study on codesigning the cinema of the future.

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Acknowledgements: We would like to thank our Masters students (DDD60001 2016-2019) for working on the ideas and designs in the presented case study. Thank you to Village Entertainment for their support over four years of codesign research and appreciating and applying some the students’ work in practice.
Letterpress: A Survey of Print Culture or an Immersive Learning Experience

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Abstract | This paper explores the culture of letterpress printing within Art and Design education in the UK and Ireland. It describes two phases of research over the last four years. The first is based on an immersive collaborative letterpress research project, in which staff and students from six UK Colleges worked together to research, write and print a letterpress publication. The second phase is a comprehensive, systematic field survey of all of the remaining letterpress workshops within Art and Design Higher and Further Education in Britain and Ireland since 1955. The combined findings of these two phases of research enable the authors to form a position in relation to the changing culture of letterpress and its role in education.

KEYWORDS | LETTERPRESS, TYPOGRAPHY, PRINT HISTORY, DESIGN HISTORY, PRINTING
1. Introduction

This chapter outlines the current breadth and depth of letterpress practice within contemporary art and design pedagogy across the UK and Ireland. It is based on the field research data which has been systematically gathered through visiting the letterpress workshops in Further and Higher Education. These research survey visits to Art and Design Schools involved traveling over 8,400 miles between 2014—2019.

Throughout the major part of the twentieth century, the teaching of letterpress was organised through training centres in technical colleges and art and design schools. This ‘training’ as opposed to ‘educational’ model is now long redundant, largely due to the growth of digital technologies the 1980s and developments in design Education. Letterpress printing, however, is more popular than at any time in since the 1990’s. The current resurgence of interest in the letterpress process makes this research timely as it examines how the education of artists and designers has changed and developed since the 1960s.

The collaboration between the principal researchers began 2011. It has involved two interconnected research projects. The first part linked six colleges with active letterpress workshops from around the UK. Staff and students from each college united in a collaborative project that allowed them to consider both the practical and philosophical approach to letterpress practice. Entitled 6x6: Collaborative Letterpress Project, it provided an insight into the different approaches to letterpress within the six colleges.¹

The second part grew out of this first collaboration in 2014. The research team asked the question, how widespread is the use of letterpress in art and design education today, as compared to its mid-century heyday?

The research has identified 43 Art and Design institutions which have active letterpress workshops. We have visited and surveyed 41 workshops, the research has systematically identifying and cataloguing the equipment and presses, type sizes and faces, both wood and metal. We have undertaken a measured survey of each workshops which supported the development of orthographic drawings to a common scale providing a physical representation of each space.

¹ The collaboration was between the University of Brighton, Camberwell College of the Arts (UAL), London College of Communication (UAL), Central Saint Martins College of Art and Design (UAL), Lincoln School of Art and Glasgow School of Art. Each had an established history of using the letterpress, and with the exception of Lincoln, had workshops staffed by a dedicated technician. The staff and students involved were all from Graphic Design or Visual Communication programmes.
2. Identifying a timeframe and the extent of the field of research

In order to trace how letterpress workshops and teaching have changed within Further and Higher Education it was important to establish a clear datum point from which to start. Two key sources from the Charles Pickering Archive LCC provided this datum point within an appropriate time frame. The typed and hand-annotated list entitled *List of Establishments for Further Education Where Courses or Classes in Printing are held 1955* is believed to have been compiled by Beatrice Warde and the *Guides to Educational Courses in the Printing Industry 1967*. The 1955 list has 72 colleges and 1967 44 colleges (44 colleges appear on both lists) and provides a list of courses leading to qualifications that could be studied relating to training for the print trade. The two principal sources were combined together with the eight additional institutions, and organised into a single list alphabetically by city or town. The total number of letterpress workshops within educational art and design FE and HE schools and colleges responsible for the training of designers and printers was established as 104 in 1967.

Tracing the history of institutions on the combined list reflect the major changes in art and design education in the UK during the twentieth century. The first significant change was the
move from the *National Diploma in Design* (NDD, 1946–1961). In 1960, the *Coldstream Report* outlined decisions to develop a *Diploma in Design* (Dip AD, 1962 – 1974) (H.M.S.O. 1960), with only sixteen colleges awarded it in the first round. It is this legacy that is evidenced in the absence of many of the original colleges listed, for ‘Coldstream had promised institutional autonomy but his committee’s reforms led to increased centralisation and the closure of almost two hundred art schools across Britain’ (Llewellyn, 2015). This was a significant watershed as Technical Colleges and Art and Design Schools either retained pre-degree courses, in Further Education, or developed degrees within Higher Education. The next substantial change came in 1992, when Polytechnics were granted degree awarding powers. This has been referred to as ‘The polytechnic era’ (Llewellyn, 2015), the period 1965—1992 that was dominated by the *Council for National Academic Awards* (CNAA, from 1974 –1992). The last major educational change was the shift from a student grant to student fees and the adoption of student loans first introduced in 1998, followed in 2009, by a rise in student fees to £9000. The dates 1967–2020, provide bookends for our research.

### 2.1 Research Methodology: The Field Survey

The field survey set out to answer four interrelated research questions:

1. How many active letterpress workshops are operating within British and Irish Higher and Further Education?
2. Where are they located and within which Institutions?
3. What do they contain and how are they arranged?
4. How are they being used?

Having established the number of institutions which could have active letterpress workshops we began to systematically contact each by phone and then email. We established that 43 Institutions from 104 had retained letterpress equipment. The field research was supported by small funding streams from a range of sources.

### 2.3 Plotting the Scale of the Survey

Using an OS maps of the UK and Ireland we began to plot the position of the 104 workshops using a single yellow dot for the 1955 list, single orange dot for the 1967 list and an orange roundel with a yellow bull for those institutions identified as entries on both lists. We now had a distribution pattern that revealed the post-war period had a significant number of small institutions located across the UK (Beck and Cornford, 2012). The distribution pattern linked, as might be expected, to major cities towns or urban conurbations. We developed a second map plotting the 43 institutions which had confirmed letterpress workshops. These colleges can be broken down geographically: Scotland (4), The North England (10), The
Midlands (5,) Wales (1), Republic of Ireland (2), South East England (15), South West England (7).

2.4 Ensuring Consistent Data Gathering

To ensure consistency and comparable results it was important to develop a transferable methodology for collecting the data. Letterpress type is stored in cases within cabinets which characteristically have space for 22 cases. We designed a simple form with 22 lines, and columns for: font, weight, size points/didots, foundry/manufacture to catalogue wood and metal type. A comments section at the bottom was used to record the cabinet maker, where this could be identified. As all the workshops contained several cabinets each form was numbered. This systematic process has provided a record of every cabinet and every case, workshop by workshop. A second form was designed to record the equipment.

2.5 Surveying Physical Workshop Spaces

As well as the type and equipment we wanted to survey the physical space. We made the 1:50 digital scale drawings. The scale drawings enabled us to compare workshops: size, organisation, workflow and student capacity. A combination of the survey and conversations with technical and academic staff, revealed how many students could be taught in each workshop. This is a critical feature of modern HE education where institution wide staff student ratios (SSR) are often applied to funding models which can restrict small group workshop teaching or make it prohibitively expensive.
Figure 2. A sketch of the workshop at National College of Art and Design, Dublin. This information was gathered onsite and worked up into a digital map afterwards.

3. Workshop Initial Findings: Type

We have completed surveys of 41 of the 43 institutions (44 workshops), a further three surveys have yet to be undertaken. The 41 workshops surveyed to date contain a total of 490 cabinets or type frames, which hold 9,272 cases of type. This figure can be further broken down into lead type, 8,132 cases, wood type 1,140, cases and 22 cases of Acrylic type. Today there are no institutions working with ‘hot metal composition’. No college has the capacity to cast their own type. The restrictions of contemporary Health and Safety practices identify the risks involved of working with molten lead. The Monotype casters from the London College of Communication (formerly London College of Printing) were donated to the Type Archive (London) in 2003. As a consequence of this loss, the quality of the type catalogued varied tremendously across different workshops. Some had seen heavy usage, some remained pristine in cases – particularly smaller, composition sizes that are labour-intensive to typeset and print.

Collections of wood type are vulnerable to theft as the attraction of acquiring a large wooden initial has appealed to generations of design students and as a result we found many cases of wood type labelled ‘mixed’, where incomplete cases had been combined. Modern digital technology has enabled laser cutting, 3D printing and CNC routing. In several
workshops we saw student and staff designed fonts and type blocks cut on end-grain wood as per historical manufacture and single designs mounted on type-high MDF in the manner of relief block printing, letterpress is not now exclusively defined by the use of moveable type.

Figure 3. 3D printed type, in the process of being mounted to type height to print.

3.1 Workshop Initial Findings: Presses

The workshop survey only records the position on the measured drawings of presses which were used for letterpress printing. It does not record all the relief printing presses in each institution in a printmaking workshops which may be used for, lithography, etching or mezzotints etc, nor those unused presses displayed in entrance lobbies as artefacts. The range of equipment, and particularly presses, varied across the different workshops. The 41 workshops surveyed to date contain a total of 84 large presses located in fixed positions within the workshops.

Today each workshop contained galley and/or proofing presses, there advantage is that students can use them under supervision. As each pull relies on hand feeding the press it is
only possible to produce small volumes. This has democratically opened up the possibilities of print production, students have authorship over each stage of the process of their work and are physically responsible for its execution. The student is in a position to produce multiple editions. By contrast, digital printing is often used by students to prototype, or produce a one off for a critique or review. Letterpress is not a facsimile of print, it is the actual print. It offers the student opportunity of working with metallic inks, fluorescent colours, pastels and printing white over a colour. Students can emboss, deboss and foil block. Educationally, this promotes a freedom and a range of print that is not possible within digital production.

3.2 Workshop Initial Findings: Layouts and Patterns of Use

At each workshop visited, the space survey and the making of measured drawings provided an insight into how the workshops are used for teaching and experimentation. The set-up had significant influence over the teaching and use. There are workshops in which the type is stored separately from the presses which enable students to set type when technical or academic staff are not supervising but do not support independent printing. We identified workshops in which all the equipment the paper, type, presses and drying racks are contained within a lockable space supported by a dedicated letterpress technician in which students can compose, proof, print and diss type under supervision. There are workshops in which the letterpress equipment is contained within a larger general printmaking room which may also support, mono printing, etching, mezzotints, lithography, and screen-printing etc and is supported by several technical staff with a range of printmaking expertise. There were also studio spaces containing type cabinets and a hand proofing press, characteristically a Farley, which enables students to compose and print independently. Only two dedicated workshops that had escaped closure were largely unused and without technical staff.
4. Reinstating Letterpress

Many of the staff with responsibility for the workshops are more investment and influence on the type collections within the workshops. At Arts University Bournemouth Sally Hope Course Leader Visual Communication has built up a collection of wood and metal type, acquired cabinets and cases, a stone and a Farley Press through which she introduces students to the process. Designers and academics Barry Tullett and Philippa Wood at the University of Lincoln house The Caseroom Press within the undergraduate Graphic Design Department. Their collection of predominantly wood type and typewriters is closely connected to their practice led research (Tullett, 2014) and this, in turn, informs their teaching. Students across all three years are taught the process through workshops which respond to Tullett and Wood’s own experiences as students.

The latest Letterpress workshop to be reinstated is at Kingston School of Art (KSA), Kingston University London, the ‘noblepress’ was founded in May 2017. Kingston Polytechnic had a letterpress workshop until 1992 (the same year it gained University status) when with the
retirement of the technician and an investment in new Macintosh Computers the workshop was dismantled and the presses sold. The set-up costs of £67,000 to establish the workshop must be considered in relation to the durability and longevity of the equipment. If serviced regularly the presses could be rolling for well over 100 years, as is demonstrated by Camberwell’s workshop which is the oldest in the same location since 1906. Letterpress equipment is rising in cost and so the presses and type are increasingly valuable assets.

5. Workshops and Curriculum Developments

The use of the letterpress process within each workshop varies according to the history and culture of the institution. The technical teaching of letterpress composition was phased out at all colleges by the late 1980’s. Digital composition rendered print apprenticeships irrelevant. The impact, scale and speed of change on the print industry and its knock-on effect on technical education which supported it in the was colossal through the mid 1980’s. Little more than a decade earlier, the print industry of 1970 employed 300,000 people in the UK. As late as 1985, 266 printers traded in the City of London, one of London’s major print areas, 111 of these were letterpress workshops.

Today, the workshops are used by a broader community of art and design students. Groups of Graphic Design, Visual Communication and Illustrators and printmakers use the space. When open access policies are adopted photographers, fashion students, architects and product students are often working alongside each other. The mode of teaching delivery varies from institution to institution, but the majority of colleges have an induction process to the workshop area, which is delivered by technical staff. This enables students to work independently with access to specialist support and technical guidance. Students at the majority of colleges are encouraged to explore design briefs through a range of media which may include: interaction, film, publication, print and print processes including letterpress. Some, including Cambridge, Glasgow, Kingston and Lincoln, stipulate a letterpress outcome on workshop or project briefs and therefore ensure that all students gain an induction into the area. Others have attempted to further embed it within curriculum through assessment submission requirements. In a strategic move to protect the workshops, courses have explicitly mentioned the letterpress process within validation documents, ensuring the preservation of the workshop. This was achieved when the workshop at London College of Communication was under threat in the early 2000s after several years without a dedicated technician. Both of these approaches mean that each student on the course in question can gain experience of the process, and work on the assumption that the most engaged students will return to undertake longer projects throughout the duration of their course. The wider adoption of letterpress as a medium by students is therefore primarily through self-selection.
Following the survey visits we conducted a series of telephone interviews with the staff responsible for the workshops which provided an insight into the way they are used in relation to curriculum. Edwin Pickston at Glasgow School of Art (GSA) identifies the advantages of the ‘Caseroom’ to Visual Communication students. For Pickstone the workshop presents the history of type. This is important as, ‘The principals of metal type underpin the systems which controls what’s going on digitally today.’ Letterpress provides the today’s Graphic Design students with a direct link to the process of reproduction key to the historical dissemination of knowledge through the printed book. For students who are familiar with digital type through word processing the origins of, typeface, size, columns, alignment, kerning (horizontal spacing), leading (vertical spacing) and alignment are made real through metal. The letterforms of type can be traced back to calligraphy, notation and writing systems leading to the origins of the alphabet. The link with history was a common thread with staff responsible for workshops. Pickstone states ‘In some ways “Graphic Design” has very short history, unlike architecture, the term “Graphic Design” was only really coined in the 20th Century’, the workshop prompts discussion about type development ‘through history’. Digital outputs are often used to present work for review and critique but these are presentations anticipating reproduction through lithography. Pickstone notes with letterpress ‘the prototypes are the real thing’. Students can make decisions about ‘…paper stock and mix and test ink, experiment with over printing using the full range of pantone inks: metallics, fluorescents, and pastels and opaque whites.’ Pickstone describes the process as learning: ‘discipline, explanation, endeavour and development’. He recognises in both his own work and that of the students the workshop naturally supports collaborative practice. The disadvantages of letterpress are that the students have to be taught in small groups at GSA 8-10 at a time. The process is slow and there is a significant learning ‘attrition rate’, the number of students who complete inductions but don’t return to the workshop. However, for those students who don’t choose to use the process again they have acquired an understanding. Pickstone reflects, ‘Perhaps not all knowledge gained through practical learning needs to be applied’. He describes the letterpress workshop as integrated into the curriculum as all the third-year students in Visual Communication Illustrators, Designers and Photographers have to compete an assessed piece of work within the workshop.

6. People

As the function of the letterpress workshops have changed between 1967 and 2020 so the experience and the demographic of the those responsible for the workshops has changed. The interviews with staff responsible for the workshops have revealed a range of routes into letterpress and a variety of career journeys. The workshops within Trade Schools of 1960’s where characteristically run by male technicians trained as a compositor or printers with commercial experience of working within the print trade. Through the early 1990’s there was a period of transition, some technicians retired and others retrained transferring their analogue knowledge of type to digital composition. Today the gender balance is improving,
staff responsible for the 41 of the workshops surveyed to date include 21 female staff and 28 men.

Both Manchester School of Art (surveyed in November 2017) and Plymouth University (surveyed July 2017) have trained compositors. Paul Collier at Plymouth had begun work as apprentice printer and learnt to set type by hand in a ‘jobbing printers’ in Plymouth. He then trained as a Monotype compositor before joining the University.

By contrast, Edwin Pickstone at Glasgow School of Art (surveyed 2017) has a full-time post which is made up of design lecturer/researcher, designer in residence, and letterpress technician. Pickstone was a student on the BA Visual Communication Design course at GSA. During his final year in 2004 Senior Tutor Steve Rigley set a project ‘What is the value of letterpress?’. Rigley’s project was both a provocation and invitation. In 2005 he combined technical support with ‘Designer in residence’ by a small grant from the National Heritage Print Fund. Fraser Ross, the technician who had trained as a compositor working at GSA since 1976 was considering retirement. A combination of wise succession planning and serendipitous opportunity enabled a period of handover and from September 2005 until April 2006 Pickstone worked with Ross. Pickstone recognises the importance of this generational handover, ‘...though he didn’t have six years to train me, I learnt rigour, and discipline from him...’.

Chris Wilson at Northumbria University views the letterpress workshop as a research ‘laboratory’ and has used it as a base his practice-based PhD. He was inspired by a week intensive workshop in the Netherlands with Thomas Gravemaker. Wilson’s role is multifaceted: design tutor, researcher and technician. ‘the workshop provides students with a historical context for typography’ and does not want ‘the workshop to become a museum or window dressing for Open Days.’ It has to be ‘a place where students actively make work’. The ‘physicality of type’ provides students who are ‘...visually aware, with a way to learn through doing, by designing on the press.’ He identifies the constraints as a positive aspect of letterpress, students can ‘Overcome the restrictions of limited number of typefaces and sizes.’ But also acknowledges that some students find it ‘Difficult to adjust to both the restrictions and the slow and considered approach to design and composition’ as the cultural conditioning of ‘the digital world provides instant gratification’.

7. Conclusion

This research has surveyed all but three of the letterpress workshops. It has established the number of workshops active in 1967 was 104, this figure has dropped to 44 workshops in 43 Institutions in 2020 (there may be some vestiges of type workshops as yet undiscovered). The research has traced the multiple name changes of the institutions and revealed that only 7 of the 104 institutions have retained their original name from the 1967 listings. Of the 43
institutions with workshops 42 are in the Higher Education sector within post ‘92 Universities, only Southport College in the FE Sector has retained a small element of letterpress. None of the 104 institutions identified on our 1967 list offer any of the print apprenticeships. The 43 workshops located within post ‘92 Universities are providing courses within Art and Design Schools or Faculties offering BA or MA degrees in Graphic Design, Visual Communication, Communication Design, or Illustration, though the workshops in some institutions are used by students from many disciplines. We have established that 41 workshops surveyed to date contain a total of 490 cabinets or type frames, which hold a total of 9,272 cases of type. These consist of consisting of: 8,132 cases of lead type, 1,140, cases of wood type and 22 case of Acrylic type and 84 large presses and 17 table top presses.

The demographic of the staff responsible for the workshops has changed. There are two technical staff who have trained as compositors and printers and the remaining 47 members of staff have learnt to use letterpress equipment through a design education. The nature of the curriculum taught within the workshops has changed radically from the acquisition of technical skills interchangeable skills for the print trade, to a creative workspace which places the student designer at the heart of print design and production. The workshops are today are learning and teaching spaces, research spaces, production spaces, and experimental studios where students can play type letterform and image through the integration of analogue and digital technologies.

Looking to the future we will analyse all the material gathered through the survey, including the equipment survey for each workshop which has yet to be collated. We will continue to conduct phone interviews with staff responsible for the workshop spaces to gain greater insight into links with curriculum and workshops use. We aim to create a digital data base which is likely to list over 9,500 cases of type, and provide press and equipment details. This will provide a listing of typefaces and sizes available in each size per workshop and the catalogue of type held within Education. It is our intention to make the catalogue of presses and equipment an interactive data base and web resource so that institutions can update new acquisitions.

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2 The research may be extended up to Universities outside Art and Design Education which have retained letterpress workshops. Birmingham University has moved the letterpress workshop Winterbourne House and Botanical Gardens as a working Museum run by volunteers. This workshop has already been surveyed but is not counted in the 44 workshops within Art and Design Education. Oxford University has a letterpress workshop in the ground floor of the Schola Musicae of the Quadrangle in the Bodleian Library, whilst Leeds University and the University of Stirling have workshops which have been revitalised.
References


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Abstract | This paper explores the concept of geometrical frustration as an alternative mode of form-making in design and manufacturing. While builders, craft makers and designers traditionally attempt to work with stress-free materials with predictable response and controlled outcome, nature often develops form and function through mechanisms of stress-informed materials. In biological systems such as flowers, geometrical frustration caused by internal stresses often leads to shape transformation. Although scientists have studied and understood this phenomena, material frustration has yet been introduced as a possibility for designers. In this paper, a frustrated materials approach is brought to the design process, through case studies in two different material systems. Both in ceramics and in latex, the material becomes an active partner in the design process, no longer controlled, predictable and “well behaved”. Through close collaboration with the scientist, the material’s behaviour is understood and analysed for further exploitation, enabling to reverse-engineer surprising new forms.
1. Introduction

Design and Production are control oriented. The history of design relies on the control over materials through manufacturing techniques such as casting and machining, making sure each chosen matter doesn’t “misbehave” (Lefteri, 2012). Processing materials involves external tools and moulds, rules and patterns – all created to ensure order and make sure each material element is passive, thus acts according to plan. The need for control is accentuated by computation capabilities, deeply rooted by now in the design and architecture realm, leaving no room for randomness, aiming at minimal tolerance and maximal efficiency, affecting the whole making of a design project: conception, visualisation, simulation, and fabrication (Carpo, 2013).

The ability to generate practically any imaginable form with ease on the computer screen, with digital design tools and advanced visualisation capacities, has led to the ongoing rising challenge of its materialisation as built or manufactured artefacts; designers and manufactures alike face the challenge of fabrication of complex geometries (Kolarevic, 2005; Austern, et al., 2018); issues of cost, sustainability and geometrical limitations come into play, raising significant barriers. The realisation of complex shapes in large scale, typical to contemporary architecture, is furthermore challenging due to the extensive use of moulds in the fabrication process (Hickert, 2016); It is echoed by the large efforts of research and technological developments in the past decades, oriented towards the development of alternative fabrication methods (Shell & Glynn, 2011; Menges, et al., 2017). While some concentrate on new technologies, such as 3D printing (Duballet, et al., 2017), other directions of development focus on the opportunities to be found in the material itself. Inspired by the philosophy of new-materialism (Miller, 2018) on one hand, and technological advancement in material research on the other, a rising awareness of matter’s generative power is at the centre of design discourse in the past years, under the concept of ‘Materiality’ (DeLanda, 2015). Seeking innovation and alternative modes of form-making, material-systems are developed, where the inherent capacities of the material itself are enhanced and exploited to achieve performance (Menges, 2012). Such material-centred approach widens morphological expression, promotes efficiency and higher performance, and inherently introduces new design paradigms (Hensel, et al., 2010).

Alternative modes for achieving form and reaching required performance, introducing concepts such as self-organisation, growth, hierarchy, redundancy and resilience, inherently relate to the world of nature (Speck, et al., 2017). In the search for alternative modes of form materialisation, nature serves as a source of inspiration and bio-mimetic development processes. While builders, craft makers and designers traditionally attempt to work with stress-free materials with predictable response and controlled outcome, nature often develops form and function through mechanisms of stress-informed materials (Weinstock, 2010). Wishing to adopt alternative material formation processes from nature, requires a shift from the traditional engineering efforts of balancing and annealing residual stresses.
within materials (Withers & Bhadeshia, 2001), to the study of the principles of stress-driven formation, for possible control.

A growing number of bio-inspired material systems are developed in recent years, mostly looking at biological models, extracting their principles of operation and translating those into a synthetic designed realm (Knippers, et al., 2012). This paper presents an ongoing transdisciplinary research that draws its theory and ideas from the world of non-linear physics into the world of design. From the physical formulation of complex form generation and motion mechanisms in nature, an analytical theory was generalised, applicable across scales and materials. This paper will present the application of the theory of incompatible shells on two very different material families, rubbers and ceramics.

2. Material frustration as shaping mechanism

2.1. Learning from Nature

Much of shape transformation in natural system is driven by internal stresses. For example, the opening of a flower, the swimming of a jellyfish and even the beating of our heart, are all driven by the build-up of internal stresses and their release via global shape transformations. The origin of these stresses is geometrical frustration, which can be described mathematically. An example that well demonstrates the principles underlying “forming via frustration” is that of the opening of a seed pod. In (Author, 2011) we studied the opening of a dry *Buhinia*’s seed pod. The pod’s valves consist of two layers of fibrous tissue, a tissue that expands/shrinks perpendicularly to the fibre orientation upon hydration/dehydration. If the fibres orientation in the two layers would be identical, the entire flat valve would shrink/expand uniaxially, perpendicular to the fibres’ orientation, remaining flat. However, the fibres orientation in the two layers are perpendicular to each other - in $\pm 45^\circ$ to the long axis of the pod. Apparently, this simple micro-architecture of the tissue, is sufficient to drive the valves' twisting in opposite handedness upon drying – a process that "shoots" the seeds to large distances. To understand the twisting mechanism, we note that upon drying, each layer “tries” to shrink uniaxially. Uniaxial shrinkage of one layer with respect to the other, induces curvature aligned with the shrinkage: If the top layer shrinks along one direction, the composed sheet would bend upward along this direction, similarly to a bi-metal ribbon. Therefore, shrinkage in two orthogonal directions in the top and bottom layers, induces a saddle curvature. However, since separately, both layers are flat, their in-plane geometry does not match the saddle geometry (imagine trying to attach a large flat sheet of paper to a saddle). This incompatibility is the cause of geometrical frustration: the valve can either fulfil its natural (or “reference”) curvature (saddle), OR its natural (reference) in-plane (flat) geometry. It cannot be completely relaxed, thus must contain internal stresses. One immediately sees that the same type of frustration can be generated in different ways, in sheets made of different materials: for example, by gluing together two flexible sheets while
they are stretched in orthogonal directions. Like the seed pod, both layers want to shrink uniaxially, in orthogonal directions, i.e., a tendency to form a saddle. This frustrated structure is described in more details in section 3.

Though the tendencies of each separate part of the material are simple and clear, the behaviour of the combined sheet is much more complicated and unpredictable. In order to understand the geometrical and mechanical behaviour of such a frustrated sheet, one has to develop a suitable theoretical modelling.

2.2. Theory of incompatible sheets

Recent developments in the theory of elasticity introduce and develop a new way of thinking, designing and manipulating solids. Within the framework of incompatible elasticity, effective theories of rods, plates, and shells were formulated (Efrati, et al., 2009; Aharoni, et al., 2012). In this framework the local intrinsic geometry of a body is expressed with the reference metric and reference curvature. These express the equilibrium distances between the elements that compose a solid body. The reference metric and curvature can result from growth, irreversible deformation, or from the geometry and connectivity of the elements that compose the body. The theory expresses the energetic cost associated with deviation from the reference metric (stretching energy) and from the reference curvature (bending energy) (Efrati et al., 2009).

The formalism opened the way to a set of quantitative experimental and theoretical studies of self-shaping sheets (Gemmer & Venkataramani, 2011; Klein, et al., 2007; Santangelo, 2009; Author, 2010). Several important notions were determined, based on the new formulation, providing useful guidelines for the design of desired shape transforming sheets, often saving the very complex process of solving the nonlinear elastic problem. The theory was successfully applied to many specific structures, including frustrated ribbons with saddle curvature, such as the seed pod described above. Experimental and theoretical study (Author, 2011) demonstrated the ability of the theory to predict a wide range of twisted and helical configurations obtained at different ribbon widths and orientations.

An important notion related to the formalism is "geometrical frustration" (which was mentioned in the previous section). This occurs when the reference metric and curvatures are incompatible – they cannot be both realized by a configuration of the surface in 3D. This is manifested by sharp mathematical constraints, given by the violation of Gauss-Minardi-Codazzi (GMC) equations. Under such conditions the body will always contain residual stresses. Within the new formalism, the origin of internal stresses is clearly “visible” and the conflicting geometries are clearly expressed.

Frustrated bodies have unique properties. Any cut or change in the shape of their boundaries results in a change in their 3D shape. This is due to the fact that any configuration is a compromise, set by the competition between the reference metric (stretching energy) and reference curvature (bending energy). Any change in the boundaries...
of the sheet changes the balance between the conflicting geometries, and a new equilibrium configuration is achieved. This responsiveness and shape variation of frustrated sheets is in a sharp contrast to ordinary stress-free sheets that stay as they are, when cut or curved. This property makes frustrated sheets much more interesting than ordinary ones. A non-trivial information is encoded within them, making them buckle and wrinkle into 3D shapes and to respond in a surprising way to cuts. To some extent such structures are unexpected, but with the theory of incompatible sheets, that holds the information about the reference geometry (in the form of the reference metric and curvature), we can "understand" the frustration of the materials and guess their response.

3. Making form by material frustration: case studies

In mirror of the new physical understanding of generation of complex curvatures in geometrically incompatible, or frustrated plates (Efrati, et al., 2009) and shells (Author, 2011), we developed two experimental design projects: ‘Frustrated Materials’ and ‘Frustrated Ceramics’. These two case studies served as demonstrators of the physical theory, as well as a starting point for future design development. The case studies described in this section operate in two very different material realms, demonstrating the application of similar sets of principles, which rely on the generalised theoretical basis of incompatible shells. From surface design in latex, a soft and flexible material, to morphology in ceramics, a malleable material but brittle once fired, the two case studies will demonstrate the agency of material frustration.

Figure 1. ‘Frustrated Material’, 31 latex tiles. Bet Binyamini, September 2018. (photo: Shay Ben Efrayim).
3.1. **Frustrated materials**

Frustrated Materials' is a composition of 31 latex tiles (36x36cm each), forming an ornamental wall-piece (Figure 1). Latex is an elastomer, used here in the form of thin (cast) sheets. It is a continuous, homogeneous and isotropic material, with a typically high stretching capacity. Here, this capacity was used to introduce directionality in the material, stretching the latex sheet to one direction only. By the bonding of two sheets, stretched in perpendicular directions, we introduced geometrical incompatibility in the system, as described in section 2. The two stretched and connected latex sheets make a bi-layered material that is frustrated, each layer tending to shrink in opposite directions. Attached to a frame and geometrically incompatible, the bi-latex surface is charged with energy. Once incisions are introduced on the surface, the stored energy is released through the spontaneous generation of three-dimensional shapes. The articulated and ornate surfaces of the ‘Frustrated Materials’ tiles were made by laser-cutting of different patterns, of stretched bi-layered latex material. To accentuate the bi-layer effect, we chose a top layer of uniform cream colour, and a bottom layer of varying colours (Figure 2).

![Figure 2. Surface design by material frustration. The bi-layer structure is accentuated by the choice of contrasting colours between the layers (photo: Shay Ben Efraim)](image)

The case study explored the design potential of controlled shape generation in the bi-layered latex surfaces, through the variation of a few elements. The effect of three main parameters can be demonstrated through the work:
Radius of curvature of the surface - Three elements are related (Efrati, et al., 2009): curvature (K) of the surface (expressed as 1/r), thickness (t) of the material, and the differential strain (ε) (unitless, $\frac{\Delta L}{L}$ as the percentage of stretch of the material), expressed as 

$$ K \cong \frac{\varepsilon}{t} \quad \text{or} \quad r \cong \frac{t}{\varepsilon} $$

This formulation indicates that the typical radius of curvature of the shapes that would form by the cutting of a frustrated surface, could be directly dictated by the thickness of the material used, and the amount of stretching applied (applicable as long as the material is considered ‘thin surface’ physically). Through a short series of samples, we identified a typical radius of curvature that would be expressive and enabling: significantly visible curvature, without reaching strongly curved forms. Based on a series of initial tests, we aimed for a typical curvature diameter of 8-10mm, being expressive, while not too curly. As we used a latex thickness of 0.4 mm, (the total thickness (t) being 0.8mm), we aimed for a differential stretching (ε) of around 15-20%, that would result in typical curved shapes of 8-10mm diameter, identified as our desired range (Figure 3). (A stronger stretch resulted in more curly or highly twisted shapes, a weaker stretch would result in less pronounced curvature, closer to flat surfaces).

Orientation over the surface - The scientific work of (Author, 2011) showed that the frustrated sheet tends to bend into a saddle-like configuration. The shape of strip cut strip out of this surface would vary according to its orientation over the surface (angle $\theta$ with one of the stretching directions), acting as a portion of a saddle-like curved surface, i.e. an identical cutting curve would generate different shapes, depending on its orientation over
the sheet ($\theta$) (Figure 4). Following that principle, the ‘Frustrate Material’ tiles were designed with mandala-like patterns, all with radial organisation. The radial array of an identical cutting curve, was used to express the variety of shapes that form out of the same cutting curve, placed in different orientation: from cylinder-like shapes in either direction of the stretching ($\theta=0/90$), to saddle-like or helical ones on the biais direction ($\theta=45$), with an identically repeating curve.

Geometry - (Armon, et al., 2011) have demonstrated both empirically and mathematically that strips cut on the biais orientation ($\theta=45$) demonstrate two different regimes: “narrow” strips that twist around a straight centreline, and “wide” strips that form helical configurations, as a cut out from a cylindrical envelope. The transition between narrow-strip and wide-strip behaviour was explored in the case study, through the variation of patterns in the tiles. Starting with a set of basic graphic elements that generated different shapes, we established a set of “building blocks”, or “letters”, with which an infinite variety of patterns could be composed.

*Figure 4 - Rotational patterns accentuating the effect of orientation on the surface over the resulting shape.*
The rotational “mandalas”, along with the biological references of frustrated formation of leaves and petals, have led us to the theme of flowers as the visual concept for the tiles. The patterns were conceived with regards to a flower type (Dahlia, Sunflower, Carnation, Thorn, Chrysanthemum etc.) (Figure 6) planning its three-dimensional outcome by using the “building blocks” that we have established in earlier stages (Figure 5). ‘Frustrated Materials’ can be considered as one whole piece and at the same time as a series of tiles; it is a showcase for the scientific work, while being the seed for creative design exploration.

Figure 5. Developing patterns (a) manual cutting, creating a catalogue of ‘building blocks” (B) polar array of curves, developing rotational mandala, pattern (c) surface.

Figure 6. Drafting biologically inspired ‘flower mandalas’ as inspiration for digital design
3.2. Frustrated ceramics

‘Frustrated Ceramics’ is a series of material explorations that takes the case study of ‘Frustrated Materials’ as its starting point. Here too, frustration is induced in a bi-layer material, enhancing its natural properties. In the basic ceramic manufacturing process, from the humid chunk of matter (the ‘ceramic body’) to the accomplished, dry and brittle final stage of the artefact, firing and drying play an essential role. Gradually, water and humidity are released out of the ceramic body in the drying phase, to be then heated in a kiln to bring the clay-body to its full maturity. As moisture evaporates, clay particles come closer and closer together, and thus shrinkage occurs. Shrinkage is substantial in the firing process as well, as glass begins forming within the clay particles (platelets), filling cavities and voids, and reducing volume. The amount of shrinkage is affected by several factors such as type of clay, size clay particle, weight, proportions, size of piece exposure to air, and more. Radical differences in shrinkage within a single piece would lead to the build-up of internal stresses, and are therefore carefully avoided by ceramists, as these might lead to cracking (Reijnders & Centre, 2005).

Wishing to induce frustration in the ceramic material, we utilised the shrinkage phenomenon, inherent to the ceramic process. We combined two material types with...
substantially different shrinkage rate, porcelain (Audrey 12.5% shrinkage) and stoneware (Terrazo Umbra, 7% shrinkage), bonded to act together as material of bi-layer architecture. The different shrinkage rates within the material introduce geometrical incompatibility (Figure 8) in the system, inducing residual stresses and resulting in large displacements. A flat bi-layered piece entering the kiln for drying and firing process, resulted in a three-dimensional ceramic form (Figure 8). While in the latex bilayer [see 3.1] the material was anisotropic, with directionality introduced by stretching, forming a surface of negative Gaussian curvature (anticlastic), the ceramic material is isotropic and incompatibility between the layers is uniform, forming a surface of positive Gaussian curvature (synclastic).

Aiming to achieve significant displacement to create morphology and maximum scale, series of samples were realised to identify the effect of different parameters over the resulting shape. Parameters related to the ceramic process, such as level of humidity of the ceramic body, positioning in the kiln and the drying-firing curve were examined for their effect over the resulting objects. Scientific principles were implemented through the exploration of geometric properties, such as thickness of the layers, width-length ratio of the element, curvature continuity of the two-dimensional contour and surface grooves, were varied to analyse their effect over the resulting form.

- **Minimal thickness** - similarly to the prior case study, here too the thickness directly affects the curvature obtained by the surface; the thicker the material, the shallower the curvature would be. However, compared to the latex, the wet clay is heavy and soft. This makes gravitation effects non-negligible. Gravity enters the scene, and should be taken into consideration, limiting the amount of curving of large samples. Therefore, we aimed at minimal thickness of the bilayer, within the possible range of the clay material (typically, 2-4 mm for each layer).

- **‘Narrow ratio’ - length to width** - In relation to the overall thickness and gravity, another geometrical consideration would be the ratio between the circumference and the surface area, i.e. the width to length ratio of the piece. The narrower the
piece, the smaller the frustration is; the conflict between lateral flatness and curvature is minimised. A more significant curvature in the long direction can take place, which is only weakly “resisted” by the tendency to flatness of the in-plane geometry (the reference metric) (Figure 10). We therefore prioritized narrow and long geometries, to achieve significant morphologies.

Figure 9. From flat sheets to shaped ceramic, illustrating geometrical incompatibilities: the matching curves in the flat sheet transform to non-matching edges once frustration is in play.

- **Oscillating curvature** - A large number of shapes can correspond to the definition of long and narrow. We have noticed that the geometry of the contour of the shape affects the obtained curvature of the surface, and a clear preference was noted to outline curves that had oscillating curvature, forming a kind of S shape (Figure 11). While this behaviour was clearly observed in samples, its origin is still unclear from the theoretical point of view and is the subject of new mathematical and physical research at the lab these days.
Figure 10. Prioritising long and narrow shapes where lateral frustration is reduced, and significant curvature can take place in the long direction.

- **Introducing grooves** – Due to the isotropy of the ceramic material, the incompatibility within the ceramic surface is homogenous, hence restricting curving as mentioned above. In order to accentuate curving, we introduced directionality in the material through grooves in its stoneware layer, as this layer restricts the movement of the material (as a result of lower shrinkage rate) (Figure 11). Whether inspired by the mechanical reference of a hinge, or biological reference of fibres in the seed pod (see 2.1), the grooves enable movement on the perpendicular direction to the groove, and thus accentuate the curving on this direction.
4. Discussion

This paper presents the implementation of frustrated materials as an alternative approach to design and fabrication, through two case studies, in ceramics and soft materials. Although the principle of materials frustration is common in biological systems, known and understood by scientists, it has not yet been introduced to designers as a possible means of creation. By working from the materials’ properties, this proposed approach could come as an alternative to the efforts invested in shape generation, creating form becomes simple through a reverse engineering process, once leaning on scientific knowledge. This approach brings new players into the design process: the material becomes active and sometimes surprising and the designer, who works closely with the scientist, no longer forms it alone. Therefore, there is a need for mapping and reorganisation of the design process, which may lead to an alternative methodology and even a new role for designers.

Making by material frustration, suggests a new form of manufacturing. Rather than technological advances it enhances material inherent capacities. Free from moulds, manual labour or new technologies, it suggests an alternative forming process, offering freedom of shape and opening new morphological horizons as well as a detour to serial production. In ceramics, as explored in the second case study, material frustration suggests an alternative to traditional form-making of vessels and may lead to more sustainable possibilities of manufacturing by reducing excessive labour, large quantities and stock.
By reflecting on these two different projects, materials frustration for design may be analysed further in order to outline an alternative design methodology. Frustration may also offer new capabilities for traditional materials. In latex, for example, by generating frustration, structure was introduced to a flat, isotropic, structureless material, thus enabling the material autonomy. Further investigation in the potential of frustrated materials in design could open more possibilities for innovation in materials yet to be explored, such as glass, wood, metals and more.

For designers, utilising frustration in materials requires a shift of control: taking a step back from the drawing board or computer screen and enabling the material properties to lead the way. Following hands-on materials experimentation and research, the design potential of the materials’ behaviour may be analysed and later translated for further development - as a bottom-up strategy for design. This strategy not only affects manufacturing methods but may also hold potential for creating original shapes and forms, difficult to foresee or plan in standard approaches. Here, the material is no longer a passive matter which reflects exactly the designer’s ambitions. Therefore, this proposed method impacts the role of the designer who should embrace a flexible mindset and reflexive attitude while gaining knowledge of the frustrated material’s behaviour, which is sometimes surprising, unexpected and even difficult to understand. A third party, the physicist, can be joined as someone who understands the materials’ frustration (knows the principles of the theory of incompatible elastic sheets) and can help the designer with his/her interaction with the material. Once understanding the qualities of the material, the designer may strategically intervene in the process in order to exploit the frustration for the desired results. In the process described in these two case studies, the designer may be seen as an agent, connecting between different partners: expert, materials and tools, to explore innovative ways of making.

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Material culture(s). Research paths in an evolving material design culture, and the connected future designer’s attitudes

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Abstract | This contribution will investigate how material design culture is evolving: in fact, as designers, we can choose materials taking into account their variety during the design process, as well as design them. The article, through the analysis of a first exploration of just some of the most active and innovative academic case-study laboratories, in which tests and experiments on innovative materials for design are performed, will highlight the most recent research directions covered by designers in the new materials world: growing and living materials, DIY materials, active materials, materials in the circular economy, manufacturing processes applied to innovative fields and innovative ancient materials, rediscovered from the past and re-launched in the next future will be discussed. Those trends will be investigated to outline the directions of designer’s and research group’s activities and their new attitudes on the topic.

DESIGN BOUNDARIES; MATERIALS EXPERIENCE; MANUFACTURING PROCESSES; MATERIAL DRIVEN DESIGN; MATERIAL ACTIVISM
1. Expanding the horizon of the materials for design

Materials, as underlined by many authors (Ashby, Johnson 2009; Karana, Pedgley, Rognoli 2014; Karana et al. 2015; Miodownik 2014), are the essence of what matters just as the choices made by the designer when contriving conscious products. Expanding the horizon of research and experimentation activities that designers constantly perform, some emerging phenomena can be highlighted within the wide world of materials for contemporary design dictated by the hybridization between different disciplines, from the birth of a "scenario founded on the collaboration between design and science" (Ito 2016; Langella 2019) and also from the changes that the production processes have undergone, thanks to the evolution of some specific technologies: the researches on materials for design are as wide as ever and offer a broad spectrum of opportunities for achieving new material experiences in design (Karana et al. 2019). This contribution will investigate how material design culture is evolving: in fact, as designers, we can choose and feel materials taking into account their variety during the design process, as well as design themselves.

In recent years, the value of craftsmanship has grown significantly: this revaluation and re-flourishing of craftsmanship (Bardzell et al. 2012), or of those who have a deep connection with the material world and can "dominate a dialogue between knowledge abstract and practical", is parallel to the spread of the maker (and Fab Labs) phenomenon who, according to Richard Sennet (2013) responds to the need (of many designers) to regain possession of the surrounding world through an active experience, a material comparison with it (Miceli 2012).

Hard experimentations, biological methods and systems found in nature are applied to the study and design of engineering systems and modern technology: these are examples of how designers and other experts in different disciplines can collaborate to transform the matter and modify it at will: Synthetic Biology and Living Technologies are some of the disciplines in which man tries to produce “natural” materials and to face some of the key sustainable challenges of the 21st century.

On the other hand, the experiments in the families of DIY (Do It Yourself), cooked materials and open materials are characterized by subtle and labile boundaries: according to the principles of molecular gastronomy and alchemy (but also of botany and biology), today’s designers are able to produce new materials for the project through new or renewed processes starting from industrial production waste, materials from plant sources (plants and fungi), animal sources and bacteria, traditional materials, such as wood or stone, and many others.

3D printing latest interesting frontiers go beyond the traditional 3D printing process: experiments have been carried out with food, ceramic and stone materials, but also for architectural fabrication. Sugar, waste polymers, flexible elastomers, organic mixtures, stone or glass can all be 3D-printed, thanks to a consolidated and renewed technology, by the use of new materials for the production process. And thanks to this technology and other
production and design processes, defined and cared for by interventions and design, they give a new shape to traditional materials and ancient arts.

Materials from the past, from local and ancient traditions are becoming more and more new future materials: an archaic material library that is still not set, should instead be conceived in the next future in Politecnico di Torino, investigating the ancient natural resources, artefacts and everyday practices of a specific area. Materials and cultural heritage, the core essence of typical territories that are disappearing or that have been forgotten by time, could be oriented to innovative and speculative further design developments.

2. Today's places of experimentation: the laboratories

In a new, more blurred vision of disciplinary boundaries, known as “The Age of Entanglement” (Oxman, 2016), the point of view changes: the focus of the materials designers – including that of manufacturers – is no longer primarily oriented towards the final application, but is increasingly curiosity-driven, i.e. guided by the pure and simple curiosity of researching, experimenting and observing the material.

The gym in which designers increasingly test the crossroads of knowledge in the matter of materials for design is represented by experiences gained during graduation theses and PhDs or – in the case of in-house designers – during their continuing education outside the company, working in interdisciplinary laboratories within universities or experimenting during workshops and summer/winter schools in close contact with artists, scientists and professionals in various fields. The research tools change too: books and scientific journals are abandoned and ecomuseums, pots and pans and microscopes are rediscovered, along with waste deposits and blogs. The following overview represents a first exploration of just some of the most active and innovative academic case-study laboratories, in which tests and experiments on innovative materials for design are performed. A selection of the most up-to-date laboratories is presented with a brief description that leaves room for the original presentation words of the team, accompanying it with the university or research body that hosts it, the country of origin, the name of the laboratory coordinator and the website, for further investigations, and a short overview on the originality of each approach.

2.1 Hybrid Design Lab

Università degli Studi della Campania “Luigi Vanvitelli”, Naples (Italy) [Prof. Carla Langella]

“Hybrid Design Lab is a research, design, and teaching laboratory geared towards testing the relationship between design and science. The lab is oriented to experience the opportunity to integrate advanced research, teaching and production through science-inspired design. One of the main objectives is to transfer the theoretical and experimental research in the areas of biological sciences, new materials and new technologies, to the design dimension of the sustainable
innovation of products and services. The ability to spread through common products, and preferably daily, new knowledge and sensitivity on the environment, human health and on social equity, offers new prospects for real and tangible improvement of quality of life and growth of awareness, precisely because based on large numbers and, therefore, a large impact. The HDL is based on the integrated processes that underlie the life of biological systems and the balance of their ecosystems. Birth, life, death and re-integration in the natural cycles become references to proposal design production, process and strategies for the recovery of resources, innovative, yet environmentally and socially sustainable.”

(http://www.hybriddesignlab.org/, accessed on February 13th 2020)

In Hybrid Design Lab, the original approach arises from the new and unprecedented prospects of intersection between scientific knowledge and design culture.

2.2 MakeGrowLab

Puławy (Poland) [Dr. Roza Janusz and Dr. Josh Brito]

“The project began with one question: What if we could grow materials instead of making them and at the end of their cycle, use it as fertilizer which would then be used to continue the cycle of a biological production system? The MakeGrowLab now consults, designs and produces bio-materials for mission-driven companies. The goal is to mimic the symbiotic processes of nature, to not pollute the environment but enrich it instead. They aim for The Biorevolution Movement - to fuse science with design, to create a fully circular production of local, sustainable materials and spread it around the world. The inspiration derives from the symbiotic processes of nature, specifically the life-cycle of plants, where there is no waste and everything is recycled. Since 2019 the team is growing with Future Farmers from different backgrounds but with the same goal: to spread The Biorevolution.”

(https://www.makegrowlab.com/, accessed on February 13th 2020)

The MakeGrowLab key-element of innovation is thinking the material as a living element, able to born, grow, live and die, exactly like any other living beings.

2.3 Design and Living Systems Lab

Central Saint Martins, University of the Arts London, London (United Kingdom) [Prof. Carole Collet]

“The Design and Living Systems Lab is a pioneering research laboratory that explores the interface of biological sciences and design to challenge established paradigms and envision new sustainable materials and forms of production for the future. The Lab explores a new hierarchy of relationships with the ‘living’ where designers operate within a sliding scale of a ‘natural nature’ and a new ‘programmable nature’ in the quest for innovative ecological design and fabrication models. The main objective is to explore biological sciences through design to grow new design
propositions that could facilitate the transition to the ‘one planet living’ horizon 2050. Not only we are beginning to explore the advantage of biological systems in terms of zero waste, minimum use of energy and materials, but with synthetic biology, scientists have developed means to bio fabricate like ‘Nature’ does. We can program and engineer living organisms to grow tailored materials. Such extraordinary tools can trigger a paradigm shift in terms of design and manufacture for the future.”

(http://www.designandlivingsystems.com, accessed on February 13th 2020)

In the Design and Living Systems Lab design is seen as a proposer of innovative fabrication models, able to set potential speculative scenarios.

2.4 Mediated Matter

MIT Media Lab, Boston (U.S.A.) [Prof. Neri Oxman]

“The Mediated Matter group focuses on Nature-inspired Design and Design-inspired Nature. It conducts research at the intersection of computational design, digital fabrication, materials science and synthetic biology and apply that knowledge to design across scales from the micro scale to the building scale. They create biologically inspired and engineered design fabrication tools and technologies and structures aiming to enhance the relation between natural and man-made environments. The research area, entitled Material Ecology, integrates computational form-finding strategies with biologically inspired fabrication. This design approach enables the mediation between objects and environment; between humans and objects; and between humans and environment. The goal is to enhance the relation between natural and man-made environments by achieving high degrees of design customization and versatility, environmental performance integration and material efficiency. The group seeks to establish new forms of design and novel processes of material practice at the intersection of computer science, material engineering, design and ecology, with broad applications across multiple scales.”

(https://mediatedmattergroup.com/, accessed on February 13th 2020)

In the Mediated Matter group, a step back to natural processes intertwined with current production processes informs the new Material Ecology culture.

2.5 [MI] - Material Incubator

Centre of Applied Research for Art, Design and Technology (CARADT), ‘s-Hertogenbosch (The Netherlands) [Prof. Elvin Karana]

“Material Incubator is a creative research lab that explores the potentials of materials from living organisms for an alternative notion of the everyday.

Bringing together researchers and practitioners from different schools, Material Incubator [MI] encourages tangible interactions with the living organisms, such as
algae, fungi, plants and bacteria, to explore and understand their unique qualities and constraints through diverse technical and creative methods taking artists, designers and scientists as equal and active partners in the material creation. The core research team of the MI includes artists and product designers specialised in bio-design, (digital) storytellers and micro-biologists.

In exploring and designing for an alternative notion of the everyday from materials from living organisms, the [MI] researchers ground on the theory of Materials Experience, which suggests that whilst our experience with an artefact may originate from - or be moderated by - a wide variety of sources, one of the prominent sources is its physical reality, i.e., its material(s).“

Material Incubator [MI] sets its original approach on a co-creation process between different expertise, within whom the design is a participant of the co-creation, and the new matter is the possible output.

2.6 Self-Assembly Lab

MIT’s International Design Center, Boston (U.S.A.) [Prof. Skylar Tibbits]

“The Self-Assembly Lab is a research lab at MIT inventing self-assembly and programmable material technologies. Self-Assembly is a process by which disordered parts build an ordered structure through only local interaction. In self-assembling systems, individual parts move towards a final state, whereas in self-organizing systems, components move between multiple states, oscillate and may never come to rest in a final configuration. The Self-Assembly Lab is located in MIT’s International Design Center, a cross-disciplinary design research centre. The Singapore University of Technology and Design was established in collaboration with MIT to advance knowledge and nurture technically grounded leaders and innovators to serve societal needs. This will be accomplished, with a focus on Design, through an integrated multi-disciplinary curriculum and multi-disciplinary research.”

In the Self-Assembly Lab the design process is informed by mathematics, physics, robotics and digital technologies, following a “techno-creative” approach.

2.7 Material Experience Lab

Technische Universiteit Delft (TU Delft), Delft (The Netherlands) and Politecnico di Milano, Milan (Italy) [Prof. Elvin Karana and Prof. Valentina Rognoli]

“Materials Experience Lab is a cross country research group bringing together researchers/practitioners who introduces unique ways of understanding and designing (with) materials to radically change and enhance the relationship people have with materials and artefacts. The lab introduces unique ways of understanding and designing (with) materials by combining research methods, techniques, and
tools from product design, social sciences, materials science, and engineering. The term ‘materials experience’ describes the holistic view of materials in design, emphasising the role of materials as simultaneously technical and experiential. In most of the research activities, the Materials Experience Lab combines interpretive and empirical research techniques in a unique iterative manner, actively promoting a Do-It-Yourself (DIY) approach to materials that pushes the boundaries of material (driven) design. The DIY approach to materials brings people and materials closer in the making, promoting further consideration of contexts and time in designing, making, and use, greater awareness of the resources required, greater agency for working with materials, all of which leads to novel design outcomes.”

(http://materialsexperiencelab.com, accessed on February 13th 2020)

In the Materials Experience Lab, the direct experience of the matter is the key point of the new materials development, with a “creating-by-doing” approach.

2.8 Institute of Making

University College London (UCL), London (United Kingdom) [Prof. Zoe Laughlin and Prof. Mark Miodownik]

“The Institute of Making is a multidisciplinary research club for those interested in the made world. The mission is to provide all makers with a creative home in which to innovate, contemplate and understand all aspects of materials and an inspiring place to explore their relationship to making. At the heart of the Institute of Making is the Materials Library – a growing repository of some of the most extraordinary materials on earth, gathered together for their ability to fire the imagination and advance conceptualisation. A place in which makers from all disciplines at UCL can see, touch, research and discuss, so that they can apply this knowledge and experience to their own practice. Alongside the collection is the Makespace – a workshop where members and guests can make, break, design and combine both advanced and traditional tools, techniques and materials. The facility brings together equipment, expertise and perspectives of making from a wide range of disciplines, encouraging users to engage in the craft, design, technology, history, philosophy, art and engineering of making.”

(https://www.instituteofmaking.org.uk/, accessed on February 13th 2020)

The original approach at the Institute of Making lies on a makers community, in which the exchange of knowledge between peers is fundamental for generating new know-hows.

2.9 Material Design Lab

KEA - Copenhagen School of Design and Technology, Copenhagen (Denmark)

“Material Design Lab consists of The Box, The Lab and The Library. The Box is a walk-in expandable box that contains an exhibition of raw materials. It is the starting point to a basic understanding of the ‘raw ingredients’ before they are processed and
mixed. The Lab itself is the heart of Material Design Lab and resembles a hybrid between a design prototyping workshop, a scientific laboratory and an industrial kitchen. It is a space designed for materials to be tested, manipulated, refined and potentially, for new ones to be created. The library is the Material ConneXion Copenhagen collection containing 1500 material samples, as well as access to the online database providing detailed information on over 7500 materials. The library also holds a wide range of books on materials relating to design and architecture.”

(http://materialdesignlab.dk/, accessed on February 13th 2020)

*Understanding and knowing the raw materials* that are at the basis of the materials that we experience every day is the original approach at the Material Design Lab.

### 2.10 LAMA - Ancient Materials Analysis Laboratory

IUAV University, Venice (Italy) [Prof. Fabrizio Antonelli]

“The Ancient Materials Analysis Laboratory was created in 1993, with the aim of carrying out didactic, research and service activities for third parties in the field of stone and lithic materials used in ancient times. The extraordinary technological development of the last few years has made science previously unthinkable progress, and therefore also the acquisition of a large mass of data on the historical-artistic materials of cultural heritage in general, data that are of significant interest for the characterization, dating and conservation of the cultural heritage itself. The institutionalization of the above teachings, as well as archeometry, geoarchaeology, and various other disciplines such as chemistry or physics applied to conservation science, as well as the creation of associations and specialized journals, among other things with specific tasks promotional, has finally positively changed the national panorama in this sector of applied sciences.”

(http://www.iuav.it/SISTEMA-DE/Laboratori3/, accessed on February 13th 2020)

A reference to the *materials of the past to understand the materials of today* is the key point to the approach of the Ancient Materials Analysis Laboratory.

### 2.11 Wearable Technology Lab

University of Minnesota, St. Paul, MN (USA) [Prof. Lucy Dunne]

“The Wearable Technology Lab (WTL) is an interdisciplinary research laboratory founded in 2009. WTL research focuses on the intersection between apparel and new technology: for instance, in expanding garment functionality through dynamic geometry and new sensing functions; in improving the way we use, manage, and consume clothing; and in streamlining the design and manufacturing processes of smart clothing and e-textile products. New technology opens new frontiers in understanding the human body, mind, and capability through pervasive sensing, actuation, and interaction. Many projects deal with translating technological potential into the real, everyday world: understanding human physical and
emotional comfort and balancing these variables with trade-offs of performance variables in a smart system design.”

(https://wtl.design.umn.edu/, accessed on February 14th 2020)

The intersection between new materials, new technologies and the world of wearables is the meeting point of the Wearable Technology Lab, where new intelligent and active “skins” are conceived.

2.12 Smart Textile Design Lab

Swedish School of Textiles, University of Borås, Borås (Sweden)

“At the Swedish School of Textiles creativity and theory are combined with practical work in several machine parks and laboratories. The unique with the educational programmes is that students and researchers have the opportunity to work with the entire process, from hand knitting machines to advanced 3D techniques, from hand weaving to effective weaving machines. Students and researchers also have the opportunity to elaborate with colours and different types of coatings in the colour lab, to use pattern construction the traditional way or use the latest computer programmes. The well-equipped sewing room gives almost unlimited possibilities. The Smart Textile Design Lab turns textile traditions and materiality upside down; the researchers develop, explore, and experiment with new expressions for textiles through the use of various technologies and textile techniques.”

(https://stdl.se, accessed on February 14th 2020)

The process, from dyeing to knitting to sewing, is the main core of the Smart Textile Design Lab, where innovation is the reinterpretation of traditional and well-established techniques and processes.

As already introduced, this overview doesn’t want to be exhaustive, it rather outlines how the matter of material design is evolving in new material design cultures, thanks to the collaboration with different disciplines and know-hows, and new approaches, producing heterogeneous materials belonging to some possible clustered trends.

3. The consequent new material design cultures

The article, through the analysis of substantial case studies of the most recent and academic laboratories, in which innovative materials for design are tested and developed, highlights the most recent occurrences and research directions covered by designers in the new materials world: materials in the circular economy (i.e. from circular materials to urban mining); growing and living materials; DIY (i.e. Do-It-Yourself) materials and material tinkering approach; manufacturing processes such as 3D printing applied to innovative fields
(e.g. food, stone, architecture, etc.); innovative ancient materials, rediscovered from the past and re-launched in the next future.

It should be pointed out how designers feel the need to "compose, modify, transform, and self-produce their own materials" (Rognoli, Ayala 2018), by using ancient materials and new technologies, by modifying traditional materials, waste materials, bacteria, vegetables (see Figure 1) (Karana et al. 2019; Ayala-Garcia, Rognoli, Karana 2017).

For example, Blood Related (Figure 2) is a material that uses waste materials, a zero kilometre, for the production of new raw materials. Awarded at the Dutch Design Week in 2018, it is a compound material, printable like plastic, selected by dried and pressed cow blood: waste from the meat and livestock industry, they become raw materials and we are asked about the limits of what can be transformed and be matter. Moreover, as underlined in the introduction, designers, alchemists and cooks experiment the production of self-produced materials from vegetable sources: the principles of molecular gastronomy and methods, the techniques of self-production, individual or collective, are the tools for the creation of new democratic materials, accessible and with a low technological impact (Rognoli, Ayala 2018; Rognoli et al. 2015; Rognoli, Ayala, Parisi 2016a; 2016b; Parisi, Rognoli, Sonneveld 2017). On the other hand, the materials grow and transform themselves within laboratories (Figure 3): “we can grow all kinds of structures using living organisms, from foams that can replace plastics in footwear, to leather-like materials without animals. Furniture, flooring all are currently being prototyped. Fungi are able to grow materials that are naturally fire retardant, without any chemicals” (Lee 2019).
While many of these activities are currently conducted on an experimental and extemporary basis, this does not mean that the approaches to research are not based on a solid scientific framework. Exploring the way that other professionals work and trying to "tune in" with their skills, sometimes borrowing their methods, helps not only material designers but also manufacturers to break free from prefabricated schemes, pursuing new currents and new avenues of research. The new figure of the materials designer is therefore more and more
outlined by ephemeral and blurred “boundaries”, coherently with the contemporary Design condition: in those laboratories, the designer turns himself into new professionals characterised by a hybrid knowledge, driven form different know-hows. We can therefore discover a “designer-maker”, a “designer-archaeologist”, a “designer-biologist”, a “designer-detective” and a “designer-alchemist”, following the latest materials culture trends (De Giorgi, Lerma, Dal Palù 2020). These and other emerging issues coming from the materials design culture are currently investigated by the authors of the present contribution.

References


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**Acknowledgements:** Special thanks go to those who have made an extensive contribution to the development of MATto, the Material library of Politecnico di Torino, and the advisory services provided to local businesses, as well as to all the companies and participants who have used the services and provided inspiration to further the research.
Mind-mapping in design culture: A tool for ideation in graphic design education?

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Abstract | This study focuses on mind-maps as an aspect of design culture – the conventions and practices adopted by a community of designers. The research aims to work towards establishing the effectiveness of mind-maps as a tool for ideation. It questions the extent to which mind-maps enable students to break away from the cultural frames evoked by design briefs in order for creative cross-space associations to occur. By comparing mind-map-like diagrams produced by nine undergraduate students with codes emerging from the analysis of the corresponding briefs, the study seeks to answer the question: What levels of cross-space mapping are evident in the knowledge representation diagrams produced as part of an undergraduate graphic design, practice-based project? The study found 301 cases of internal linking, as opposed to 23 instances of cross-space mapping, however it concludes that there is value in knowledge representation diagrams for ideation and makes recommendations for their use.

KEYWORDS | MIND MAPS, CREATIVITY, KNOWLEDGE REPRESENTATION, FRAME THEORY, CONCEPTUAL BLENDING

As lecturers, both researchers worked on the BA(Hons) Graphic Design course at the Arts University Bournemouth. The project grew out of a conversation in which we both expressed a scepticism with regard to the value of mind-mapping as a method for ideation. Despite our scepticism, it was noticeable that mind-mapping was a feature of many students' work. We questioned whether this practice had become part of a “project culture” or “la cultura di progetto” (Julier, 2004, p.6) instilled through prior educational experience. Conversely, there are claims for the facility of Mind Maps™ and concept maps in the literature. Novak and Gowin (1984, p.17) state that, “concept mapping may be a creative activity and may help to foster creativity”. Whereas Buzan and Buzan (2010, p.93) include being “able to create new associations from existing ideas” as a key feature of Mind Maps™.

The students’ use of mind-mapping, together with such claims above, raised questions: were we undervaluing the usefulness of mind-mapping? What value did students attribute to this method? Or more simply, “What’s happening here?” (Glaser, 1978).

Our conversations occurred during the assessment of fifteen submissions that were later entered for the International Society of Typographic Designers Student Assessment Scheme. These provided the sample for the research, the ISTD briefs were also included as data. Prior (cited in Charmaz (2014, p.45), notes how researchers can address what documents do as well as what they contain. These mind-maps, as part of the unit submission, and in relation to the ISTD scheme, are assessed. We should therefore acknowledge that what the mind-maps might do is present a systematic and smooth process of development in order to acquire marks. Another possibility is that they do little but are used unthinkingly; replicating previously instilled behaviour (Martin, 2006, p.262). In contrast however, there are numerous possible explanations for what mind-maps might legitimately do within a design task, including:

1. To develop lines of enquiry.
2. To scope a field of study.
3. To capture what the student already knows about the topic.
4. To break down and categorize complex words and phrases.
5. To make creative leaps.

Although students referred to their knowledge representations as “mind-maps”, they are not Mind Maps™ as described by Buzan (2010). The students’ diagrams did not follow the procedures advocated by Buzan (2010) in relation to Mind Maps™, or by Novak and Cañas (2006) in relation to concept maps. This project therefore analyses practices of knowledge representation as presented by undergraduate students rather than ideal examples from the literature.

The research was initially motivated by a wish to understand the reason why students engage with mind-mapping. A Grounded Theory, data first approach therefore seemed appropriate where concepts could emerge from the data itself. The question slowly turned...
however, through the open coding stage, to questions about what kinds of knowledge were being used and the nature of the links made. Did these links resemble creative leaps or a more mundane filling in of the territory defined by the project brief?

2. Open coding stage

The open coding strategy follows Corbin and Strauss (2008, p.160) who describe a three-stage process, involving breaking “data into manageable pieces”; “interpreting those data”; and giving the pieces of data names that stand for the ideas they contain.

Coding schemes in the literature, are frequently based on interview transcripts (Charmaz 2014). These are essentially monomodal; using character strings to capture vocalisations stripped of intonation, physical gestures, and expressions. In contrast, the mind-maps which in part comprise the data for this project, are multimodal: involving multiple kinds of communicative resources. In the open coding phase, three different issues arose out of the dissimilarity between the coding of interview transcripts and mind-maps.

2.1 Units of analysis

The first difference involves the breaking down of data into units of analysis. In relation to interview transcripts, Charmaz (2014, p.127) lists the following: “Word-by-word, line-by-line, segment-by-segment, and incident-with-incident”. This repertoire of units is not sufficient to engage with mind-maps as data. Meanings attributed to mind-maps are also mediated by such things as placement, and scale, and depend on more dynamic spatial relationships with other network elements. Figure 1a is a schematic version of the first mind-map analysed, this is abstracted further in Figure 1b. A range of different supplementary structures are defined below:

- There are individual elements.
- Elements are connected by paths.
- Two elements connected by a path make a binary construction.
- Branches are built out of one or more binary constructions.
- There is an element in the centre of the mind-map from which branches radiate, this is the central node.
- Paths can have a direction, for example moving from the centre to the periphery of the mind-map (indicated by arrows in the data).
- Binary constructions have an inner element closer to the centre of the mind-map and an outer element further from it.
- All of the elements at the same remove from the central node are referred to as being on the same orbital.
- All of the elements connected to one radial element are referred to as a radial sub-network.
- Elements not connected by a path to any other element are referred to as radical elements.
- Links are paths that link an element in one branch to an element in a different branch.

**Figure 1.**
In the open coding stage, it became apparent that patterns in the data are manifest in these additional units of analysis: different categories are often represented as branches for example. A focus emerged based on the links between elements. The binary construction provided the basic unit of analysis in the subsequent coding.

2.2 Reading paths
The second dissimilarity between data types arises from interview transcripts unfolding chronologically. This translates spatially into written text where each line reads from left to right, and each column from top to bottom. This same logic however does not apply to mind-maps which have any number of branches that can be read in any order.

2.3 Topics addressed by data
The topics explored in interviews are in many cases the focus of the researcher too. However, the topics explored by students in these mind-maps are not the primary focus, but rather, the relationships established by linking topics – whether the relationships are categorical or cause/effect for instance. It is at this more generalised level of analysis that we can begin to form inferences about the originality of the connections made between topics.

2.4 Coding Procedure
The coding procedure entailed starting at the central node and then moving out along one branch toward the periphery, this was then repeated for each branch. Branches included different kinds of links: chronological, categorical, etc. But these different connections frequently linked concepts directly related to the brief. This quality of the mind-maps – to remain categorically related to the central node – was emphasised when links were made to elements not circumscribed by the brief, and these appeared to be far fewer in number. This observation in the first round of coding led to the study focus, and two core concepts: internal linking and cross-space mapping.

3. Core categories: internal linking and cross-space mapping
As the first round of coding progressed it was noticeable that there were different levels of creativity in terms of the links made. One aspect of this concerned categorisation; if the outer-element was a sub-category of the inner-element this suggested a logical, straightforward association. If on the other hand, the outer-element belonged to a different category far removed from the inner-element, then this suggested a more creative association. The researchers were familiar with: conceptual blending theory (Fauconnier 1994; Fauconnier and Turner 2002), and frame semantics (Fillmore 2006), and recognised that these theories could provide useful conceptual tools for analysing the links between elements in mind-maps. Two concepts in particular were utilised: mental spaces and frames.
Mental spaces are constructed in the moment, as we think, for purposes of understanding. They are, “interconnected in working memory, can be modified dynamically as thought and discourse unfold” (Fauconnier and Turner, 2002, p.102). Many spaces can be active simultaneously enabling us to capture useful information from long-term memory and link them together in various ways.

The idea of a frame in Fillmore’s theory is that words attain their meaning through the relationship they have to a structured conceptual setting. The often-cited example is the commercial event frame (Fillmore, 2006, p.378). Here a word such as “sell” is understood because of its relationship to other words such as “buy” and “seller” in the same conceptual setting.

Mental spaces can recruit elements from different frames, and whole spaces can be organised by a frame: whereby every element in the space is organised with reference to one conceptual setting.

The assumption in this article is that, within design culture, there is a familiar frame for a “brief” Although each brief is unique, there are recurring features in the way briefs are written. Analysis of the ISTD brief data yielded such recurring features (Figure 2a). Decisions about framing were not based on linguistic analysis, but on introspective reflection.

Each of these features – using the terminology of cognitive linguistics (Coulson 2001, p.19) – are slots that can be filled differently according to the brief concerned. Encountering a brief will prompt the construction of a mental space in which these slots are filled by elements. Though different elements can come from different conceptual frames they are still organised by the brief frame. We therefore think about them in terms of how they participate within the context of a brief.

An illustration is probably useful at this point. One generic feature of the brief frame listed in Figure 2a is meanings to communicate and such meanings can be tightly or loosely defined. The Anniversaries brief requires the communication of meanings about anniversaries and “Anniversaries” is therefore a filler for the slot meanings to communicate. Different students took this “anniversaries” filler and interpreted it at a more specific level. One, for example, focused on alcoholic spirits which introduces another frame (but this time not an organising frame): making alcoholic spirits. In this case, the alcoholic spirit is a cognac ready to drink on its 100th anniversary. This processing involves the construction of a mental space organised by the brief frame. The brief frame recruits those elements from the making alcoholic spirits frame that are relevant to the Anniversaries filler.

As the illustration below demonstrates there were different levels of generalisation amongst the codes emerging from the brief data. The mind-map data codes also showed different levels of generalisation, corresponding to those of the brief data (Figure 2b).
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Figure 2a. Recurring codes from the brief data. All of these are potential fillers for the slot at level 3 of figure 2b.

<table>
<thead>
<tr>
<th>Elements of brief frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>the product to be designed,</td>
</tr>
<tr>
<td>the audience or user,</td>
</tr>
<tr>
<td>the design problem,</td>
</tr>
<tr>
<td>the social and cultural context,</td>
</tr>
<tr>
<td>desired outcomes (deliverables),</td>
</tr>
<tr>
<td>technical and/or commercial constraints,</td>
</tr>
<tr>
<td>meanings to communicate (propositions),</td>
</tr>
<tr>
<td>tone of voice</td>
</tr>
</tbody>
</table>

Figure 2b. Hierarchy of different levels of frame components.

<table>
<thead>
<tr>
<th>Level</th>
<th>Frame component</th>
<th>Potential instantiations of frame component</th>
<th>Level of generalisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frame:</td>
<td>Brief</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Sub-frame of brief frame:</td>
<td>ISTD Anniversaries Brief</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Element of brief frame (slot):</td>
<td>For example, meanings to communicate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- part of frame</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Type of meaning to communicate (filler):</td>
<td>For example, anniversary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- part of sub-frame</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 and below</td>
<td>Specific meaning to communicate:</td>
<td>For example, 100 year old cognac</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- student’s response to Anniversaries Brief</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2c. Different types of meaning to communicate as indicated by the ISTD briefs. All of these are potential fillers for the slot at level 4 of figure 2b.

Figure 2.

All of the codes in Figure 2a are potential fillers for the level 3 slot “Elements of the brief frame” in Figure 2b. The codes from the brief data related to level 4 of Figure 2b (the type of meaning to communicate) are listed in Figure 2c.

This conceptual framework of mental spaces, and frames, is used to distinguish between links that stay within the territory delineated by the brief, and those that connect to other outside elements. It is questionable as to whether it is desirable to be completely confined to the space delineated by a brief. While the brief’s aims, and specifications cannot be ignored, designers often use other means such as metaphorical expressions to communicate which can involve two organising frames. Within mind-mapping this can be indicated by including two central nodes in the mind-map and by making links between these two networks.

The idea of relating concepts from two separate and distinct domains unites the concept of cross-space mapping – that emerged in this study – with: transfer recall (Guilford, 1967, p.214), bisociation (Koestler, 1964, p.35) and cross-domain transfer (Pereira, 2007, p.3), described in theories of creativity. These are all forms of what Guilford (1967) termed divergent production. Furthermore, according to Pereira (2007, p.29) convergent production is also linked to creativity, if this is understood as the “creation of a novel and useful product” (emphasis in the original). Here, divergent processes provide novelty while convergent processes provide usefulness.

We should not be too dismissive of working entirely with the conceptual elements circumscribed by the brief. As we have said this mental space will contain elements from different conceptual domains and it is possible to make metaphorical or counterfactual links between these also. In mind-maps this can be represented by making links between the different branches of the mind-map.

Just as cross-space mapping loosely corresponds to aspects of divergent production, internal linking – which concerns associations made within one mental space – suggests convergent production. The twin aspects of convergent and divergent production that are a prominent feature of theories of creativity are therefore supported by the codes emerging from the data.

4. Second stage coding

The central nodes in all the mind-map data refer to the ISTD briefs, although some more explicitly than others. The assumption is that the central node prompts for the construction of a mental space, thereby evoking an organising brief frame. Those elements of the mind-maps that form part of this mental space should therefore be coded as examples of internal linking; those on the other hand that fall outside of this mental space are candidates for cross-space mapping. This coding stage employed a two-track strategy.

This strategy involved working progressively outward through the binary constructions in each branch. If the inner and outer elements of each binary construction were deemed to be 1) in the same frame, and 2) related to the organising brief frame evoked by each brief; then the link between these elements was recorded as an internal link. If, on the other hand, one of these conditions was not met then this raised the possibility that the link was a cross-space mapping, requiring further scrutiny of the binary construction to determine which frames were involved.

At this point it is probably helpful to provide examples of different scenarios, emerging from the data.
Table 1. Internal linking using a single conceptual domain. ISTD brief, Anniversaries.

<table>
<thead>
<tr>
<th>Elements from the data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central node: “Anniversary”</td>
</tr>
<tr>
<td>Element 1: “Culture”</td>
</tr>
<tr>
<td>Element 1: “Thanksgiving”</td>
</tr>
</tbody>
</table>

Here the topic “anniversary” is provided by the brief’s title. Of all the yearly events that take place, some are “cultural” and within those is a particular anniversary “thanksgiving”. This involves a movement from the generic to the more specific within one frame – anniversary.

Table 2. Internal linking using two conceptual domains. ISTD brief, Writing women into history.

<table>
<thead>
<tr>
<th>Elements from the data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central node: “Writing women into history”</td>
</tr>
<tr>
<td>Element 1: “Hidden figures”</td>
</tr>
<tr>
<td>Element 1: “NASA”</td>
</tr>
</tbody>
</table>

In this example NASA is not an established sub-category of “hidden figures” in the same way that “thanksgiving” is in relation to “culture”. The label “hidden figures” is part of the “recognising achievement” frame while “NASA” belongs to the “fields of endeavour” frame (Figure 2c). Consequently, this construction requires more work from the reader to determine which part of the “NASA” frame relates to the frame “hidden figures” (workers in NASA that are “hidden” from history). Also, we are not interested in all hidden figures, only those that are women (a focus handed down from the central node). This branch therefore results in a similar movement from the generic to the specific as in example 1 but one that requires more processing since two frames are more clearly involved. However, since both frames are part of the same organising frame evoked by the brief, this is still an example of internal linking, rather than cross-space mapping.

Table 3. Cross-space mapping using two conceptual domains (two organising frames – metaphorical). ISTD brief, Mark my Words.

<table>
<thead>
<tr>
<th>Central node: “C word” and typography</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Branch 1</strong></td>
</tr>
<tr>
<td>Element 1: “Sound”</td>
</tr>
<tr>
<td>Element 1: “Short quick”</td>
</tr>
</tbody>
</table>
In this example two elements are linked suggesting the metaphor expletive is gun shot. The “short quick” sound of the “c word” linking here to “gun-shot”. This involves two different organising frames: that of words and typography (part of the brief frame), and the shooting of guns (external to the brief’s organising frame). Interestingly the recruitment of this second frame seems to have happened in Element 2 where an association is made between a bullet point (a typographic glyph) and bullets/ammunition. The implicatures of this metaphor would seem to provide useful communicative potential so that swear words become wounding and are fired off in a hostile act.

Table 4. Cross-space mapping using two conceptual domains (two organising frames – counterfactual). ISTD brief, Mark my Words.

<table>
<thead>
<tr>
<th>Elements from the data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Central node: “what if”</td>
<td></td>
</tr>
<tr>
<td>Element 1: “nice had a smell”</td>
<td></td>
</tr>
</tbody>
</table>

This central node here makes an indirect reference to an ISTD brief; the connection is only clear once the link is made between “what if” and “nice had a smell” since “nice” is explored in relation to the “Mark My Words” brief. The cognitive work involved in this “what if” processing is impressive. “Nice” is of course a word used to describe physical things or events and is therefore part of the language frame. But the “what if” – “nice had a smell” construction forces us to think of “nice” not as a word but as part of another frame, one of physical things. When combined with this second frame “nice” becomes itself an object that is available for scrutiny by our sensory organs - it has a smell. This objectified imagined manifestation of “nice” moves it outside of the language related elements listed in Figure 2c. It is an example of a counterfactual construction.

All of the data were coded on the same basis as these examples and were assessed as being a case of internal linking or cross-space mapping using the criteria discussed above. Codes were collected and analysed using NVivo 12 software.

5. Results

The sample consists of fifteen students who entered the 2018 ISTD Student Assessment Scheme. Of these entrants, ten produced mind-maps as part of their submissions and nine of these participated in the study. There were fourteen different mind-maps produced by these nine students, all of which were coded and analysed.

Database queries of the codes yielded 301 links that were assessed as being internal linking, as opposed to 23 links being assessed as cross-space mapping. Of the 23 cross-space links, twelve came from a single mind-map that labelled the central node “what-if”. The other 11 cross-space mappings were distributed across two other mind-maps; of those one had a
central node providing a level 3 (see Figure 2b) reference to the brief, this provided nine cross-space mappings. The remaining one was a response to the Anniversaries brief and the central node was labelled “whiskey + distilleries + spirits”, this mind-map yielded two cross-space mappings. Overall there were 16 links which were either illegible or so vague or ambiguous that it was decided that their inclusion in the study would introduce unreliability.

With regard to examples of counterfactual thinking, there were two examples of counterfactual thinking as internal linking, and 12 cases in which it occurred across spaces.

6. Discussion

This study began with a degree of scepticism as to the efficacy of mind-mapping as a tool for idea generation. The coding results at first suggested that this scepticism was not misplaced, with comparatively few cross-space mappings in relation to the number of internal links established. The nature of the internal links is often rational, relevant but somewhat unsurprising, consisting – as many do – of categorical links stepping down from superordinate classes, to subordinate classes. Generally, the mind-maps tend not, to provide links to more distant conceptual domains suggestive of divergent thinking.

Yet there was one exception that generated twelve out of the total of 25 cross-space links. What differentiated this mind-map from the others was the placement of “what if” in the central node of the mind-map – rather than a more direct link to a brief. The “what if [x was ...?]” statement prompted counterfactual scenarios to be imagined that often included concepts from domains distant from those organised by the brief in question. Further possibilities could be achieved by placing other questions at the centre of mind-maps “x as ...?”, or “x is ...?” for example, and this could be a source for further study.

The second most productive mind-map (nine cross-space mappings) has “c**t & typography” in its central node. This expression itself involves two conceptual domains; that of typography and the body. This may explain why the mind-map constructed around this node was so prolific in terms of cross-space mappings.

A further reflection on the mind-maps concerns the way that the central node potentially frames enquiry. By starting with a superordinate class in the central node there is the question of whether this primes the creator of the mind-map to think of other categories, rather than say attributes or abstract qualities. For example, in one of the mind-maps, “Anniversaries” is placed in the central node which links to another radial element “Cyclical nature of the universe”. This might have triggered an exploration of the abstract quality of cycles, building associations with domains not directly related to anniversaries such as bicycles, vinyl records, and so forth. Mapping a single revolution of a record to the year of a life, could result in surprising outcomes that highlight different aspects of anniversaries. For example, a revolution on the periphery of a record is longer than a revolution closer to the centre; which is reflective of the experience of time passing more quickly as we get older.
However, it would seem that the line of reasoning set up by the superordinate category of “anniversaries” led not to the abstract quality of cycles but to the category of astronomical cycles – which is a less creative leap, since the annual cycle of the Earth around the Sun links directly to the concept of “anniversary”. The question arises therefore as to whether mind-mapping constrained thinking in this case.

Pereira’s observation above is worth consideration here, where he notes that a creative product should be both novel and useful, and that these attributes arise from divergent and convergent production respectively. If “usefulness” in this context is translatable as “relevance”, it appears that most of the internal links made in these mind-maps have quite a high degree of relevance to the idea placed within the central node. At first glance, the cross-space mappings perhaps less so. But according to Schilperoord’s (2018: 14) summation of current accounts of metaphorical meaning, the incongruity resulting from the juxtaposition of “two objects stemming from disparate domains” is an important prompt for metaphorical association. It induces the viewer/reader to do cognitive work that finds the connection between two seemingly disparate things. The importance of these cross-space mappings should not therefore be undervalued.

If there are priming effects at work in mind-maps then this might account for the disproportionate number of internal links reported in the results, since one element in the mind-map would prime the creator of the mind-map to find another element closely associated with it in memory – and this suggests convergent production. Consequently, whatever appears in the central node would frame and to some extent determine, what appears in the branches that radiate from it. It could be argued that this is precisely the point of mind-maps. But if this is the case, is there less opportunity for the divergent, cross-space mapping of which the brain is capable? It is conceivable that this potential is even suppressed, in the creation of mind-maps.

From the admittedly small number of mind-maps analysed in this article, it would seem one way to open up mind-mapping to divergent, cross-space mapping is to put questions such as “what if x was ...” in the central node of the mind-map rather than simply the name of a category.
References


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Marion Morrison MA RCA FHEA is Course Leader BA (Hons) Graphic Design Arts University Bournemouth. I consider design as a hybrid, discovery led creative process that is open-minded, and focused on asking questions as well as solving problems. I believe ideas emerge through investigation and experimentation and as designers we can use our creativity to develop new tools to create ideas.
New scenarios for developing cooperative platforms for local manufacturing

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Abstract | This paper analytically connects the theme of collaboration, with an emphasis on the historical production structure of the Emilia-Romagna region and the increasing spread of cooperative platforms. This analysis gives rise to reflections on the characteristics and processes that distinguish the object systems from research. The multitude of instruments that appear in the research underlines the partial coverage of the area of the specific project, which is characterized by the complex process that relates raw materials to the logistics of distribution by the systems and the companies based on cooperative platforms. Within this research area, this contribution aims to elaborate some guidelines for the development of these systems on the subject of welfare, the relationship between collaborative and cooperative forms and the future application of artificial intelligence in the assessment processes that are crucial for the design of innovative models of cooperative platforms for processes of product creation and management.

KEYWORDS | COOPERATIVE PLATFORM, PLATFORM FOR DESIGN, DESIGN AND TERRITORY, DIGITAL MANUFACTURING, CREATIVE COMMUNITY
1. The state of the art of the cooperative system

The Italian context, particularly that of the Emilia-Romagna region, was characterized by different forms of consumption and production of goods and services that are jointly managed. In the course of time these development processes of the work have strongly shaped the area, which has always shown a particular preference for viewing these aspects as typical elements of a regional system, both socially and culturally. They promote socio-cultural growth through models in which the customer is at the center of the innovation process, and they themselves become actors of change and active figures in the creation of new forms as well as entrepreneurial and social processes (Villari, 2018). These are changes in goods, services and processes to meet the need for intelligent growth that is open to social responsibility and innovation, creating new market modalities and new relationships within the participants (Celaschi, 2016).

One modality is the collaborative economy, a model that redefines and updates the relationship between market, product/service, production processes and consumers while activating new avenues of production and consumption. A social and economic approach that is heading towards a dynamic of collaboration and co-creation between subjects and aims to create solid relationships between the offline and online attitudes. Vincenzo Cristallo (2018, p. 37) highlights how three actions emerge from the collaborative economy: the "collaborative consumption", the "collaborative market" and the "value of experience". The first activates three elements: the role of the community, mobile collaboration, and inexhaustible resources. The second relates to resource sharing and the third shows how the value of products and services is related to finding an experience. The goal is no longer the use and ownership, but the empirical value that enables access to this asset.

While it is clear that the phenomenon of the collaborative economy still has very broad and changing boundaries due to its growing diffusion and heterogeneity, the main features and differences within the most common collaborative models are examined. Starting with governance, this can either be centralized or widespread, geared towards profit or pursuing a social purpose, more capitalist with centralized control to more democratic and horizontal (Battistoni et al., 2015, p. 23; Kostakis & Bauwens, 2014)) it shows that the forms in which these models are implemented are mainly four: collaborative consumption, collaborative production, collaborative learning, and collaborative financing (Stokes et al., 2014). In these contexts, the element that most unites the different forms is the peer-to-peer dynamic and the contribution of digital technologies as a connecting tool between users.

As we proceed to analyze each of the models, some of them appear to use collaborative and exchange practices to respond to the material and social needs of the community. An approach that turns to some principles of the cooperative model to create alternative businesses to capitalist companies that combine the associative dimension with the entrepreneurial.
Historically, the cooperative model starts with the beginning of the industrial revolution and the first models emerged in Europe in the mid-19th century, focusing on consumption, work, agriculture and credit. An interesting case study is that of the labor cooperative, which was born in Paris in 1831. This was the first cooperative association of carpenters, which was later followed by others related to goldsmiths, furniture makers, bakers, stonemasons and all interesting forms of community experimentation (Zamagni & Zamagni, 2008). The members were also the workers themselves, and all equally enjoyed the principles of reciprocity, the founding feature of cooperatives, aimed to meet common economic, cultural and social needs. Italy was no stranger to these processes of job innovation and stood out for the development of models of cooperation in different areas, from consumption to production, from agriculture to credit, up to the social cooperative model.

The first evidence found from the sources is in Turin, 1854, with the first consumer cooperative, and always in the same period, 1856, in Altare near Savona was registered the first cooperative production dedicated to glass art. The cultural and associative model was already existent in Italy, as it was in Europe from the mid-18 century thanks to the Mutual Relief Societies between workers, born to replace corporate structures, which for their formula dedicated to community support and mutuality were inspiration for the creation of Cooperatives (Zamagni & Zamagni, 2008, p.73).

By its definition, a "cooperative is an autonomous association of people who have come together voluntarily to meet common economic, social and cultural aspirations and needs through the creation of a common and democratically controlled corporation,” as in the Declaration of Cooperative Identity displayed in Manchester in 1995. It is also defined by the following principles: free and voluntary membership, democratic control by its members, economic participation of its members, autonomy and independence, education, training and information, cooperation between cooperatives and interest in the community. Over time, market changes have contributed to the development of cooperative forms and the introduction of new legislation, which have also led to the creation of new forms of governance.

In this regard, the emphasis in determining some of the parameters in the tables below has been rather on the prevailing cooperative model of reciprocity, which keeps the intrinsic principles of the cooperative more intact. In addition, the fields of production and labor were further examined, a sector which, by its conformation, bases its actions on a continuous synergistic dialogue between the different actors in the supply chain and guarantees the identity values of what they produce. A distinguishing feature of cooperative production is the figure of the worker member who "pursues the good of the cooperative by lowering personal expectations of mutual exchange". (Legacoop, 2010, p. 67). If we compare this model with that of the collaborative production economy, we find connections that highlight how both are based on the idea of a common project of the community involved in it. It is plausible to argue that some rationale, such as equipment sharing and the collaborative manufacturing spirit, are common, especially when it comes to collaborative
manufacturing which is intended in the context of open manufacturing (Battistoni et al., 2015, p. 50). In Emilia-Romagna in particular, an analysis of the territory's entrepreneurial systems shows that the cooperative model is an entrepreneurial method of collaboration that is still relevant and has a strong connotation with social innovation processes. The UnionCamere dataset for 2018 confirms this with 80,765 cooperative companies on Italian territory, of which 5,006 are articulated in the Emilia-Romagna region and employing 12.5% of national employment related to cooperatives (Rapporto sulla Cooperazione, 2019, pp. 55-56).

Basing on the literature as early as the twentieth century, the development of the new cooperative business models of Emilia-Romagna distinguish itself at national level thanks to the historical ability of the regional territory to create a system, to its geographical conformation rich in small-medium enterprises well integrated in the productive regional setting, and to its aptitude to combine political culture, integration between public and private, entrepreneurial culture and social integration in a virtuous formula. All elements that in the second half of the twentieth century defined the "Emilian Model" (Menzani, 2007), which was one of the driving forces behind the transformations of the territorial cooperative model which differed from the others precisely because of one of its peculiarities: the social integration. Its widespread diffusion in the region, already after the war, allowed the regional economy to consolidate and renew itself, creating close ties with community and institutions.

Within this territorial ecosystem, the development of production and labor cooperatives is interesting as they find their best locations within the production districts and new resources both in the know-how of the local artisanal production tradition and in the training of high-level skilled professional (Menzani, 2007). The manufacturing cooperation was able to take advantage of the large training capacity and capillarity that had settled in the region, guaranteeing a high level of skills that contributed to the success of the manufacturing cooperatives in the ceramic, shoe, foundry and mechanical systems market.

The cooperative model is particularly interesting because it is still relevant today and, according to its principles, corresponds to the objectives of the European Community in matters of social innovation and inclusion as well as the development of new socio-economic sustainable models. A model that, when applied to the online world and contaminated with new trends in open design, can be an alternative approach and solution to the complex needs of the current and future market.

To understand this phenomenon and develop design-oriented processes, the different systems and types of contemporary entrepreneurship in the market are examined.
2. Contemporary digital models of collaboration and cooperation

The development and diffusion of ICT infrastructures, the reduction of transaction costs, the change of buying habits from a “own” to a “share” approach and the disappearance of the clear distinction between consumers and producers (prosumerism) are some of the conditions that have spread the sharing economy. There are misunderstandings and contradictions where some of the patterns of consumption that are commonly grouped under the term “sharing economy” do not reflect their principles. This can often be attributed to the habit of extending the metaphorical meaning of neologisms associated with the digital world to related concepts, tools, and practices. This phenomenon tends to dilute the specificity of the terms and introduce a number of umbrella terms that create ambiguity and semantic confusion (Ciracì, 2013). According to Giana M. Eckhardt and Fleura Bardhi (2015) the term “sharing economy” is not used properly on platforms such as Uber\(^1\) and Air B & B\(^2\). In fact, the exchange of goods, services and information based on the Peer2Peer model is a phenomenon that occurs between individuals without any currency exchange taking place, but which is driven by a mutual and supportive approach. When there is a market broker between users who do not know each other, an economic exchange relationship is established by defining an access economy rather than a sharing model. This dynamic has a direct impact on how users of the platform use the service. It favors the return of economic value over social value and makes us wonder to what extent the peer relationship is perceived as an added value or a compromise to access the service.

The platforms that offer this type of service do not own the resources, nor are they responsible for the actions of the individuals. For example, Uber does not own the vehicles and has no obligations to any of the operators involved in providing the service. In the food delivery sector in particular, the use of bikers as the only resource without protection and recognition of their status as employees has a significant impact on the economic competitive dynamics of the dominant service companies. There are alarming social implications in this regard, and in response to these models, a debate has emerged in recent years about the role of platform cooperativism as a fairer and more sustainable economic model (Rifkin, 2014; Scholz, 2015).

The cooperative platforms are part of a panorama of typologically different online platforms on which the differences in the processes guide the structure and implementation of the actions they generate. Cooperative platforms are identified with four main characteristics (Scholtz, 2019): ownership that is extended to the members of the platform; democratic management of the same when a member's vote is worth one; the co-design processes that

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1 Uber, https://www.uber.com
2 AirB&B, https://www.airbnb.com
guide the development of the platform; the obligation to support an open source development of its organizational instruments.

These features underline the similarity and diversity of the platforms that result from the collaborative economy. Two platforms enabling a transportation service could serve as examples, with the first, Uber, gathering self-employed workers under the same brand and app and asking for a percentage to pay for the service. The second platform, Eva³, guarantees the same service, but structures the internal processes according to the scheme of the cooperative platforms. This choice, based on blockchain mechanisms, allows the members, through the development of the common platform, to generate a surplus of profit intended to transparently redistribute the value on the territory. The cooperative model generally guarantees higher profit margins for members, their participation in company decisions through voting, and better protection by hiding the verification data from the application interface.

The models are similar from the user's perspective, but different from the employee's perspective.

Cooperative platforms interweave multiple relationship models between members and the market by defining competitive, collaborative, algorithm-based forms with multiple stakeholders. For example, when using the American UP & GO⁴ platform, the user does not have the option of selecting the operator responsible for cleaning based on the personal profiles of workers whose ranking or public rating does not exist. The user relies on the evaluation process carried out by the cooperative when selecting staff. This decision was guided in particular by tests carried out by the platform and studies that suggest that personal profiles could lead to harassment (Scholz, 2019).

Some models of cooperative platforms are characterized by the fact that several participants with different roles are accepted as members. These cooperatives are defined as multi-stakeholders and consider the involvement of workers and producers as members of the cooperative. For example, the Resonate⁵ model expects content producers and users of the service to have the right to vote on the decisions that determine the development of the platform. In addition, the profits are shared among all stakeholders, who can choose to withdraw them as cash or use them as credit towards using the music streaming service on which the platform is based.

The mapping of active cooperative platforms is constantly updated (#PlatformCoop Directory - The Internet of Ownership, n.d.). In the past year, Scholtz (2019) divided the platform types into five categories:

3 Eva, https://eva.coop
4 UP&GO, https://www.upandgo.coop
5 Resonate, https://resonate.is/why-were-a-cooperative/
• The production cooperatives are constructed as spaces where the members who create the content independently benefit from a single diffusion vehicle (i.e., Stocksy⁶), or as aggregation places of professionals developing joint projects (i.e., Enspiral⁷).
• Data platform cooperatives deal with user-driven social media;
• Cooperative platforms are based on blockchain protocols (i.e. Eva);
• Labor cooperatives aimed at providing services to their members (i.e. Up & Go);
• Collaboration platforms for common tasks aimed at bringing together non-group professional groups and helping them manage work activities. (i.e. Docservizi⁸, Smart-it⁹)

Figure 1. Collaborative and cooperative platforms.

Figure 1 shows how it is possible to insert other categories in relation to those already identified, with an emphasis on different aspects. Similar difficulties with categorization arise in connection with collaborative platforms, which, as mentioned above, often have a similar

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⁶ Stocksy, https://www.stocksy.com/
⁷ Enspiral, https://enspiral.com/
⁸ Docservizi, https://www.docservizi.it/
⁹ Smart-it, https://smart-it.org/
user interface on the user side, but with specific internal procedures that sanction a profound ideological divergence.

The diagram shows how both branches represent platforms that are mapped to fields related to the project area. On the collaborative platform side, it can be stated that this area is essentially represented by two macro-categories: instrument supply platforms and network platforms. The former offers designers digital tools for their work like GitHub\(^{10}\); The latter connect the stakeholders of the design processes (i.e. co-hive\(^{11}\)) and in some cases collect real orders that have been established between the company and the platform and which are then managed by the designers through working groups (Zooppa\(^{12}\)) or competitions (Desall\(^{13}\)).

By focusing the analysis of collaborative platforms on issues related to product design, it is found that the role of the platform is mainly limited to distributing the goods. The collaborative development processes seem to be mainly hosted on digital platforms that provide tools for coordinating workgroups like GitHub and Wikifactory\(^{14}\). Although these platforms are based on the active involvement of the participants in the development process, they do not contribute to build long-term collaborations, but create collaborations that are linked to individual projects. In this sense, the platform is only used as a collaborative tool and does not represent a common basis for the exchange of values and purposes, an element that characterizes cooperatives.

In order to be able to deepen the processes of the case studies of cooperative model platforms that intervene in the area of design, a descriptive matrix (Fig. 2) of internal processes was used where the case studies are analyzed through the characteristic coming from both the traditional cooperative model and the digital cooperative platforms. While two case studies declare themselves in their statute as cooperative platforms, the remaining take alternative forms in which the social aspect towards the members and the reinvestment of profits in the same area can be registered.

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\(^{10}\) Github, https://github.com/
\(^{11}\) Co-Hive, http://co-hive.com/
\(^{12}\) Zooppa, https://www.zooppa.com/
\(^{13}\) Desall, https://www.desall.com/
\(^{14}\) Wikifactory, https://wikifactory.com/
New scenarios for developing cooperative platforms for local manufacturing

The policies implemented by the recent regional councils of Emilia-Romagna have, amongst their objectives, the regeneration and development of employment, in line with the demands of the European Community for a new social cohesion. Attention to the development of new business methods through the cooperative entrepreneurial system is seen as a tool for sustainable and strategic growth of the territory. The goal is to develop new forms in areas other than traditional, including through the creation of start-ups and measures that contribute to cross-sectoral contamination within the supply chains (Alberani, A., et al., 2018). Among the initiatives to support the regional development lines, mention should be made of the Social Hackathon\textsuperscript{15}, which was organized in Piacenza in 2017 by Confcooperative, a collective hacking action based on the open innovation model of Henry

\textsuperscript{15} Social Hackathon, La prima maratona di Solution Making a Piacenza, http://www.confcooperativepiacenza.it/social-hackathon/
Chesbrough (2003) but more cooperative and the Coopstartup Bologna\(^{16}\), a new co-op development program that offers winners an annual call, guide, and acceleration process.

As mentioned earlier, this research focuses on the interventions and development of digital and immaterial forms and tools in the specific area of the project. In the selection of the analyzed case studies there is a single example that does not belong to this classification: the Sensorica\(^ {17}\) community, whose goal is the development of open source hardware by its members. Together with the Enspiral project, this platform does not define itself as purely cooperative, but actually fulfills many of the requirements identified by Scholtz. The two platforms offer digital rooms in which working groups are created on specific project priorities. In the case studies analyzed, it is interesting to highlight the Stocksy and Resonate platforms, which are characterized by offering members a collaborative / competitive model that is integrated into associative management and allows them to participate in the decision-making processes of development and active cooperation in the EU to participate in the management and design of the platform. Their front-end model is configured as a wider audience digital space where preferred content can be purchased. The basis of these two online platforms is the clear desire to protect the copyright of individuals and to guarantee their members fair compensation. Transparency and clarity in managing retained earnings through both platforms is one of the most important added value values that enable it to attract members from competitors.

Taking into account the specific area of product design where there are currently no examples of structured collaborative platforms, a significant contribution to their development, particularly in the production and distribution phases, could come from the contexts that have evolved on the EU basis for open and shared philosophies such as Fablabs, Maker and Hacker Spaces.

In fact, the digitization of the design phase and the spread of the enabling technologies of Industry 4.0 offer the opportunity to imagine innovative and flexible production and sales processes. One analyzed case study based on these issues is the Distributed Design Market Platform project\(^ {18}\), which is funded by the European Union through the Creative Europe fund. This project promotes platforms and tools that support designers and makers not only in the design, but also in the manufacture and marketing of their products and support processes that are based on the exclusive handling of data and widespread production.

By digitizing the project, digital collaboration platforms can be used to simplify co-design processes. Many of these online tools were developed to facilitate software development, particularly in the open source area. They offer hosting services, version control, bug tracking systems, feature requirements, task management and wikis such as GitHub and

\(^{16}\) Coopstartup Bologna, https://bologna.coopstartup.it

\(^{17}\) Sensorica, https://www.sensorica.co

\(^{18}\) Distributed Design Marekt Platform, https://distributeddesign.eu/about/
Based on these models, additional platforms for the co-design of physical products were developed. On these platforms, the project management and tracking tools are flanked and integrated by tools that have been specially developed for product design, e.g. B. the online visualization of 3D models and the creation of a dynamic parts list that can be shared with external suppliers and manufacturers. Examples are Wikifactory, GrabCAD\(^{20}\) and Thingiverse\(^{21}\). Although the tools described are not hosted on cooperative platforms, they represent technological solutions that correspond to the characteristics of cooperative models.

In addition to the technical support tools for design, there is one area of particular interest for design, namely the collaborative platforms for common tasks.

The analysis provided in this discussion summary shows that application models of the collaborative system cannot really be used to create platforms dedicated to the context of design. Hence, it seems necessary to create design scenarios that lead to the development of guidelines to ensure true compliance of these tools with the cooperative model.

### 4. Guidelines for design and productive cooperative platforms

The findings that emerge from this study of the cooperativism of Emilia-Romagna and the cooperative platforms in a broader and more general context, frame possible development of the cooperative platforms towards complex production realities characterized by the participation of several participants in the production processes.

Thanks to these developments, new cooperative models should take into account some aspects that deal with the field of production through digital mediation. In particular, three macro-themes emerge: the importance of the welfare system, the contrast between a competitive and collaborative approach, and the assessment processes that need to be developed to improve member evaluation.

One approach highlighted in the platform case studies is to improve community welfare. On the one hand, there are platforms to support freelancers by inserting them into networks and assisting them with the tax and organizational administration of customers. On the other hand, a regional system that has always been recognized for having pursued the aspect of social integration within regional and economic policy and which is still moving in this direction today through communal welfare projects involving institutions, citizens and communities work together to create systems that contribute to the economy of caring for

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19 SourceForge, https://sourceforge.net  
20 GrabCAD, https://grabcad.com  
21 Thingiverse, https://www.thingiverse.com
the common good (Symbola, 2018). Social relationships and quality of services are a combination that leads to a better quality of work and a more sustainable and conscious production, which is now also demanded by the end consumer.

The welfare instrument can also be inserted between the innovation and systems practices of cooperative platforms for both production and design in order to improve relationships in the network and in labor management.

From the analysis of the case studies it appears that the platforms that offer digital products are configured on the user side as places where one member’s content and not the other’s can be purchased, which of course creates a competitive aspect among members that is not possible is easy to evaluate.

Due to the number of participants involved in the process, the content distributed by these platforms is less complex than for material products, in which machines are used, raw materials are handled, stored and sold.

The cooperative model of Emilia-Romagna, closely linked to specific productions and combined with the concept of a cooperative platform, proposes what is necessary for the creation of aggregative digital places of the manufacturing vocation.

The cooperative networking of partners in synergy effects on a productive goal and not in the internal competition for the results could more closely adhere to the digital platform model intended for specific productions. Collaborative processes, managed through processes of transparency and equality between members, can lead to higher quality in the development of end products by improving the productivity of the platform.

Finally, the paper focuses on the processes of evaluating the work of shareholders. Comparison systems based on algorithms and artificial intelligence can lead to possible tools for managing the assignment of work activities to the platform operators. As in the Up & Go example above, the user relies on the selection criteria used by the platform and adapts to the system. At this level of interaction between the parties, the question arises of how fair and transparent the rules on which these algorithms are based are. Indeed, making machine learning and artificial intelligence (AI) mechanisms understandable is gaining political value in terms of equity, reliability, and transparency as these systems are increasingly used in managing sensitive data and decisions (Matsakis, 2018).

AI can also be used to create value for users within the platforms. Little by little, platforms are emerging that integrate processes based on neural networks to improve profiling systems. For example, Open Maker Digital Social Platform uses an AI-based value system to search for innovators on social channels, connect them based on common interests, and provide metrics to assess members’ social impact and innovation. The application scenarios of technologies based on blockchain systems that help manage the transparency of the assessment processes are just a few of them that could lead to innovations in these decision-making tools in a short period of time. The crucial hub of the relationship system between
New scenarios for developing cooperative platforms for local manufacturing members is a fundamental element that will determine the future of collaborative platforms. The logic of the processes commanded on performance data must leave room for really comparable quality indicators.

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Playing for change: designing a board game for the circular economy

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Abstract | There is a lack of public engagement in sustainability initiatives such as the circular economy (CE). This can be attributed to an absence of understanding and promotion of this new way of living and consuming. This lack of engagement is hindering the implementation of the CE. This paper aims to address this through an exploration of the role of games in explaining difficult concepts. There will be a particular focus on board games as tools for exploring aspects of sustainability, as they allow for a more discursive experience with other players and are a simple way to relate complex ideas. The paper will then detail the design and development of a serious board game Circul8. Designed by the authors to encourage engagement with complex systems, it aims to introduce ideas of the CE to the general public. The paper will explore the methodology of game creation and detail initial gameplay results.

KEYWORDS | GAME DESIGN, CIRCULAR ECONOMY, PLAY THEORY, LEARNING THROUGH PLAY, RAPID PROTOTYPING
1. Introduction

There is an urgent need to engage the public in the circular economy as part of the fight against climate change. The basic principles of the circular economy are simple enough; “design out waste and pollution; keep products and materials in use; regenerate natural systems” (Ellen MacArthur Foundation, 2017). However, understanding how these principles can work in reality is more complicated and there is a risk that people will switch off if they don’t understand. Research into the circular economy has revealed that public engagement is one of the most difficult aspects of circular economy implementation (Kirchherr et al., 2018). This paper will firstly explore the potential of the circular economy as a model to tackle some areas of the climate crisis, and the barriers around public engagement that are hindering its implementation. The paper will then go on to explore the potential of games to engage the public with complex ideas through a simple system, with a particular focus on board games. Finally, the paper will detail the designing of a serious board game, Circul8, by the authors, that will be used to engage audiences with circular economy ideas and provoke discussion around it.

2. Circular economy

The circular economy is gaining traction as an idea across business, governments and academia. It is seen as one of the ways to tackle the climate crisis by radically changing the way businesses operate and people consume (Ellen MacArthur Foundation, 2013; Ghisellini et al., 2016; Kirchherr et al., 2017; Mathews & Tan, 2016). The fundamental idea behind the circular economy is to move us from a linear economy of ‘take-make-dispose’ to one where resources are in constant use for their full usable life. There has been a variety of definitions for circular economy, ranging from product reuse and advanced recycling to eco-design and sustainable consumption (Gallaud & Laperche, 2016). Kirchherr, Reike and Hekkert (2017) analyse 144 definitions of the circular economy in order to consolidate and create transparency around current understandings. Their research concludes to define circular economy as “an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes.” (2017, p. 229). The Ellen MacArthur Foundation (2013) adds that systems should be restorative by design, focusing on nature-based systems as well as technical ones. The circular economy cycles are demonstrated by Figure 1, known as the butterfly diagram. This shows the inner cycles of reuse, repair, repurpose and remanufacture and the technical side, with the outer cycle and final process as recycling. The organic side focuses on extracting as much energy as possible, either directly through biomass or indirectly through calorie consumption, before the matter is returned to replenish the soil.
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As well as working through different cyclical iterations, the circular economy works at different levels of implementation. Micro, at the product, company or consumer level (Elia et al., 2017; Kalmykova et al., 2018; Lewandowski, 2016), focusing on design for end of life (McDonough & Braungart, 2009) and product-as-service business models (Bressanelli et al., 2018; Spring & Araujo, 2017). Meso level implementation looks at eco-industrial parks like those being developed across China, where business are deliberately placed together to enable the waste from one business to be easily transferred to another that uses that waste as a resource (Mathews et al., 2018; Yuan et al., 2006). Thirdly macro, at national, regional or city level implementation, ensuring that the infrastructure is in place to support the effective sharing of resources and implementation of many small loops that feed into the overall circular system (Blomsma, 2018; Ellen MacArthur Foundation & ARUP, 2019; Kirchherr et al., 2017; Saidani et al., 2018).

Figure 1. Circular economy butterfly diagram developed by the Ellen MacArthur Foundation (2013)
2.1 Role of consumers
At every level of implementation and every stage of the circular economy cycles consumers play an important role. From product design consultation and uptake of subscription models of ownership, to actively seeking out second-hand goods and repairing what they own rather than throwing away, consumer involvement is vital for the success of the circular economy.

“‘Closing the loop’ in the circular economy essentially requires much closer and more extended collaboration between participants. Consumers also become much more integrated because the value chain does not end at the consumption stage.” (Ellen MacArthur Foundation, 2013).

Designers and engineers working in circular economy need to make sure that consumers are actively involved in each stage of the production process. For example, the purchaser could ultimately be one of many, so the resource recovery needs to be as painless for the consumer as possible (Lofthouse & Prendeville, 2018). City planners wanting to create circular urban systems must do so with the active involvement of their city’s residents (Ellen MacArthur Foundation & ARUP, 2019). Not involving the people who will use the products and services being designed for them is likely to lead to costly vanity projects and products ultimately failing (Singh & Giacosa, 2019).

2.2 Barriers to adoption
Despite the importance of consumers and the public in general to the circular economy, they are one of the biggest barriers to its implementation. Research conducted by Kirchherr et al. of 208 businesses and policy-makers explores barriers to circular economy adoption in the EU and finds that “lacking consumer interest and awareness” is the most pressing issue preventing wide-scale adoption (2018). Since this research has been published there have been a few high profile circular economy media stories, such as IKEA’s announcement to introduce take back schemes on their furniture (Inter IKEA Systems B.V., 2018), a focus on fast fashion (Britten, 2018; Farmer, 2020) and the business potential of circular economy (van Houten, 2019). As consumers are so vital to the success of the circular economy more needs to be done to engage them with the underlying principles of how the process should work. Preliminary research undertaken by the authors has found that often employees of companies engaged in the circular economy do not fully understand how and why their employer is engaging with the circular economy. It is prudent to point out here that, like everyone taking part in society, these employees are also consumers. To bring about this new model it is vital that we are all conscious of the roles we play, as designers and also as consumers. If we cannot take steps to become more circular in our work and daily lives, then how can we expect other people to engage.
3. Gamifying circularity

The question that needs to be asked is: how do we enable engagement with principles of the circular economy in a memorable, actionable and involving way? The authors have concluded that one of the ways to introduce ideas about the circular economy to people could be through a simple board game. Games can be important tools for educating audiences about wicked problems and are gaining more significance “as a way to bridge the communication gap between different stakeholders and support sustainability education” (Whalen et al., 2018, p. 336). They are useful devices to explain complex systems to audiences, demonstrating how different elements of these systems work together through non-linear access points that come about during gameplay, rather than linear speech. This allows audiences to come to an understanding through their own exploration instead of being told through written or verbal form. Games, “can be treated as small models of much more complex, much larger systems” (Castronova & Knowles, 2015, p. 41). Prominent game designer and theorist Jane McGonigal (2011) believes that games have the power to change by teaching ecosystems thinking, giving players the ability to think about complex ecological systems. “A good ecosystems thinker will study and learn how to anticipate the ways in which changes to one part of an ecosystem will impact other parts.” (2011, pp. 297–298).

Introducing ideas of circularity through a board game can provide a method to help the public understand their roles in the ecosystems necessary for successful circular economy implementation.

3.1 Serious games

A serious game is one that has a purpose beyond entertainment, their use is gaining prominence in sectors such as healthcare, education and workplace learning (Cannon-Bowers & Bowers, 2010). The majority are computer-based games, providing simulations for professionals such as firefighters or military. As they are generally designed with a specific, intended audience they are less commercially viable than video games designed solely for entertainment. They might not be practical for development in highly specialised areas, or areas where the use of computers is not permitted (Lamey & Bristow, 2015). Board games are an underused but useful avenue for the development of serious games. Serious board games offer a number of potential points over computer games: they can be developed without needing skills in programming, they can be cheap and quick to prototype, and most importantly, they involve interaction between players which can foster conversation during and after play about the subject (Castronova & Knowles, 2015; Illingworth & Wake, 2019).

3.2 Examples of serious board games

The potential for the use of serious board games is very broad reaching. For example, Bristow and Lamey (2015) developed an informal, homemade board game for use in mental health services to aid service users “in the design of their hospital environment. The advantage of a board game format is that it is familiar and unthreatening.” (2015, p. 243).
This familiarity with the format allows for initial barriers to be broken down in a setting that can often be stressful and unfamiliar to patients.

To bring a serious issue to a wider audience Illingworth and Wake (2019) adapted the popular tile-based game Catan (Teuber, 1995) to introduce a global warming element as a way to generate dialogue around this complex topic.

“Tabletop games, which offer high levels of sociability, adaptability, and tactility, create a shared space in which complex topics can be discussed and debated, and it is this capacity to foster dialogue that makes them such a productive means for discussion on the topic of global warming.” (2019, p. 3).

There are a few other examples of games that tackle environmental issues. CO2 (Lacerda, 2012) is a commercial board game designed to raise awareness of the global pollution crisis. This game has been modified by Edward Castronova to explore “the difficulties that policy-makers face in dealing with the CO2 problem” (2015, p. 45). He chose CO2 as a base game as it already provided a simplification of a very complex system. By adding and removing parts of the game mechanics and adapting the rules, he was able to create a new game Climate Policy. This adaptation of the game was made using a pen and paper so can be used by anyone who owns the original game – the rules are freely available online in the International Journal of Serious Games.

Focusing on the circular economy, In the Loop Games design board games that help different groups explore areas of the circular economy specifically related to them. Katie Whalen et al. created the serious board game In the Loop to respond to the lack of understanding around complex circular economy implementation for engineering students (2015). Research had found that teaching the circular economy:

“demands a departure from the current disciplinary and subject-focused teaching that predominates current educational paradigms, particularly in engineering education” (Whalen et al., 2018, p. 335).

The focus during gameplay is to teach students about systems thinking and material criticality through active involvement in a simulation of these systems as an addition to the traditional learning structure the students were part of. They found that “the students were able to reconnect the game to reality, think in systems, and utilize critical thinking” (2018, p. 342). The research also found that the game had implications beyond its initial intention with the potential for use with groups outside the target audience.

3.3 Serious games as boundary objects

When a game moves outside of its original intention, it becomes a boundary object. This is explained by van Pelt et al. (2015) as:

“instruments used to facilitate the interactions between science and practice and function as the operating space between different ‘social worlds’ in which actors
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The potential for games as boundary objects when exploring complex subjects such as climate change can be investigated further when looking at the role of simulation games to bridge the boundary between climate change science and various groups. The game players do not need to have an extensive knowledge about the subject in order to understand the important concepts put forward in the game. The game play becomes a *magic circle* (Salen & Zimmerman, 2003), allowing players to experience the consequences of making different choices in the safe space of the game.

3.4 Research summary

As demonstrated in this section serious board games are an accessible way to introduce complex systems to non-expert audiences. The social dynamic allows for dialogue during and after gameplay, so players can discuss the issues around the theme of the game, potentially developing a deeper understanding of the subject. A serious game developed for a broad audience could have the potential to explain circular economy principles to different groups of people. By playing a game, audiences can experiment with a system and push the boundaries, allowing themselves to develop their own understanding of a concept.

4. Introducing ‘Circul8’

This section will detail the development of a serious board game, ‘Circul8’, designed to explain the principles of the circular economy to a general audience. The game was initially conceived as a modification for the game Carcassonne (Wrede, 2000), a tile placing game where players can build cities, roads and farms claiming them with character tokens. The original idea was to allow players to build their towns and farms and be able to trade with one another, with a focus on the waste from one area being used by another area to create a new product. As mentioned previously, this is known as meso-level implementation (Kirchherr et al., 2017). The decision to focus on meso level implementation was taken to demonstrate the symbiotic nature of the circular economy – how one group will be reliant on another for resources. This also ties into research by one of the authors into the role of communities and networks in the circular economy.

4.1 Research and development

During the very first research and development session, the game designer trialled the game using a small selection of cards and a copy of Carcassonne (Figure 2). Trade elements were introduced through a series of cards that were selected randomly and detailed a raw material source, i.e. an oil refinery or forest, or a manufacturing base, i.e. electronics or furniture (Figure 3).
The first playtest of Circul8 was held at a small doctoral conference which encouraged open and honest feedback of each workshop (CC). The feedback received followed some general questions that could be applied to any of the workshops being played but was useful. Some players mentioned aspects of game mechanics they would like to see added or improved, whereas others suggested applications for the game that had not been thought of. Table 1 shows a matrix of the initial research and development session’s play testers feedback, their names are encoded for anonymity.
Table 1: First play test responses matrix

<table>
<thead>
<tr>
<th>Reviewer</th>
<th>Key Takeaways</th>
<th>Key Opportunities</th>
<th>Key Challenges</th>
<th>What Else?</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCR1</td>
<td>The interactivity and how it can relate to policy &amp; planning for space.</td>
<td>Taking the game to policy makers/planners or communities for co-design</td>
<td>Incorporating all elements for a circular economy - but interesting approach, could see it working</td>
<td>Make an online version. Keep this one too but get it online if/when people are happy with the plan/ideas</td>
</tr>
<tr>
<td>CCR2</td>
<td>Idea of learning about circular economy through a game with a focus on local/regional places</td>
<td>Influence local/regional planning in northern powerhouse</td>
<td>Level of complexity – making it give the message without oversimplifying</td>
<td>Lego pieces for resources. V. interested in how in how waste fits into cir. econ</td>
</tr>
<tr>
<td>CCR3</td>
<td>How the game starts with random layouts and slowly they become more intentional with players planning their next move based on potential future relationships</td>
<td>Making game more strategic by giving out cards before setting out tiles</td>
<td>How would the exchange work between cities and farms?</td>
<td>Money? Is the purpose to create wellbeing? How do you win?</td>
</tr>
<tr>
<td>CCR4</td>
<td>It's really good way of thinking where resources come [from] and how they are used. The interaction at the beginning is good as you play, and then the second part makes you think about the strategy and resources</td>
<td>Opportunities to modify the cards in order to give different life</td>
<td>How to reduce the game to not open it up that much?</td>
<td>Really hard work to create a game</td>
</tr>
<tr>
<td>CCR5</td>
<td>Great idea to gamify a quite serious subject</td>
<td>Game used in industry, to raise awareness of the circular economy Also, education</td>
<td>Making sure industry see it as serious, perceptions. It's a great idea, as a way of bridging, but for industry to</td>
<td>Make it digital in the future?</td>
</tr>
</tbody>
</table>
The research and development session introduced the two authors of this paper. Tom Cockeram is a game designer and had designed a board to be used as a base for other games. He has expertise in game mechanics and was able to take the ideas of Jessica Robins and turn them into a serious game with engaging gameplay. The following illustrates the changes the game went through to its final iteration.

Figure 4: T. Cockeram’s multi-use board displaying games previously designed with school groups.
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Figure 5: (on the left) First planning meeting using the pre-designed board by T. Cockeram and resource cards from the R&D session. (on the right) Development of the resource cards and gameplay logistics.

Figure 6: The green and pollution tokens, introduced as the mechanics needed to win the game.
4.2 Gameplay

Circul8 will focus on meso level implementation, looking at how waste streams flow in, around and out of an area. By focusing on this level of implementation the game could have a broad appeal. It doesn’t use specialist terminology or concepts, simplifying the manufacture of products to 5 components: organic (plant-based materials), natural textiles (i.e. wool, cotton, leather), metals, minerals and petrochemicals. Players control a number of material processing plants and/or product manufacturing factories, they are able to choose what proportion of each they own, selecting cards randomly from a deck. Players are able to change their manufacturing factories after every turn, but they cannot change what types of material processing plants they own. The material processing plants process raw materials and also recycle or remanufacture materials once they have been used to create a product. Players earn green tokens for using second-hand materials to create their products but gain pollution tokens for creating products or making decisions about their products that are seen as detrimental to the environment, most products can be broken down into their component materials, however, some cannot and must go to landfill. The game is won overall when a player has 10 green tokens.

4.3 Methodology

Once the rules and game mechanics are finalised the game will be tested with a variety of people to gather a cross section of responses. There will be a rage of ages, including a teenage test group; testing with boardgame hobbyists, design students, and people working...
in the circular economy. The players will be asked to fill out feedback forms immediately after playing and their discussions will be recorded. From the research and development session the game designers know that the game provokes a lot of conversation and that the feedback given was timely and specific, even if the questions were not. The play testers will be asked more specific questions about the game mechanics, thoughts about the systems contained within the game and overall impressions. By playtesting with a range of audiences the researchers will be able to assess what ability the game is best pitched at, and whether it is suitable for an expert and general audience. They want to be able to assess whether the messages about circular systems come across to the different groups and what changes could be made to improve the game. There is always a risk that in making something to please everyone they will create something that pleases no-one, but this is why it is important to gather a range of feedback and to be able to assess whether one or two of the test groups can be side-lined to create a wider appeal.

The intention is to make the schematics for the game and playing cards freely available so they can be printed off using a standard printer and laser cutter (or scissors, if players don’t have access to a laser cutter). This way anyone will be able to play the game, regardless of finances. To keep the game as sustainable and circular as possible we will encourage players to use second-hand cardboard (from old packaging) to create their board and pieces. By keeping the game accessible to many groups the intention is to create conversations about consumption habits and how open source access could be a valuable tool in moving to a circular economy.

5. Conclusion and next steps

Through this paper we have argued for the importance of board games in disseminating ideas of circular economy. By using board games as tools, we can start to bridge the gap between a prominent model being worked towards in business and academia, and the uptake and acceptance of a new way of consuming by the public. Through the board game Circul8 we hope to develop something engaging and timely that can help audiences understand the importance of the circular economy in the fight against climate change.

The next steps for Circul8 is to be play tested with a wide variety of demographics; refining the rules and gameplay to make it accessible and enjoyable for a general audience. The authors would like to see the game printed, played and enjoyed by others, this will involve online promotion through game communities and general social media. One of the authors is looking to incorporate Circul8 into their PhD thesis, though inviting interview subjects to participate in a game with their colleagues and supply written feedback on the messages and gameplay. As the game is a microcosm of one part of the circular economy system it will be important for the authors to receive feedback from experts working within the field. This will allow the authors to assess how useful the game will be to explain circular economy concepts to a general audience.
Lastly, this paper makes a contribution to the fields of design for the circular economy, specifically design for public engagement in the circular economy, and provides another valuable example of the use of serious board games for public education. It positions Circul8 within a developing field of serious board games that focus on sustainability, and the smaller area of circular economy board games. Drawing particular attention to the importance of board games as affordable tools, their ease of creation or modification, and how they can be disseminated openly. By focusing on the circular economy as an underlying concept we have positioned the paper at an important cross-section of research: design, game theory, and sustainability.

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**Tom Cockeram** (Tang Mu) is a Dad, Doodler and Designer of Papercraft and rapid prototyped Toys and Games. His core ethos is to Make Stuff, help other people Make Stuff, and Make Stuff that helps other people Make Stuff.

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**Acknowledgements:** The authors would like to thank the team at Corridor Conversations whose mini conference was the reason they met and embarked on this project. They would also like to thank all the participants who have played the game in its various forms and given feedback.
Progetto Glume: from milling waste to resource for new materials.

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Abstract | The article discusses the results of experimental research concerning the enhancement of waste from wheat milling. It focuses on the analysis of Mulino Marino's production system, a leader cereals' milling company in the Cuneo province (Italy). The analysis of material flows identifies wheat husks and organic sand (about 30\% of total wheat grains in weight) as processing residues not classified as by-products that must be discarded as waste, following current regulations. Chemical-physical characterization certifies that they present qualities that are not optimized in their current end-of-life management. Looking at the main purposes of the circular bio-economy and the SDG12, the study focuses on defining a craft protocol for testing potential uses of company's organic waste through a set of basic experimental tests to investigate performances of wheat husks as a biopolymer, similar to thermoplastics, and as a compound for a bio-based material to replace to disposable plastics (e.g. for packaging).

KEYWORDS | ORGANIC WASTE, BIO-BASED MATERIALS, MICROBIAL PROCESSING, CRAFT-MAKING, CRADLE-TO-CRADLE
1. Introduction

Nowadays, one of the most important global challenges is to undertake tangible actions toward zero-waste production processes. The SDG 12 promotes resources and energy efficiency to ensure a better quality of life and to avoid the increasing degradation of the natural environment. The improvement of natural resources management is necessary to face the trend of increasing global population that could reach 9,7 billion people in 2050 (Department of Social and Economic Affairs, 2015). K.E. Boulding (1966) suggested that humans should move towards a “spaceman economy”, considering the Earth as a single spaceship, with strict limits for extraction and pollution. An effective proposal is to move from a linear approach to the production system towards a circular or systemic one (Bonaccorso et al., 2019), increasing waste recovery and creating industrial symbiosis between complementary supply chains (Ellen McArthur Foundation, 2015).

Agriculture and food production systems present a lot of environmental issues, in terms of land use changing, soil degradation and resource depletion. It also presents critical issues in waste management like all mining processes that exploit ecosystems (Thackara, 2015). The cereals supply chain is an essential part of the food system because it is the basic diet of millions of people. In Italy, wheat cultivation is the core for the production of many basic foodstuffs. It occupies almost 1.8 million ha (Faostat, 2017) and it represents an important productive sector for the Italian economy. The Italian milling industry has more than 350 companies spread over the territory and it produces almost 7,8 million tonnes per year of wheat flour (Italmopa, 2017). On the other side, the milling industry produces also almost 3,3 million tonnes of residues not for human consumption. A part of them are used as feed in the livestock industry, but a huge amount of residues are treated as waste. In some cases, these residues present chemical-physical and mechanical properties useful for the development of bio-based materials (Genovesi & Pellizzari, 2017).

This article investigates the opportunity to enhance the milling process's residues from waste to resource for the production of new bio-based materials. The research is based on a collaboration with a company in Piedmont Region, the two residues are tested to evaluate possible applications in the design practice. The article discusses the strengths and constraints of materials obtained in terms of environmental, economic and social aspects. It also promotes the change of mind of making towards a systemic approach.

2. Design considering products’ origin and end of life

Considering that the most environmental issues should be addressed to decisions making during the design stage (Thackara, 2005), the design culture of making products, processes and services plays an important role in promoting sustainability. Systemic Design (Bistagnino, 2011; Peruccio, 2017) proposes to adopt a systems thinking-based approach to design practice in order to reduce the ecological footprint of production processes. The
systemic approach considers products’ end of life during design stages and it is inspired by nature’s design principles that don’t support the concept of waste (Pauli, 2015). Following the principle that “the output of a process is the resource of another one”, the concept of waste should be reconsidered. Residues obtained as results of manufacturing processes can be classified as by-products only if they respond to all requirements shown in Figure 1 (MATTM, 2017). Otherwise, they should be treated as waste. This standard is both an opportunity and a limit for alternative applications of manufacturing residues.

Figure 1. Conditions for classifying a residual substance as a by-product.

The opportunity to use them as by-products is essential to undertake tangible action towards circular supply chains. Materials and resources become strategically important in the design of production and consumption systems. Especially, the improvement of bio-based materials, composed of plant or bacterial resources, could produce a considerable effect on preventing environmental depletion. Bio-based materials are obtained by processes and technologies that allow their use in new fields of application (Genovesi & Pellizzari, 2017). Supply chains should respond to three main requirements to implement the circular approach:

1. improve the reuse of manufacturing residues looking at the “zero-waste” production;
2. promote the industrial symbiosis approach between manufacturing processes;
3. reinforce local supply chains.

The agri-food sector produces a huge amount of by-products and residues that could be used to create new valuable production processes and products (Bistagnino, 2011). Considering cereal processing inside mills, the most of residues are obtained during cleaning (mixture of dust, chaff, weed, seeds, broken and unprocessable grains) and milling processes (bran and wheat germ). The mixture of residues is not considered as by-product due to the complexity of characterization. While, bran, with high content of fibers and proteins, and wheat germ, rich in vitamins, proteins and oils, are classified as by-products suitable for human consumption and pharmaceutical usage (Grundas, 2003). Recent studies are
evaluating the opportunity to use these by-products for other applications (Kwiatkowski, 2006; Galanakis, 2018; Dietrich et al., 2018). These studies highlight by-products’ properties increasing also their economic value. Significant examples can be found also in the field of products, packaging and bio-based materials, but they could present some critical aspects linked to the land-use for cultivating plants for non-food purposes. The attention should be focused on highlighting the value of agri-food waste to overtake these environmental issues.

3. Progetto Glume: from waste to resource

Progetto Glume evaluates the opportunity to test new applications of organic residues for foodservice items and food packaging that present the urgency to replace plastics from fossil resources. The concept of “Glume” refers to the leaves of graminaceous plants that protect the caryopsis until it reaches maturity and they are separated from plants and collected during the cropping and cleaning process. The study was carried out in collaboration with the “Mulino Marino”, that since 1956 is a leading milling company located in Cuneo province (Piedmont Region, Italy). The province of Cuneo is mainly characterized by agriculture and farming economy of small and medium enterprises and in 2017 cereal cultivation reached 26% of the total agricultural area under cultivation. Annually, the company produces almost 420 tons of flours and it excels in the Italian scenario for the attention to environmental sustainability and process innovation.

In the first part of the study, the Systemic Design approach, in particular the Holistic Diagnosis (Battistoni et al., 2020), was applied to analyse the company’s materials flows (raw cereal grains, by-products, final products and waste) and to identify the main critical issues linked to organic waste. While the second part focuses on lab tests to evaluate the potentials of organic residues to create alternative food service items and food packaging, following a conceptual map of testing (Figure 2).

3.1 Material flow analysis

After the grain acceptance at the mill, it undergoes some pre-cleaning processes in order to separate the non-milling parts. Foreign matter, such as weeds, straw, stones and metallic foreign elements, are collected by compressed air machinery and sieves. Organic sand, composed of dust, non-regular grains and vetches, is obtained as the output of other consecutive cleaning processes that are carried out on grains. Before milling, cereal grains must be brushed and filtered by a vertical peeler, following the ATEX Directive (Atmosphere Explosive, ATEX 2014/34/UE) in order to reduce the risk of explosive dusts and ashes in the milling plant. This step is compulsory to maintain high standard levels of safety inside the plant that works at high concentration of dusts and using electrical machinery which could cause the trigger. Wheat husk [WH] is obtained as residue at the end of the peeling process and it cannot be classified as a by-product following current regulations (MATTM, 2017). Unsuitable grains for milling are separated by an optical sorting machine, while the suitable
part is conditioned and prepared for cylinder or stone milling. Flour, as the core product, and bran, as a by-product, are obtained at the end of the process. In 2018 the Mulino Marino has processed about 680 tons of grain obtaining 420 tons of flour. About 30% of raw cereal grain is lost as processing residues (Figure 3). Wheat flour and the first selection of bran is sold in HDPE package for human food consumption, while the other part of bran are sold as feed for the livestock industry (about 0.30 Euro/kg). On the other hand, organic sand and WH are not classified as by-products and they must be managed as organic waste, defining a critical issue for the mill. Considering the high quality of raw cereal grain processed by the mill, these residues could present properties that should be enhanced.

3.2 Qualitative analysis of organic residues

The characterization of these residues is the second step to evaluate the opportunity to reuse them for alternative uses. After processes wheat bran is stored following food management standards, minimizing risks of product contamination and alteration, while WH are collected in 25 kg bags and kept in an uncontrolled environment. Chemical analyses are carried out to assess their chemical composition, toxicological values, starches and protein values (data are available on request). Results assert that WH do not present any harmful toxicological value and they content noticeable values of proteins and fiber and about 20% of starch. The starch content is particularly important for the production of bioplastics as it is responsible for the phenomenon of gelatinisation (Lubis et al., 2018). However, the amount of starch should be increased to allow proper WH processing as a bio-based polymer, increasing cohesive property.
3.3.1 Vegetable polymer

This experiment is based on previous studies carried out by Jiang et al. (2016) and by the designer Pontus Törnqvist (The James Dyson Award, 2018). Looking at the Circular Economy and sustainability purposes, the starch used for tests, for increasing cohesive properties, is extracted exclusively from potato peels. The first step consists of the assessment of the percentages of amylose and amylopectin present in matrices of wheat and potato starch. Both of them present a range of 21-25% of amylose and 75-79% of amylopectin (Thakur et al., 2019).

The process to obtain the proper composition of the basic mixture is reached by gradually adding WH to a pure starch-based mixture for bio-polymer. This step is essential to assess if the addition of WH, as fiber, can cause adversities. Water is the solvent essential to dissolve starch crystals and moisturize WH fibers. The vinegar and lemon solution acts as an acid and it helps the ionization process in order to make the compound homogeneous. Glycerine gives more flexibility to the compound being a natural plasticizer. After gelatinisation, the samples are flexible and viscous, suitable for processing.

These proportions were indicated as Base Formula [BF], on which the following tests have been carried out to reach a Vegetable Polymer [VP] (Figure 4).
3.3.2 Manufacturing process

The BF is used to process the VP samples at room temperature, while the starch gelatinisation is done directly on the overheating phase. Preliminary tests are carried out to assess the performances of VP samples using wooden moulds under different compression times and at different drying conditions. Results of these tests are considered to improve the moulding process and the drying step.

First of all, VP samples are coated with waterproof and non-stick paper to allow a homogeneous gelatinisation process during overheating. This procedure limits the risk of dehydration of the samples surfaces exposed to contact with hot air. Furthermore, the coating avoids the adhesion of the sample surfaces to the mould surfaces during the moulding phase. The moulding process of VP sample is carried out by 3D printed moulds and counter moulds (Figure 5). Digital modelling and 3D print file generation are performed by Blender and Cura software, while printed moulds are obtained using the Anet A8 printer and Sunlu filament (PLA). Moulds shapes have sharp edges and inclined surfaces to improve the mechanical properties of VP samples.

Variables taken into account during tests concern the time of exposure to heat, the temperature reached on overheating and the drying temperatures. Drying conditions are decisive for limiting and controlling the retrogradation process of the material. VP samples are tested under different processing and drying conditions (Table 1).
Figure 5. Set of PLA moulds used to give shape to the vegetable polymer.

<table>
<thead>
<tr>
<th></th>
<th>T1(DC)</th>
<th>T2(DC)</th>
<th>T3(DC)</th>
<th>T4(DC)</th>
<th>T5(DC)</th>
<th>T6(DC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overheating</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>187°C</td>
<td>248°C</td>
<td>&gt;250°C</td>
<td>175°C</td>
<td>235</td>
<td>&gt;250°C</td>
</tr>
<tr>
<td>Timing</td>
<td>3’</td>
<td>5’</td>
<td>7’</td>
<td>3’</td>
<td>5’</td>
<td>7’</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inbound</td>
<td>19 gr</td>
<td>19 gr</td>
<td>19 gr</td>
<td>19 gr</td>
<td>19 gr</td>
<td>19 gr</td>
</tr>
<tr>
<td>Outgoing</td>
<td>10,2 gr</td>
<td>9,7 gr</td>
<td>8,8 gr</td>
<td>10,4 gr</td>
<td>9,5 gr</td>
<td>9,2 gr</td>
</tr>
<tr>
<td><strong>Drying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>25°C</td>
<td>25°C</td>
<td>25°C</td>
<td>7°C</td>
<td>7°C</td>
<td>7°C</td>
</tr>
<tr>
<td>Timing</td>
<td>48 h</td>
<td>48 h</td>
<td>48 h</td>
<td>48 h</td>
<td>48 h</td>
<td>48 h</td>
</tr>
</tbody>
</table>

Table 1. Processing conditions test to find the basic formula.
The BF used to process the T5(DC) sample is taken as reference for subsequent tests, to assess which mechanical process is the most suitable for VP material. Base Formula has been exposed to lamination, compression at high contact temperatures and extrusion.

Simultaneously, experiments on the moulding of tableware were carried out in order to investigate the samples’ deformation using different PLA mould and countermould. The texture of their internal surfaces is accentuated in order to fragment the surfaces and reduce tension during the drying phase. Mould’s internal surface mesh allows the samples to lose humidity uniformly without temperature changes. Moreover, a dehydrating machine is used in order to limit retrogradation and to better control the drying process (Figure 6). Scraps obtained by pressure mouldings are collected and left to dry without specific constraints. After retrogradation, they are crushed and placed under pressure at high contact temperature (160°C), obtaining the melting of all fractions. This result highlights that VP samples present properties similar to thermoplastics. Furthermore, the hydration of the fragments improves the (re)gelatinisation process.

Figure 6. Self-built dehydration machine.

3.4.1 Microbial cellulose

According to From Peel to Peel project (FPTP) (Sicher, n.d.), the interaction between food-waste and microorganism can generate potential new materials. "SCOBY", the acronym for the Symbiotic Colony of Bacteria and Yeasts, is usually used to produce fermented foods, such as vinegar or Kombucha. This bacterial culture presents distinctive chemical-physical properties to be used as a starter to grow microbial cellulose through sugars fermentation: an extracellular polysaccharide produced by some bacterial strains such as Acetobacter,
Agrobacterium, Gluconacetobacter (Rangaswamy et al., 2015). It represents an alternative to vegetable cellulose and it is already applied in medical and food sectors. Environmental conditions of microbial cellulose growth are essential to define the final result. Parameters such as carbon source, nitrogen source, temperature, pH and type of sugars influence the generation process. The key qualities that lead to testing the WH potential through microbiological transformation are:

- Specific surface area;
- high water retention;
- excellent mouldability;
- tensile strength.

Tests are carried out to validate whether wheat husk could feed this bacterial culture, since WH is composed of starches. Moreover, WH contains residues of graminaceous plants and its values are similar to straw, already used in unconventional fermentation to produce bacterial nano cellulose (Corujo et al., 2016).

3.4.2 Manufacturing process

According to FPTP experiments and the results obtained by the Production of Microbial Cellulose by Tea Fungus (Shehata et al., 2007), the WH experiment was set up using the SCOBY from Fermantaholics.com and 3 tempered-glass tanks for culture growing. The percentages of elements for bacterial culture growing are calculated starting from 1 l of water (Table 2). SCOBY is placed into emulsion after mixing all elements. Tanks are covered with fabric to allow the respiration process and to avoid dust contamination. The temperature is set between 22-25°C.

After 3 weeks, the layers of bacterial cellulose are extracted from the emulsions. Results of the tests showed that tank 3, containing WH as a nutrient for bacterial culture, is the best in terms of microbial cellulose growth. The Microbial Cellulose [MC] layer is grown over the entire area of the emulsion and it reaches the maximum of 1.8 cm of thickness. The layer is left to dehydrate upon a grid frame to promote ventilation. Once dehydrated, mechanical tests are carried out on the MC to evaluate its properties. The MC layer is rehydrated and stretched between two transpiring surfaces in order to obtain a thin film. Both two layer’s sides are clamped to prevent deformation during the second drying phase. Fans are used to maintain ventilation and to avoid mould contamination. After this step, the MC is pulled out from frames and it looks like a thin and tough film.

<table>
<thead>
<tr>
<th></th>
<th>T4(DC)</th>
<th>T5(DC)</th>
<th>T6(DC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat husk</td>
<td></td>
<td></td>
<td>5%</td>
</tr>
</tbody>
</table>
Table 2. Percentage of the elements for bacterial culture medium.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinegar</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Sugar</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Green tea</td>
<td>5%</td>
<td>5%</td>
<td>-</td>
</tr>
</tbody>
</table>

Before dehydration, the MC shows excellent tensile strength and high malleability. These characteristics suggest to test it as a bio-based material for packaging. A moulding test is performed to transform the film into flour packaging. The test foresees three steps of transformation: three-dimensional forming of the film and sealing of the flaps; folding and closing of one end; fill the pack with flour and close it by sealing. Firstly, the sample is slightly hydrated and wrapped on mould; two edges are joined, folded and pressed to be welded by compression. Secondly, the bottom of the sample is made by folding and compression of the lower end. Finally, after pouring the flour, the upper ends of the sample are sealed by moisturizing the surfaces that are bent and compressed. The result is a prototype pack (Figure 7).

Figure 7. Detail of the sample manufactured by artisanal process.
Scraps of MC layer are hydrated to reduce their stiffness due to natural moisture loss and to make them highly malleable. Two moulds (hemisphere and truncated cone) are used as a three-dimensional shape on which the MC residues are manually laid and compressed. The presence of water makes the residues adhere to the moulds and single fragments blend together without being more recognizable. The detachment from the moulds does not present problems of adhesion between their surfaces and MC samples easily take the same shape of moulds.

4. Discussions: critical issues and positive aspects

Main issues are related to material deformations during the drying processes: water loss leads to results that are difficult to control. In the case of VP, samples shrink by about 1 cm and the thickness decreases from 2 to 1 mm once dried. The same phenomenon is observed for the MC which drastically reduces the thickness from 1.4 cm to 0.007 cm. The VP samples with less post-drying deformation are those processed with compression at high contact temperatures (160°C): however, this process requires high energy consumption. The drying process has a significant effect on the mechanical properties of samples. Therefore, it is necessary to perform tests in a controlled environment monitoring the below parameters:

- Air circulation;
- Temperature and pressure changes;
- Influence of external light (especially for MC processing).

The VP experiment shows that the temperature between 60° and 70°C is the optimal condition to promote a low viscosity fluid state. Once the 90°C threshold has been exceeded, starch processing is not possible, compromising the final result.

MC tests present the processing timing as the main critical issue, especially compared to other industrial materials. 3 weeks are necessary to obtain an area of 0.28 m² with a thickness ranging from 0.8 to 1.8 cm. Another negative issue concerns the control of acetic fermentation during MC formation: only a part of the film is cohesive and compact. Temperature changes can generate spontaneous contamination by other bacteria strains that compromise the uniformity of the surface layer. The well-formed portion of MC is generated close to the bacterial culture starter (SCOBY). Therefore, the amount and placement of SCOBY used as a starter affect the final result. Nevertheless, positive aspects are related to the possibility of generating bio-based material using a low amount of energy and without fossil-fuel components. Materials obtained don’t present any physical or chemical constraints to deny their reintroduction into different production chains, nor do they contain elements harmful to the composting phases.

Positive aspects of VP processing concerns the preparation of the mixture before gelatinisation that can be carried out at room temperature (20°-25°C). VP samples reach a
volumetric detail of 1 mm thanks to compression processing, while the most performing manufacturing processes are lamination (minimum thickness reached 0.5 mm) and compression at high contact temperatures, because the sample gelatinizes and takes shape simultaneously. VP can be compared with thermoplastics because VP scraps can be easily re-processed.

Microbiological processes to obtain the MC don’t require energy: the cellulose layer naturally grows on the whole surface in contact with oxygen. This process presents innovative aspects that look at the hybrid frontier of biodesign. Biodesign approach incorporates living organisms (bacteria and yeasts) into design processes as essential components (Myers, 2018). This property allows designing custom two-dimensional configurations, eliminating the production of waste from any shaping or cutting. The culture of bacteria and yeasts regenerates itself by "new" fermentation. Unlike traditional material processing, it has the ability to generate new microbial cellulose as a starter for subsequent production. MC generates two residues: solid and liquid. The solid part is composed of fermented WH that can be gelatinized following the VP procedures. While properties of the liquid fraction have not yet been characterized. These two residues are biological matrices that should be optimized.

5. Conclusion

The goal of Progetto Glume is to explore new strategies to optimize and validate the transformation of milling waste into by-products and bio-based materials through the application of an experimental approach. The study highlights many positive aspects and some constraints that should be considered as challenges for future steps. Critical issues should be taken into consideration as an opportunity for the development of WH’s validation tests and to define possible future scenarios. Future challenges can be organized into two main areas: the first one focuses on translating the handcraft approach to industrial one considering VP’s and MC’s mechanical performances, while the second one designing the system of local supplier (mill companies) and product processors. The research project promotes sustainable development strategies that acts locally. Indeed, future challenges include the involvement of small and medium-sized enterprises in cereals transformation sector that are able to exploit their residues reducing the environmental footprint, the exploitation of natural resources and economic costs for waste management. Project improvement should focus on design engineering, on testing VP’s and MC’s sustainability, compostability and their compliance with current regulations. The handcrafted approach adopted in the experimental research highlights that both proposals present a high potential for improvement and application in an industrial way. The abundance of locally ground cereal and the low energy requirements for waste transformation processes are the key aspects of the project. For effective development, Progetto Glume needs to create a multidisciplinary research team composed of professional figures from different fields such as biotechnology, engineering mechanics and materials science. Mill industries, feed mills
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and malting plants are playing a key role in the project because they provide waste/resources for the project development. Progetto Glume is inspired by many people working in the cereal sector, agriculture and design with the aim to involve and connect people of different work and research fields. This study suggests a joint-venture of design manufacturing for sustainable and strategic development in relation to the territory and its resources.

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Acknowledgements: We would like to thank Mulino Marino, in particular to Fausto, Flavio and Ferdinando Marino, for their collaboration to the research project.
Re-distributed manufacturing in makerspaces. Towards a model of sustainable production.

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Abstract | This paper examines the current trends within the «making» landscape and brings forth a vision for the future evolution of the role and status of makerspaces in local communities. It does so by bringing together observations from several Danish makerspaces and the insights collected during a subsequent design experiment. This tangible, empirical and design-influenced data is contrasted and analysed throughout the process using a range of relevant literature, touching on the topics of Maker culture, distributed manufacturing, and their sustainable implications. The outcomes of this research process describe the ongoing transition taking place within the Maker movement. They also give a sense of how it is perceived from a design perspective. The paper sets out the potential that makerspaces represent in terms of local manufacturing, circular economy, and collaborative work, while highlighting the difficulties and challenges that such a vision will have to overcome in order to be achieved.

KEYWORDS | MAKERSPACE, RE-DISTRIBUTED MANUFACTURING, ENVIRONMENTAL SUSTAINABILITY, FUTURE MODEL OF PRODUCTION, DESIGN-BASED RESEARCH
1. Introduction

This paper takes its start point in the identification of a literature gap concerning productive aspects of makerspaces by Hennelly et al. (2019). They point out a “distinct lack of in-depth case study work”, as well as missing analysis of makerspaces’ “role in building local productive capacity”. Therefore, the present research, through the use of case studies and design methods, aims to contribute to the exploration of this field by investigating the possibilities that are opened up by a makerspace-based decentralized model in terms of re-distributed manufacturing.

The first makerspaces, Fablabs, demonstrated at the beginning of the 21st century the transition from virtual to physical, from bits to atoms, with the promise to allow everyone to build everything (Anderson, 2012; Gershenfeld, 2012). As they spread, the original layer of tinkering was supplemented with a layer of education and empowerment. This is now leading Fablabs to be more and more integrated within public spaces and educational institutions, as they are seen to elicit creativity and provide a culture of technology and hands-on experiments (Barrett et al., 2015).

Nevertheless, the evolution of original Fablabs also led to the emergence of other typologies of makerspaces. Hennelly et al. (2019) categorize them in three types: «Type 1 - educational and concept design; Type 2 - design and prototyping and Type 3 - prototyping and production», categories which will be used as a theoretical frame in this research.

In light of the current environmental and societal pressure, this paper premises that the conscious development of more production-centred makerspaces – above-mentioned Type 3 – could greatly disrupt our present manufacturing and consumption patterns, enabling more collaborative, reflective and sustainable behaviours (Kohtala & Hyyssalo, 2015; Kostakis et al., 2016; Millard et al., 2018). The possibility presented here is that that Type 2 makerspaces will fade and make way to a bipolarization of makerspaces offer, and that the remaining poles will nurture each other in a symbiotic relationship.

These conjectures, beside taking their roots in a review of contemporary theory, are the result of an investigation consisting in two loops of Design-Based Research. The first step is based on the observation of four case studies from the region of Copenhagen, Denmark. The results from this phase were subsequently used in the elaboration of a design experiment – the second loop.

2. The case studies

The ethnographic inquiry at the base of this paper started off with the setting up of four case studies. Yin (2003) was used along this process as a framework to assess both the design and the conduct of the studies. Yin provides the current matter with an interesting definition when he writes that a case study “investigates a contemporary phenomenon within its real-
life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2003, p.13). Within each case, Pink’s (2015) precepts for sensory experiences of places and people also guided the initial passive understanding. More active methods, mainly semi-structured interviews, were subsequently used.

The choice of the cases was motivated by the will to collect contrasting observations to provide empirical backup to Hennelly et al.’s (2019) above mentioned classification. The Copenhagen area was targeted for its relatively wide range of makerspaces, some of them organized in emerging structured networks. Four cases and therefore four sets of observations were conducted during the time of the study.

2.1. The cases

The first case was conducted at FabLab Copenhagen. This observation holds a specific role in the study since the FabLab network has for long been communicating a clear focus on technology education, sharing and non-profit, volunteer-based business model (Massachusetts Institute of Technology, 2012). These characteristics undoubtedly place it within the scope of Type 1 makerspaces (Hennelly et al., 2019), directing its efforts toward openness, knowledge sharing, and hands-on experimentation. Therefore, it became a sort of benchmark for ensuing cases, mainly regarding the assessment of their typology.

FabLab Copenhagen’s premises are certainly the first evidence of the institution’s practicality, as it is hosted in former sport facilities, made available by the municipality. It therefore consists in a succession of changing rooms, repurposed as different workshops corresponding to different technologies. These latter range from desktop 3D printers to laser cutters, vinyl plotters and more traditional power and hand tools. During the observation, several people coming and going hinted at the openness and informal aspect of the place. However, one of the interviewed superusers specified that since the recent acquisition of bigger, expensive machines that the FabLab «can’t afford to lose», the presence of a supervisor was required to control the access.

The second observation took place in Helsingør, at the open workshops of the recently opened Centre for Art, Design and Technology (CATCH). The makerspace is part of a cultural and leisure offer comprising a library, an exhibition hall and a food court, hosted in a mix of newly built facilities and repurposed shipyard warehouses. Beside the small 3D printers and electronic tooling found in the main building, bigger machines – CNC milling, laser cutting and power tools – as well as workbenches are available in the warehouses. The location of this makerspace as well as its short existence are plausible explanations to the very low attendance experienced there, later confirmed by an interview with the workshop manager.

The third case was conducted at Underbroen, at the heart of Copenhagen. The workshops – displaying similar technologies as in Helsingør – as well as the several working or meeting areas accessible there are placed in a succession of decreasingly sized rooms, making the most of this unique space (it is part of a bridge pier). The institution benefits from a robust
community, that was described by one of the founders as an “even mix between businesses and individuals”. This distinction is reflected in the available memberships, full-time or evening access, from which Underbroen is mainly financed. This mix of audiences was confirmed during the main observation: from the relatively large amount of people using the space that day (mainly occupied doing computer work in groups or operating the laser cutter and 3D printers), short informal interviews allowed to determine that both start-ups and non-professionals were present. A second visit on a different day gave evidence of lower attendance periods, demonstrating the difficulty to establish presence patterns (Klemichen et al., 2018).

The fourth case was organized at the Beta Factory, in the district of Sydhavn. This makerspace, hosted in large industrial facilities, features two distinct workshops with heavy-duty wood machinery. The first one comprises large wood-oriented digital tools (CNC milling, laser cutting) as well as fixed power tools, while the second offers different metal-oriented machinery. Besides that, an industrial-grade CNC sheet processing machine was being installed during the observation. Members are also provided with workbenches, material storages and dust-free areas. Despite offering the same membership plans as Underbroen, Beta Factory is much more business-oriented, both towards craftsmen and start-ups. Members, besides their own activity, also work together on collaborative projects whenever Beta Lab – the umbrella organization – receives projects requiring different skills. Different informal talks with the craftsmen highlighted the permeability between fields of competencies, as well as the exchange of skills and knowledge. A meeting gathering all the members present that day to discuss the optimization of the workshop areas confirmed the communal aspect in the management of the space (Figure 1).

Figure 1: An example of members-based decision-making at Beta Factory.
2.2. Report

The cases, selected to provide this study with contrasting data, proved to be very different examples of makerspaces. However, despite the obvious distinctions, they also showed some interesting converging trends.

The observation of the FabLab confirmed the expectations regarding Type 1 makerspaces and helped setting the benchmark standards. The openness as well as the “system D” approach were palpable. Nevertheless, it is tempting to see dynamics of expansion in the acquisition of bigger machinery. Dynamics which were interestingly also visible in Beta Factory, although in a dissimilar context.

In Helsingør bigger tooling was also observed. However, this part of the workshop really appeared under exploited, and the offer found in the main premises proved to be similar to the one at the FabLab. In addition, the overall cultural supply displayed by the CATCH and the obvious wish from the municipality to use this space as a technology-centred mediation tool makes it a good example of Type 1 makerspace. Yet it will be interesting to observe its future developments, as interviews raised evidence of a nascent networking with artists and businesses.

This business perspective is already omnipresent at Underbroen. Strong insights were provided in that sense, by the interviews with professionals as well as by the observation of a meeting held with a delegation from a big furniture company. However, these insights also revealed that what professionals found in that place is an experimental ground, at best a prototyping one, this being explained both by the location – close to other businesses – and by the limited available space. Underbroen was therefore deemed to be a Type 2.

The space constraint did not exist at Beta Factory, and the business aspect was also particularly tangible. Moreover, it displayed noteworthy dynamics in terms of internal organization, translating the FabLab’s mutual aid and sharing philosophy in a professional context. In that sense, the occasional formation of skill-based “taskforces” to answer productive challenges was also decisive in assessing Beta Factory as a developing Type 3 makerspace. Although its current activity is not so much an example of re-distributed manufacturing – most of the craftsmen are working on one-offs, for example for the event sector –, it undoubtedly displayed a great potential to one day host such local, crafts-based production.

The presented case-studies undoubtedly brought empirical evidence in favour of a makerspaces categorization such as the one proposed by Hennelly et al. (2019). Even though it has to be acknowledged that makerspaces represent an eclectic group of entities, with different focuses, approaches or social implications (Klemichen et al., 2018; Barrett, 2015; Kohtala & Hyysalo, 2015), their level of professionalization and involvement in productive activities seems to provide a convenient measure in defining overarching typologies. This classification is important since it should inform and guide the adoption of conscious
strategies and policies for the future development of makerspaces, and hopefully towards the development of a viable decentralized manufacturing network.

3. The design experiment

Capitalising on the results of the case studies, a design experiment was constructed to explore further and contrast some of the collected data. The goal was to find out significant commonalities and differences between current typologies of makerspaces, to build upon in order to envision a plausible model of decentralized, community-based production system. Designers composed the experiment panel, as it was deemed their approach could help to identify both the potential and the flaws, both the commonalities and singularities, of the exposed cases, in pragmatic and forward-looking manners (Kimbell, 2012).

The experiment was crafted on the base of two methods used in design thinking (Friis, 2016). The first one, sometimes referred to as Investigate Opposites, is a data analysis exercise aiming at comparing two radically different entities within one field or group, to explore the gap left in between and the opportunities lying there. In this case, participants were introduced to two of the aforementioned case studies, the Fablab and Beta Factory, deemed to be situated at both ends of the makerspace’s spectrum – Type 1 and Type 3, from Hennelly et al.’s categorization (2019). The second method involved, Future Scenarios, is a speculating exercise where participants build on contemporary phenomena to imagine possible future evolutions for these phenomena. To ease the transition from one method to the other, the overall experiment was divided into three phases: Reaction, Confrontation and Projection. Figure 2 was produced to visually support the conduct of the workshop.

3.1. The phases

For the first phase of the experiment – Reaction –, the designers were split into two groups. Each group was assigned a case and given a time to familiarize themselves with it through a video montage of the actual space complemented with an audio record of a member from each makerspace describing the institution. An access to the websites was also granted, both to enrich the informative aspect and to inform about the communication strategies.

Then, the participants were asked to express their reactions and feelings on sticky notes that were then sorted according to four pre-established tracks: Institution, Technology, Social aspects, and Sustainability. Each track was defined using a list of keywords to make sure participants would reach equal understandings. It could be argued that the sustainability aspect is implied in the first three tracks, but it was decided to emphasize it as it has been proven to be often overlooked in similar contexts (Klemichen et al., 2018; Kohtala & Hyysalo, 2015; Millard et al., 2018).
Re-distributed manufacturing in makerspaces. Towards a model of sustainable production.

Figure 2: This graphic was showed to the participants in order to facilitate the conduct of the experiment.

For the second phase - Confrontation -, both teams gathered to briefly introduce the institutions they had been working with, before moving on to the presentation of their reactions, track by track. Along the subsequent discussion, the participants were prompted to start small debates around the different commonalities or singularities between the two models. All this second phase, as well as the third one, was audio-recorded and photographed for further analysis.

Thanks to the designers’ natural propensity to envision future potential developments, the conversation was easily conducted towards building future visions for makerspaces, the goal of the third and last phase - Projection.

Participants were thorough in reading current trends in the evolution of both types of makerspaces, then translating these trends in potential future scenarios and evoking both their strengths and flaws. They even touched upon how such models could be economically sustained. Some of the points raised during this phase played an important role in the elaboration of the conjectures presented in section 4.

3.2. Report

The results of the experiment will be broken down into the four tracks given to the participants: institutions, technology, social aspects and sustainable aspects. More cross-
category analysis and discussion will take place in Section 4. (Note that from this point and until the end of the present subsection, quotations marks were used to quote contributions from the participants, either oral or written.)

The Institution track was introduced with notions such as business model, membership system, philosophy, rules or codex, etc... Within this discussion, some points were made about the «functional» and «professional» aspects of Beta Factory’s set up, in opposition to the more «after-work club» look of the Fablab. If both were in turn described as «messy» and «chaotic», the aesthetic of the website and the work produced at Beta Factory were considered «design-oriented», while the free access to the Fablab and its non-commercial aspect raised questions about its business model.

Technology was the least discussed topic through the experiment, probably due to the fact that the Institution track had already absorbed some of the discussion related to the level of tooling. As for craft-related discussions, they rather took place within the Social track. In the end, beside the scale of the machinery, participants did not observe a clear difference between the two case studies. A consensus emerged around the mix of low and high tech in both spaces.

The Social track, together with the Institution, gathered most of the reactions, which could be explained by the intrinsic collaborative characteristics of both places, as well as by the human-centred approach of most designers. Observations mostly orbited around the sociality of making found in makerspaces. For Beta Factory, it was seen as the possibility for «like-minded people» to work in a «community hub» that allows them to «interact with their immediate neighbourhood». In the case of the Fablab, it is more the «focus on sharing» and more widely the social inclusion and low skill threshold which caught participants’ attention.

Even though it seemed clear to the participants that sustainability was not at the heart of makerspaces preoccupations, they identified shared trends of both conscious and unconscious sustainable behaviours. The local «reuse of materials» and «sharing/donating» were among the conscious ones, while the Fablab’s initiatives to build product from discarded material, and Beta Factory’s shared entrepreneurial facilities were cited as unconscious sustainable features, both environmentally and socially.

4. Analysis and Discussion

From the results of the ethnographic inquiries displayed above, this section aims to identify patterns that could be further explored and harnessed in the perspective of a transition towards a productive makerspaces landscape.

Beyond the useful but static classification of the case studies, it is essential to consider the transformations at stake. In the context of this research, the main identified pattern is a bipolarization of the makerspace’s spectrum.
Re-distributed manufacturing in makerspaces. Towards a model of sustainable production.

Figure 3: The participants first familiarized with their given case in groups, before sharing their insights and observations in plenary. The contrasting between cases led to the exploration of possible future scenarios regarding the development of makerspaces.

4.1. Towards Two Complementary Poles

The first premise of this paper, building on Hennelly et al.'s work (2019), is that Type 2 makerspaces will progressively disappear and be absorbed by the two other types. This will firstly stem from the emergence and enhancement of more makerspaces embracing the productive aspect of digital fabrication – Type 3 –, invigorating short supply chains and local economies. Beta Factory gives a good example of this transition, originating in the impossibility for Underbroen to accommodate the productive ambitions of both its founders and some of its members.

This evolution was perceived, during the experiment, as a way to add to the Maker movement a higher level of craft and expertise, as well as to sustain «craftsmanship and make sure that craftsmen will persist in the future». This combination of craftsmanship values, sometimes compared to the original hacker ethic (Himanen, 2001), and digital tools of communication, conception and fabrication, represent a real disruption potential (Micelli, 2015). Incidentally, an increasing number of frameworks now advocate for “globally connected, locally productive” models (Fab City Global Initiative, n.d.)

Nevertheless, there is a risk for Type 3 makerspaces to be taken too far away from their Maker-based roots, following the same path as the “sharing” economy with examples such as Uber and Airbnb. The Maker movement being absorbed back into business-as-usual is in fact one of the three potential scenarios derived from the two years long European Make-it program (Sbeih, 2017). In the Copenhagen context studied here, the yellow line might be
quite close. With the high running costs induced by the rent and the energy consumption, Beta Lab is in need of big projects and partners coming from the outside, which could eventually divert them from the forward-looking decentralized model they started setting up (Javelle & Péché, 2013).

This concern is obviously not a plea to slow down the move towards productive makerspaces but more an invitation to operate this move reflectively, in order to avoid these shifts to generate «negative patterns with unfortunate consequences» (Stewart & Tooze, 2015).

The second expected dynamics of this bipolarization process are the strengthening of existing educational poles. Through their accelerating implementation in diverse public spaces and educational institutions (Barrett, 2015), and with the increased awareness about the culture of making, it is believed that these spaces will gain agency as well as more design sensitivity.

This drift could be matched with the observed expansion of Fablab Copenhagen. This topic was also raised by the designers during the experiment, questioning what could be the consequences of such a scaling up.

4.2. Two Poles, One Hub

The second premise internalizes, while pushing further, some of Stewart and Tooze vision (2015) of the potential for educational makerspaces to prepare «a future generation of ‘employees’» for their productive counterparts.

This vision is the core contribution of the design experiment to this paper, and perhaps the core postulate of the paper itself. The anticipated bipolarization, instead of creating two very discrete entities, could rather give birth to a duo, or Hub. Considering simultaneously the role of super users in the Fablab organisation and the sharing of skills and knowledge already taking place at Beta Factory, the experiment participants quickly visualized the potential of bridging these two into a single loop. Instead of paying for their membership, willing craftsmen could facilitate introductions to certain skills, as superusers do, therefore substituting money flows with knowledge ones andreviving a commons-based economy (Kostakis et al., 2016). Hobbyists would benefit from experts’ supervisions and have the choice to keep their activity as hobbies or to scale it up in the adjoining facilities.

This theorized Hub would provide communities with locally produced goods and services, as well as with a pool of locally shared skills and competences. Municipalities and regional political bodies, in return, could provide support through subventions and public sector partnerships. It is believed that making this fabrication culture more visible and desirable will ease the shift of current consumption habits towards more conscious, sustainable and local behaviours (Clune, 2010; Shove, 2003). The Hub could also become a favourable platform for the emergence of “local discontinuities”, easing the generation of sustainability through social innovation (Manzini, 2015).
4.3. Towards a Sustainable Model of Production

By drastically shortening supply chains and reorganising the economy around distributed Hubs; by empowering people and communities through a culture of making and a strong local alternative to global-market goods; by establishing tight connections with both local political bodies and SMEs; it is strongly anticipated that the above-described shifts could deeply impact the current societal model. The focus would then be moved away from profit-making only, allowing a true path towards sustainable development, or, in a more utopian but enviable vision, a path towards the true «roots of sustainability» (Erhenfeld, 2005).

It is shown that, at the moment, environmental sustainability is not at the core of Makers preoccupations (Klemichen et al., 2018; Kohtala & Hyysalo, 2015; Millard et al., 2018). However, the case studies and the design experiment indicated that, despite this lack of attention, local making and manufacturing practices are already embedded with a number of unconscious sustainable behaviours. This is inherent to the nature of the Makers and Hackers movements (Kohtala, 2015; Himanen, 2001).

Besides the environmental aspect, there are signs that the Makers movement is already generating great social sustainability (Kostakis et al., 2016). Furthermore, the experiment laid the foundations for an economically sustainable re-distributed model of production.
These existing patterns only need to be fostered and, in certain cases, guided to meet their full potential (Klemichen et al., 2018). Progressively integrating more links of the design chain within makerspaces will give them more agency and, it is hoped, generate a bigger impact. Finally, moving away from Type 2 makerspaces will help establishing them more as truly local institutions and less as incubators for ideas to enter back the globalized market afterwards.

5. Conclusion

In an attempt to open new perspectives towards more preferable futures, this paper advocates the implementation of a strong decentralized, re-distributed manufacturing model. Its main postulate is that this vision could be met by guiding more makerspaces towards productive purposes, and by operating them in parallel with existing education-oriented spaces. It is expected that the newly created Hubs will play a big role in diffusing a «making culture» within local communities or, at least, in raising the awareness of these communities about their disruptive power.

It would of course be incorrect to consider the case studies presented in this paper as the sole and entirely representative reflections of the current makerspaces landscape, mainly because of its heterogeneous nature. However, they give real-life examples of a possible model of development for these spaces.

The future of makerspaces as well as the path to decentralized production in general are highly uncertain, and subject to a number of threats that could spoil their original discourse and ethos. But this paper aims, building on the visions of numerous other authors, to look beyond the inevitable and apparently inexorable. It urges the concerned stakeholders – makers, designers, educational institutions, politics and potentially everyone – to join forces towards preferable futures that could sustain and gather communities around values such as respect, collaboration and sustainability.
References


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Louis Rose is a post-industrial designer. He strives to generate genuine sustainability by investigating alternative models of production anchored at the local scale: models which promote a wiser use of human and natural resources alike.

Acknowledgements: I would like to thank Ulla Ræbild for insisting that I should bring this paper to the world, as well as Richard Herriot and María Vitaller del Olmo for providing precious feedback on the way to the final form of this paper.
Research on the Application of Lacquer Craft in Modern Accessories

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Abstract | From the perspective of the environment, mood, behavior and significance, the present study analyzes why and how Chinese lacquer is applied in modern accessories. A bodiless rapid prototyping method is proposed in the study for accessories coated with Chinese lacquer, and a drying method is put forward for 3D-printed metal materials coated with Chinese lacquer. The feasibility of the two technical solutions is verified by experiments. Finally, from the perspective of future opportunities and challenges, the study analyzes the environmentally sustainable value of lacquer and people’s demand for lacquer accessories, and looks forward to the lacquer craft assisting Chinese accessories manufacturing industry to upgrade and transform.

KEYWORDS | LACQUER CRAFT, ACCESSORIES DESIGN, TRADITIONAL TECHNOLOGY, RAPID PROTOTYPING
1. Research Background

“The Inheritance and Innovation of Chinese lacquer” has been a hot subject in the design and craft research field of East Asia (especially China, Japan and South Korea) in recent years. To apply traditional craft elements in modern design has become a consensus within the academic circles and a hotspot of attention of today’s craft artists and designers. Throughout the history of craft development, craft has been corresponding to art all the time. “Art is created for appreciation while craft is born for a practical purpose”\(^1\). Inheriting the traditional craft in the modern society does not mean documenting and reviewing the craft only, but also means returning it to the original concept of “craftsmanship” to primarily meet living needs. “Usage” values are more important than “ornament” values. For this reason, “usage” must be blended with “ornament” to make the traditional craft adapt to the modern society.

Lacquerware used to be indispensable articles in the Oriental society and infiltrated in many sectors such as food utensils, furniture, ornaments and architecture. Unlike royal ornamental lacquerware and modern lacquer artworks, long-standing lacquerware for daily use does not provide an amazing visual effect, but it can meet our needs for production and living. The same is true for accessories. An exquisite crown stands for the status and power like a piece of royal lacquerware, displayed in museums to be appreciated by visitors; however, most accessories (e.g., bags, footwear, hats, cuffs and brooches) are nothing more than articles requisite for common people like lacquerware for daily use. Not only are they used in everyday life, but they make us move with ease. On the other hand, lacquerware for daily use is slowly disappearing from life for the reason that the traditional lacquerware prototyping method is time-consuming, costly and complicated, and that many new materials have come into being along with the development of modern technology. Will Chinese lacquer remain useful? In the present study, the author tries to review material performance from the perspective of an accessories designer and then points out the application values and methods of Chinese lacquer in modern life from the angle of accessories design by combining people’s needs for accessories with their aesthetic demand in modern society. Then, the author compares the traditional technologies by which lacquerware is made out of different materials, including wood, bamboo, cloth, paper and earthenware, from a Chinese lacquerer’s perspective, and conducts experiments on bodiless lacquerware using a new method and metal lacquering based on the modern prototyping technology, effectively shortening the production time and lowering the manufacturing costs of lacquered accessories.

2. Chinese lacquer performance and accessories design

2.1 The Application and Conflict of lacquer craft in Modern Life

Chinese lacquer, made from lacquer tree sap, is referred to as the “blood of the Orient”. It is a material that becomes increasingly bright-colored as time goes on, and has been used as paint in China for more than 7,000 years. In Asian countries such as China, Japan, South Korea and Vietnam, it can often be found that artists use lacquering technology to convey ideas. They have created lots of world-renowned works. Application of Chinese lacquer can also be seen in the works of art created by western countries such as France, Germany, the USA and Belgium. There is a Chinese idiom which goes, “cleave together as firmly and inseparably as glue and lacquer”. It suggests that in the Oriental history of technology, Chinese lacquer is an important binder. Mother-of-pearl inlay, gold foil, jade, crystal, pearl, coral, agate, tortoiseshell, lapis lazuli, turquoise, beeswax, agilawood……whether it is a rare gem or a precious metal or other common materials for accessories manufacturing, it can be inlaid on the surface of an object through Chinese lacquer, producing a magnificent and colorful visual effect. With high impact resistance, Chinese lacquer is used as a surface coating for lots of industrial products (e.g., fountain pen, camera, automobile and mobile phone) to enhance product performance. With a certain antibacterial activity, Chinese lacquer plays an important role in food preservation. Therefore, most of sushi plates are coated with Chinese lacquer. In addition, the physiological activity of laccase was tested in Japan, confirming that laccase has an antitumor activity and can inhibit platelet coagulation.

Although Chinese lacquer has many excellent characteristics, with the development of technology, lots of new compounds have been created as adhesives and coatings, which have basically replaced Chinese lacquer. Although the new substances do not have so gorgeous color or ultra-strong stickiness, and neither can they inhibit bacteria, prevent corrosion, resist acid or suppress shock, they can fully meet common people’s daily needs. Moreover, the cost is very low, and the molding or production process is very easy to operate. Therefore, almost none of Chinese lacquer is applied for the articles of everyday use. Tableware is primarily made of porcelain, glass and plastics while furniture and building coatings are made from chemical composed materials and clothes are decorated with synthetic metals and plastic gems……In the Chu and Han Dynasties of China, lacquer could be applied for everything, including clothing, dinnerware, housing and vehicles, but it is rarely seen in modern daily life. In the face of wide varieties of new materials, Chinese lacquer becomes increasingly substitutable. Compared with efficient and convenient new production methods, the complicated lacquer craft is to be lost. The splendor of daily lacquerware has disappeared. Except the exquisite lacquer artworks displayed in museums and galleries, we can only find its trace in luxuries, whose “ornament” values are more important than their “usage” values. The applicability of Chinese lacquer may be found out from the perspective of the “usage” of luxuries. Expensive lacquer products can be used as “components” and combined with rapidly

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2 Tetsuo Miyakoshi. Chapter 7: Minutes of Lacquer Science Conferences, 1993
producible parts; then, the production efficiency of “lacquer components” can be improved for mass production; finally, products with more “usage” values than “ornament” values may be created.

2.2 Lacquer’s performance and accessories design

In luxury goods, accessories (such as jewelry, glasses, watches, bags, shoes and so on) account for a large proportion, so that people pay attention to whether it can properly display taste and shape personal image in key occasions. They should not only be suitable for daily use, but also match clothes in a specific environment. What matters more is whether they can demonstrate personal taste and build a personal image on an important occasion. In the present study, a long-lived daily-use accessories design scheme with an aesthetic additional value is proposed based on the attributes and visual effect of Chinese lacquer. Taking presbyopia glasses for middle-aged and elderly people (figure 1.) for example, sandalwood beads, which can calm the mind, are inlaid at the root of the temple according to the health habits of Chinese middle-aged and elderly people. After reading a book or newspaper or playing with a mobile phone, they can take off the glasses and use the temple to massage their periocular acupuncture points to relieve eyestrain; the frame is composed of redwood, Chinese lacquer and mother-of-pearl inlay. Its color and texture tone in with middle-aged and elderly people’s dressing style, making wearers look simple, natural, quiet and easy-going. Taking a small bag suitable for a dinner party (Figure 2.) as an example, its volume and opening-closing pattern are clearly designed based on the quantity and size of contents taken to a dinner party in the bag; in consideration of the requirements for the user’s image at the party, the exquisite handicraft art is used to convey the Oriental taste and traditional culture. As for a brooch and handbag for daily use (Figure 3.), they are designed in line with a quiet, elegant, cordial and simple dressing style. The thick color of Chinese lacquer is blended with folding and cutting marks, giving office ladies a clean-cut look in daily life and the workplace.

Figure 1. presbyopia glasses
Research on the Application of Lacquer Craft in Modern Accessories

3. Feasibility study of bodiless rapid prototyping for accessories lacquering

3.1 Traditional bodiless lacquer prototyping technology

The bodiless prototyping technology came into being in China during the Warring States Period. It was widely used for the construction or production of Buddhist statues, architecture and daily necessities. Bodiless lacquerware is light and durable. Taking the lacquered plate with phoenix pattern painted on (as shown in the figure 4) unearthed in the Mashan 1st Tombs of Jiangling as an example, its shape changed a little, but the color is still bright and the surface is still flat although more than 2,000 years has passed. As for the traditional bodiless prototyping craft, the inner body is made in the manner of clay sculpturing, wood carving and throwing. It takes about 1 week to make a body only. After the end of body-making, the 3D surface layer is wrapped in ramie fabric. In case of morphological protuberance or shrinkage, the fabric is folded in the form of tailoring with the redundant plane cut away so that the ramie covers the 3D surface up. In this process, Chinese lacquer is used as a curing agent to harden the ramie and as a binder to make fibers adhere to the 3D surface. The redundant plane is often cut away unevenly, causing the formation of holes or humps on the surface of the ramie. In this case, Chinese lacquer needs to be mixed with plaster for filling. If Chinese lacquer is still not dried when used as a binder, surface fibers may easily be dislocated during filling, ruffling and deforming the ramie, making the surface rougher. To be dried, Chinese
lacquer needs to be placed in a shady room\textsuperscript{3} for over 12h. It cannot be mixed with plaster until the next day. In order to make the surface smooth, the plaster needs to be ground and filling needs to be repeated after drying. In this way, it usually takes about 1 week to smoothen the surface by covering the surface with a single layer of fibers and plaster. This process has very high requirements for the craftsman’s craftsmanship, and carelessness is bound to make fibers fail to be tight against the surface, further roughening the surface. The above steps often have to be repeated 3 to 5 times before the shell is strong enough to have the inner body removed. Even a skilled craftsman must spend about 1 month finishing the work. Costing high, this prototyping method is unsuitable for modern fast-paced production. So, it is rarely used for the production of accessories and daily necessities at the present time.

![Figure 4. lacquered plate with phoenix pattern painted on unearthed in the Mashan 1st Tombs of Jiangling](image)

3.2 Quick bodiless prototyping experiment based on accessories application

The use of modern technology to improve the prototyping efficiency brings about a total difference in every aspect, including inner body making. 3D modeling and printing was performed in the experiment, with only 2~3 hours spent in making a complex inner body. The ramie was not cut when used to wrap the body up. Instead, the multilayer sinamay prototyping method used for traditional European hat accessory-making was adopted. Since the coarse ramie fabric is woven both longitudinally and latitudinally, when it is pulled at a

\textsuperscript{3} A shady room is a device essential for lacquering and an enclosed space at temperature of 20-28°C and relative humidity of 70%-80%. Under the above environment, the urushiol in Chinese lacquer must fully absorb water molecules before a lacquer film forms and the liquid lacquer is solidified. The more humid the environment is, the faster the Chinese lacquer dries. When the relative humidity exceeds 80%, colored lacquer tends to turn brown with the lacquer film darkened and unable to be reduced. Excessive relative humidity has great effects on the color and glossiness of lacquer only, and has little effect on the form and hardness of the body.
certain angle, the density at the junction of the longitudinal and latitudinal lines can be changed to generate deformation. With a hollow structure, the ramie yarn becomes very resilient in water. So, after wetted, the ramie fabric was attached to the body with fibers straightened out by hand to adjust the density of the junction of the longitudinal and latitudinal lines in accordance with the body form until the fabric was deformed and tight against the body surface. After the 5 layers of ramie were basically prototyped in this way, it was removed layer by layer and coated with Chinese lacquer from inside out. Then, the ramie was attached to the body again and placed in a shady room until it was dried. When the outer layer was basically dried the next day, the inner body was taken off with the rest continuing to be dried in the shady room (as shown in figure 5.). On the third day, the inner and outer layers of the ramie shell became dry, but the Chinese lacquer on the middle layer was still liquid. Without the support of the body, the shell was severely deformed, so the inner body was stuffed into the shell gain so that the shell would be further dried. On the fifth day or so, the 5 layers of ramie were completely dry. With the body removed, the shell was placed in the daily environment for several months but was not deformed.

Figure 5. Quick bodiless prototyping experiment based on accessories application

For the use of this method, it takes only 3 days to do the work and only 5 days to have the shell fully dried. It takes a long time to make a body on the first day, but a much shorter time needs to be spent adjusting the body on the remaining 2 days. Compared with the traditional method, by which the prototyping process takes one month, the new method greatly reduces the time costs. In addition, this method is so easy that even an inexperienced primary or middle school student can do the work without difficulty. Compared with the traditional method, which requires a well trained craftsman to work meticulously with great care, the new method is easier to be promoted in the society. For a ramie shell made by the new
method, its hardness and impact resistance are obviously lower than that of the traditional ramie-assisted bodily lacquerware for lack of plaster support, but significantly higher than that of sinamay hat accessories and headwear. In addition, a body made by the new method has high water resistance, wear resistance, folding resistance and corrosion resistance. Dust in and around it can be washed away with water and daily detergent. From the perspective of accessories, a body made by this method can fully meet the requirements of daily use.

4. Research on the Application of Metal Forming Methods in Lacquer Accessories

4.1 Traditional forming methods and lacquer accessories

In addition to bodiless prototyping, the common bodies of traditional lacquerware are divided into the wooden body, bamboo body and ceramic body. The wooden body and bamboo body are made of wood and bamboo by the gouging method\(^4\), turning method\(^5\), rolling method\(^6\) and weaving method. The surface is coated with Japanese lacquer evenly. Because there are tiny holes on it, the plant surface needs to be coated with cloth and puttied (the same as the way single layers of ramie are wrapped and puttied in the step of body removal) to prevent the body from being wetted and deformed and the lacquer surface from being broken. The prototyping process usually takes 2~3 weeks. This type of body cannot be used for modern fast-paced production. Neither can it be used for production of light accessories such as bags and hats, owing to its large mass.

Ceramic forming takes a short time and is easy to operate. Some process steps, such as blank making, drying and firing, are the same as that of ceramic ware making. After it is made, the prime ceramic body just needs to be coated with lacquer. However, the ceramic body has poor impact resistance with high fragility. “Without the skin, where can hair rest itself?” After the body is broken, the lacquer on the ceramic surface will be no longer in existence. That’s why lacquerware with a ceramic or vitreous body is relatively rare. In addition, the sharp shards of a broken body are likely to

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4 The gouging method is a wooden body manufacturing technique, by which a sharp tool is used to gouge a solid log until the columnar wood is shaped like a bowl.
5 The turning method is a wooden body manufacturing technique, by which a solid log is cut with a sharp tool when it is rotating on a turning lathe until the columnar wood is shaped like a bowl or a morphological change takes place with the log turned into something like a vase, kettle or basin.
6 The rolling method is a wooden body manufacturing technique, by which a wood veneer or thin batten is soaked in water for a number of days until it is softened and then shaped like a barrel in a mold. After drying, the mold is removed and the barrel-shaped veneer or batten is lacquered.
cause damage to the human, so it is not a suitable body for accessories. 3D printing is one of the currently common rapid prototyping methods, and common printing materials include engineering plastics, photosensitive resin, rubber and metals. Although the above materials are light and durable, a lacquer film can hardly be attached to them owing to their smooth surface. If lacquer are dried in a shady room in an ordinary way, lacquer finish will scale off their surface, so the lacquer craft cannot be applied. According to a traditional lacquering technique, Chinese lacquer is baked for better coating ironware in order to protect it from rusting. So, for the combination of a 3D printed body with lacquer, the lacquer is baked when being applied to the surface of metals.

4.2 Experiment on lacquering a 3D printed metal body

Silver alloy and aluminum alloy, metals commonly used for 3D printing, are selected in the present study. First, a blow torch is used to burn the back of the two lacquered metals, according to the traditional metal lacquering method. Although the lacquer film is dried quickly, the lacquer finish may be ignited carelessly, causing failure because of carbonation. Chinese lacquer comes to the boiling point at about 200°C and to the ignition point at 450°C. The temperature of the blow torch is hard to control. In addition, if high temperature lasts too long, the hardness of the lacquer film will be affected, reducing the wear resistance of the coating.

As the experiment went on, a constant-temperature oven was used, and the hardness of the dried lacquer film was recorded. After lacquered, the silver alloy and aluminum alloy were baked at 150°C for 15min. The lacquer film surface was obviously viscous while the Chinese lacquer was brown but not so transparent. 30min later, lacquer film surface was slightly viscous, and the texture of the metal materials could be seen on the lacquer surface. 45min later, the lacquer film surface became dry, but an obvious mark could be left on the surface by fingernail pressure. 60min later, no mark was left by fingernail pressure, and the lacquer surface became more transparent; however, the hardness was not so high that the lacquer surface was damaged and metal body was exposed after it was ground slightly with 2000# fine sandpaper. There was no significant change taking place 75 and 90min later compared with 60min later. When baking lasted for 120min, the hardness of the lacquer surface was obviously enhanced and became resistant to the 2000# fine sandpaper. 150min later, the lacquer surface became resistant to the 600# moderately coarse sandpaper, and it felt hard in the grinding process. An experiment was performed at a constant temperature of 170°C in the same way. 45min later, the lacquer film became very strong, and felt harder in the grinding process than it did at 150°C 150min later. At a constant temperature of 190°C, there appeared speckles on the thin lacquer surface in the drying process while the thick lacquer surface was crinkled, but the surface became fully dry 15min later and the hardness became resistant to grinding treatment. The speckles might be due to an actual temperature approximately equal to the boiling temperature of Chinese lacquer while crinkling might be caused by excessively quick surface drying. There was basically no difference in lacquer surface between the silver alloy and aluminum alloy. As can be seen from experimental results, under the condition of
170°C and 45min, the lacquer surface was flat, hard and wear-resistant and rarely peeled off. This condition is more suitable for lacquering the surface of a 3D-printed metal material. A metal body wrapped in lacquer was barely visible and lighter than one made of the lower-cost aluminum alloy. The 3D printing method, which could also shorten the time of body-making, is better for the production of accessories such as headwear, jewelry and brooches as well as the hard parts of bags and belts. (As shown in Fig.6)

Figure 6. Daily accessories of Lacquer Craft such as brooches, headwear, jewelry

5. Research on the Application of Japanese Lacquer to Accessories Manufacturing

5.1 Sustainable value of Chinese lacquer for the environment

With current development of information technology and intelligent manufacturing, traditional lacquering craft can be combined into modern design and modern industry. In addition to solving the complicated and time-consuming production mode, we should also think about the sustainable value of Chinese lacquer for the environment so as to guide consumers to discover a new lifestyle, thus helping them form an environment-friendly and energy-saving consumption concept. Originating from nature, Chinese lacquer is a pure plant material. Chemical synthesis is not required for its refinement or deep processing. Lacquerware production is mainly in manual mode, with low energy consumed, suggesting that it is a process technology in harmony with the natural environment. After dried, Chinese lacquer is highly stable, acid-resistant, corrosion-resistant, waterproof and difficult to degrade naturally. The body is sturdy, highly impact-resistant and hard to break. Lacquerware is very difficult to damage fatally, and longtime use may just leave scratches on its surface, but it will be made new again as long as its surface is re-lacquered and polished in a simple way. Even
cracks can be repaired by the simple Kintsukuroi technique (a lacquering technique commonly used for restoration of historical relics). If you are visually tired of lacquerware that has been used for a long time, you just need to polish its surface finish rough and then redecorate its surface in another way to “change” it into a new object. Thus, the durability and variability of Chinese lacquer make it possible to effectively prevent people from discarding lacquerware at will after purchasing.

5.2 Continuous demand for lacquer accessories and its future application

Lacquer accessories are durable and can be handed down from the older generations of a family. Looking calm and quiet, Chinese lacquer boasts the Oriental elegance and simplicity, which enable it to match clothes for an impressing appearance on different occasions. Different demountable and easy-to-install lacquer components can even be applied to accessories made of different materials to meet many practical and aesthetic requirements. For example, these lacquer components can replace the metal accessories and ornaments on bags and shoes to form a wide range of accessories by combining with different materials, patterns and colors. It can also be made into modular multi-purpose accessories, such as used on scarves and cuffs to decorate formal wear or as earrings and key chains to match casual clothes. It can even be made into accessories used on mobile phones, computers, stationery and other products to decorate not only the body, but also a space. The emergence of universal and modular lacquer accessories can set a consumption trend, thus making it possible to provide the public with technical services including lacquerware maintenance, repairing and customization. If so, jobs can be created for lots of lacquerers to continue this traditional craft.

In the present study, the traditional lacquering technology is applied to the design of accessories not to change the traditional manufacturing technology, but to propose a futuristic lacquer craft’s survival mode as well as a kind of accessories production mode based on profound insights into scenes of life and manufacturing techniques. Although the daily necessities created by industrial technologies have greatly met our material needs, overcapacity has been caused, followed by waste of resources and environmental degradation. The fashion industry, to which accessories manufacturing belongs, is one of the typical industries troubled by overcapacity in China. In today’s China there are a large number of OEM of accessories, which have poorly-educated workers and thus can hardly make independent innovations in technology and design; for lack of advanced equipment, they can only produce low-quality products with a low added value. In the fast-paced and high-stress modern society, people have a preference for individualized and differentiated high-end accessories. Thus, for Chinese accessories manufacturers, they must transform their low-end traditional sub-contract manufacturing mode into creation of high-end brands with independent intellectual property rights. “The traditional technology is not merely a culture, but a productive force.”

Cultural integration is one of the important ways to increase the high value of the fashion industry chain more quickly. As the “all-round renaissance of the traditional culture” is promoted as a mainstream ideological trend in the Chinese society, the Oriental humanistic factors, including cultural accumulation and traditional crafts, make an increasingly significant value contribution to accessories manufacturing. By applying Chinese lacquer to modern accessories, “China fashion” can endow “Made in China” with a cultural connotation to set a new consumption trend and accelerate the transformation and upgrading of some accessories manufacturers from low-end production to high-end customization so as to further resolve the problem of overcapacity.

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The Emerging Fashion-Tech Paradigm in the Contemporary European Landscape.

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Abstract | Fashion-Tech is an emerging sector resulting from the intersection of design, natural sciences, engineering and business. The paper is aimed at exploring innovation trajectories of the emerging fashion-tech phenomenon in Europe. The work is structured in five sections aimed at giving a systematic overview of historical references and current experimentations. The first paragraph retraces the three industrial revolutions to pinpoint the interdependence of fashion and technology. The second introduces the 4.0 paradigm origin, technologies and configurations, offering preliminary insights on potentials deriving from its adoption in the Fashion-Tech industry. The third section illustrates the main challenges of emerging and established fashion-tech businesses. The forth section offers insights on possible trajectories for the long-term competitive advantage of the European Fashion-Tech industry, starting from the observation of the ongoing research agenda. The insights emerge from a multiple case study analysis of four fashion-tech design-driven innovation projects funded by the European Commission. Finally, the paper concludes identifying trans-disciplinary and cross-sectoral strategic partnerships as the key factors to effectively support the growth and development of the sector, leveraging on the European emerging ecosystems.

KEYWORDS | FASHION-TECH, ENTERPRISE 4.0, DIGITAL TECHNOLOGIES, PROCESS INNOVATION
Fashion and technology have always had a symbiotic relationship, interwoven paths, and mutual influences on both cultural and material level (Tomico, et al, 2017). Technological developments have always fostered process and product innovation in fashion and, at the same time, “fashion has always been a wearable expression of the technological state of society” (Scaturro, 2008, p.473). Evidence of this relationship can be demonstrated by retracing the evolution of industrial revolutions from the textile and clothing sector’s perspective, pinpointing their key role in shaping and disrupting both production and consumption patterns of fashion products, processes, and services (Duarte, et al, 2018; Bertola and Teunissen, 2018). This preliminary overview will lay the foundation to state that the emergent Forth Industrial Revolution, also referable as 4.0 paradigm, is going to influence and bring together actors from inside and outside the traditional sphere of the fashion system, involving existing and new stakeholders throughout all the stages of the value chain, challenging traditional dynamics, and introducing new consumption, production, and entrepreneurial patterns.

The First Industrial Revolution, historically located between 1760 and 1830, led to a general mechanization of manufacturing industries powered by water and steam technologies. One of the key and exemplar inventions fostering improvements in the textile industry was the Spinning Jenny, developed in Britain by James Hargreaves in 1764. It consisted in a spinning system that allowed to turn raw materials (i.e. cotton and wool) into thread processing at the same time from 8 to 16, 24, 80 and eventually 120 spindles (Bellis, 2010). Prior, weaving was performed at home by farmers who alternated spinning and weaving with work in the fields (cottage industry) or manufactured raw materials provided by merchant entrepreneurs (putting-out system). In both cases, workers could not fulfil the market demand for textiles, as the production of yarn and fabrics was time demanding and economically not sustainable. With the introduction of the Spinning Jenny and further improved models, as well as the development of fully mechanized looms, the domestic and artisanal handmade production was replaced with mass manufacturing of consumer goods coming from factories and textile industries. High production volumes and manufacturing speed led to the decrease of yarn and fabric costs, generating a greater availability of textiles for a wider audience at more affordable prices (Bellis, 2010; Duarte, et al, 2018).

The Second Industrial Revolution, occurred between 1850 and 1914, was characterized by an intense micro-invention activity in energy, manufacture, chemical, steel, and railway industries. Such clusters of novel inventions entered as never before into workers’ and middle classes’ daily lives increasing their living standards and their purchasing power, as consumers. Defined by Homburg et al. (1998) “science-based industrial capitalism”, this period presented an acceleration of connection and mutual feedback between science and technology, the emergence of large scale corporations gaining economic benefit from it and the spread of First Industrial Revolution technological systems, previously limited and localized, towards other European countries. Improvements in the manufacture industry
concerned the adoption of electricity as power source, the set-up of continuous-flow production process, the scientific organisation of labour and the mass production of interchangeable parts. Breakthrough developments in chemistry laid the ground for research, development and supply of new artificial materials and synthetic dyestuff. In textiles, progresses occurred gradually. The major innovation was the introduction of the sewing machine – perfected and patented in America in 1851 by Isaac Bashevis Singer – a machine able to replace hand-stitching, greatly speeding up the apparel making process. The annual production of sewing machines went from few thousands in 1853 to half a million units in 1870 (Mokyr and Stortz, 1998), becoming a mass-manufactured and mass-marketed consumer good, mainly intended for a domestic environment (Duarte, et al, 2018). On the other hand, mechanized machines for wool combing, spinning and weaving, mainly perfected in the US, started to be adopted and slowly spread only towards the end of the XIX century, due to the reluctance of adoption by European industries (Mokyr and Stortz, 1998).

The Third Industrial Revolution, also called the Digital Revolution, started in the 1970s and has been historically paired with the invention and development of microprocessors, integrated circuits and advanced electronics with computational capacity, and the spread of Information Communication Technologies (ICT). The integration of such technologies within the Textile and Clothing Industry led to a further automation of manufacturing activities (Bertola and Teunissen, 2018; Duarte, et al, 2018; Hermann, et al, 2015) increasing again production volumes, lowering prices, and fostering over-consumption patterns, leading to manufacturing delocalization to further reduce costs. From the industry perspective, since the 1990s, the combination of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software with ICT strongly influenced the evolution of design and production processes in the fashion system (Rose Sinclair, 2014). They enhanced connections among stakeholders operating along the supply chain, helping them managing the entire process in more seamless ways. In particular, the former sped the creative design process, making it easier to communicate it at different stages, the latter made the prototyping and testing process better connected and allowed a greater management of the different manufacturing phases. Moreover, from 2000s on, the emergence of Internet and the Web 2.0 led to a radical change in the user’s perspective and involvement. Digitally-mediated interactions disrupted the relationship between producers and consumers (Crewe, 2013), fostering Business to Consumer (B2C) and Consumer to Consumer (C2C) exchanges, giving rise to experiences of co-creation of fashion products and values (Prahalad and Ramaswamy, 2004).

In the last decade, an emerging Forth Industrial Revolution has been introducing a set of disruptive technologies and approaches, once again, promising to impact and challenge traditional industries and established systems, including fashion (Bertola and Teunissen, 2018). A key differentiation factor of the 4.0 concept, stressed by Herman et al. (2015), is that for the first time an industrial revolution is illustrated a-priori, not interpreted ex-post. This leads to multiple opportunities for different stakeholders, from research centers and
academic institutions to entrepreneurs and businesses, to dynamically shape the future (Herman, et al, 2015).

The present paper aims at exploring how the 4.0 paradigm could be implemented supporting emerging fashion-tech realities to grow and foster product, process and business model innovation. The reflection is limited to the European landscape, mostly including SMEs, start-ups, self-employed, micro-companies, and individual craftsmen (EC, 2012).

2. The Potentials of 4.0 Paradigm in the Fashion-Tech Industry

The Industry 4.0 (I4.0) concept was formalized in 2011, during the Hannover Fair in Germany, where representatives of politics, business, and academic institutions presented a future project aimed at implementing and strengthening the competitiveness of the German industrial sector leveraging on the possibilities offered by upcoming technologies (Hermann, et al, 2015). The support from German Government followed by integrating it within national strategic plans and, in 2013, Acatech—the German Academy of Engineering Sciences—shared a research agenda illustrating development recommendations for the Industry as well as the vision behind this model (BMBF, 2015). I4.0 aimed at the introduction of digitization at all stages of the supply chain, based on the development of cyber-physical systems/environments, on the integration of digital-mediated interconnected networks thanks to cutting-edge technologies enabled by the Internet of Things. Brunelli et al. (2017), from the Boston Consulting Group, listed nine I4.0 digital enabling technologies: Advanced Robots, Additive Manufacturing, Augmented Reality, Simulation, Horizontal&Vertical Integration, Industrial Internet of Things, Cloud Computing, Cybersecurity, Big Data and Analytics. From 2010s on, further initiatives spread all over Europe, and similar ones were being performed in the US and China (Hermann et al., 2015). Leveraging on multiple investigations involving both large scale businesses and start-ups, Brunelli et al. (2017) extract key learnings to support businesses in the set-up of an I4.0 implementation strategy. The findings are clustered in the following five lessons learned:

- Use Industry 4.0 to accelerate operational improvements,
- Integrate new and existing capabilities and technologies,
- Manage information architecture as a critical enabler,
- Thoughtfully design the transformation roadmap,
- Approach 4.0 as a change of managerial project.

In 2015, contemporary to the acknowledgement around I4.0, Klaus Schwab - the executive chairman of the World Economic Forum - introduced the expression “Forth Industrial Revolution” extending the conceptual paradigm shift to all disciplines, economies and industries, as well as people’s way of living. This revolution, built on the previous digital one, is characterized by the fusion and combination of different technologies blurring the lines among physical, digital, and biological worlds (Schwab, 2016).
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Being an international and cross-sectoral phenomenon impacting all industries, also fashion system stakeholders are starting to contextualize the 4.0 paradigm. Among the scholars investigating such scenarios, Bertola and Teunissen (2018) offer a comprehensive overview of the overall impact the 4.0 paradigm could have in the Fashion-Tech industry evolution:

“Digital networks and interaction can create an integrated system of actors, assets and stakeholders where not only supply-chains can be real-time tuned with the factory, but also retail channels and even products and final customers can communicate and exchange data within the system. [...] Therefore, decision making processes can be better informed by market and users demands, making of the factory a knot of a complex networked eco-system. [...] Consequently, all upstream manufacturing process (such as R&D, sourcing, inbound logistics etc.) and downstream functions (such as outbound logistic, retail, customer services etc.) should be included within the 4.0 architectural model.” (Bertola and Teunissen, 2018: p.353)

The scholars’ contribution suggests an interesting twofold reflection. On one side, it is argued that the introduction of disruptive technologies in the “smart factory” is by definition linked to the other actors and phases of the value chain, because they are integral part of the cyber-physical interconnected environment enabled by the 4.0 architectural model. On the other side, it implies that consumers and prosumers—producer + consumer—perform an active role, both conscious and unconscious, in the decision making process. As a matter of fact, the exchange of data is the basis of 4.0 concept. The efficient analysis and integration of such data generated by all interested parties could inform the product development process, if properly implemented (Duarte et. al, 2018).

Further potentials deal with trans-disciplinary approaches, at the crossroad of engineering, computer science, design, and business management, constantly and iteratively explored beyond the boundaries of the factory. The cross-fertilization of fashion with engineering and computer science is evolving the creative process, fostering experimental projects and paths (Musto, 2017) stimulating the development of wearable technologies, smart textiles, and systems as instruments to augment the self. Software developments and digital fabrication tools are giving rise to new industrial models where start-ups and digital craftsmen are able to deliver on-demand and tailor-made products (Mazzucotelli and Lunghi 2015), as well as promote locally designed and globally manufactured fashion products. At the same time, the democratization of such technologies is enabling figures like the Designer = Entreprise (Arquilla, Bianchini and Maffei, 2011) to grow and approach the market. The opportunities offered by the integration of Augmented and Virtual Reality technologies and processes in the downstream of the supply chain are trying to disrupt the retail customer experience, developing more and more sophisticated phygital—physical and digital—spaces (Chastel et al. 2019). 3D modelling and simulation technologies are redesigning the way apparel and accessories are experienced, from digital fitting towards products designed to live in the digital domain only. Big Data and analytics as integral elements of the infrastructure could nurture the whole system, from production processes optimisation to consumer demand anticipation. While existing technologies such as RFID (Radio Frequency Identification) and
NFC (Near Field Communication) embedded in textiles and accessories, are starting to be adopted not only to improve supply chain management, security, monitoring and tracking of resources (Nayak, Singh, Padhye and Wang, 2015; Garrido Azevedo and Carvalho, 2012), but also to improve in-store shopping, promote events (Ryan, 2017) and improve the customer-brand relationship (O’Neil, 2019) based on transparency and co-creation of value.

Key reflections emerging from the described scenarios suggest the need to formalize and extend the conceptual remit of this revolution from the industrial context only to a wider and more inclusive entrepreneurial one. This is possible also by exploring supportive governmental actions set-up by individual European countries, i.e. Italian National Plan called “Impresa 4.0” (Enterprise 4.0), introduced by the Ministry of Economic Development in 2016. Its aim is to promote training activities for new skills development and access to investments, in order to support innovation and competitiveness of national enterprises regardless of their legal nature, economic sector, size and accounting regime adopted (mise.gov.it, 2019). From this standpoint, “Enterprise 4.0” could be considered as a wider scenario in which “Industry 4.0” factory automation concept co-exists with “entrepreneurial-led augmented experiences”, addressing micro, small, medium enterprises, as well as start-ups and artisans as potential adopters and implementers.

3. Challenges of Emerging Fashion-Tech Businesses

This section intends to collect main challenges emerging fashion-tech start-ups and SMEs need to tackle when embracing the Enterprise 4.0 paradigm. The phenomenon is illustrated clustering the challenges identified by Bertola and Teunissen (2018), CBInsights (2019) and Fashion Technology Accelerator (Filocamo, 2020), under the ones codified by Salamzadeh and Kawamorita Kesim in the paper “Startup Companies: Life Cycle and Challenges” (2015): support mechanism, human resources, financial challenges and environmental elements.

- **Support mechanism.** The lack of access to support players as incubators and accelerators, investors, and technology parks could increase the companies risk to fail. Many traditional incubators and other support organisations does not incorporate the specific know-how necessary to offer tailored support for fashion-tech innovative businesses. Furthermore, lack of financier networks focused on fashion-tech could lead to underestimation of the sector investment potentials and growth.

- **Human resources.** If the team lacks adequate knowledge of the sector the company risks to fail due to unsuitable management of human resources. The lack of awareness about contingent and future skills that in-house professionals will need to embody in order to support the company evolution and the lack of knowledge on domain specific issues (Bertola & Teunissen, 2018) could hinder the business success. Building the right team of professionals with different backgrounds, expertise and skill set corresponding to the company key activities,
and evaluating internalization of professionals vs resources externalization, are fundamental actions to consider (CBInsights, 2019; Filocamo, 2020).

- **Financial challenges.** Running out of cash, choosing the wrong time for fundraising, and underestimating the importance of pricing and costs (CBInsight, 2019; Filocamo, 2020) are some of the ingredients bringing start-ups to failure. For established companies, substantial re-engineering of existing assets as well as a profound reorganization of managerial processes (Bertola & Teunissen, 2018) could be difficult to achieve due to low system flexibility and high costs. Moreover, fashion-tech businesses are not aware of where to access funding or how to present themselves to attract investment.

- **Environmental elements.** Start-ups can encounter many difficulties in surviving if they lack attention to relevant external elements. The challenges related to the environment could deal with unawareness of existing trends, markets limitations, consumers’ negative feedback, market competition (CBInsight, 2019; Filocamo, 2020), legal issues, and vendor inertia in B2B context (Betts, 2015). Such underestimation, along with the absence of a real product market need, the lack a clear business model and solid market strategy, could greatly contribute to the company fail.

The European Commission’s “Action Plan for Fashion and High-end Industries”, published in 2014, suggests a roadmap to address many of the challenges previously identified. Among the policies and activities to be performed, the following key actions are pointed out (EC, 2014):

- Anticipating skills needs and promoting cooperation between industry, governmental and educational institutions.
- Supporting innovation by integrating ICT innovative solutions in traditional businesses.
- Stimulating transdisciplinary partnership to enhance creativity towards product, process and business model innovation.
- Stimulating cross-sectoral cooperation boosting to new industrial value chains and business models to support and implement the innovation potential of SMEs.
- Improving access to finance.

The document prepared the ground and set the guidelines to support the growth of the European Fashion-Tech Industry leveraging on collaborative networks. As a matter of fact, in the last ten years, the birth of a great number of start-ups has stimulated the funding of European projects aimed at supporting their competitiveness and the diffusion of alternative support systems inspired by the culture of innovation of high-tech Silicon Valley hubs (Engel, 2015).
4. Addressing Fashion-Tech Challenges Through Strategic Partnerships: a European Perspective

This paragraph contextualizes how the fashion-tech ecosystem could be supported at a European level. A multiple case study analysis on four pan European fashion-tech design-driven innovation projects, currently funded by EASME COSME\(^1\) and Erasmus+\(^2\) programmes, is illustrated. The aim is to distill insights on possible trajectories for the long-term competitive advantage of the European fashion-tech industry starting from the observation of the ongoing research agenda.

The projects illustrated hereafter are represented by consortiums of trans-disciplinary and cross-sectoral professionals, in which fashion and design, engineering and business management academic and research institutions are joining forces with tech-driven and design-driven entrepreneurs and businesses, network of business support organisation (accelerators, incubators and hubs), trade associations and/or investors. According to the Boston Consulting Group (2017), such strategic partnerships are key for entrepreneurial realities to “gain an insider’s perspective on the development of breakthrough innovations” (Brunelli, et al, 2017, p.7).

The case study analysis that follows combines the four challenges clusters identified in the previous section with a detailed breakdown of the actions performed to tackle them, foreseen by the European projects selected for the analysis: DeFINE, WORTH Project, Education4FashionTech, and FTAlliance.

**DeFINE – Developing a Fashion-Tech Innovation Network for Europe** is a 3-year project co-funded by the COSME Programme, aimed at building a Pan-European network of fashion-tech start-ups and SMEs, incubators and accelerators, and investors. The project delivers a series of inter-related events, training sessions and mentoring programme for selected companies, as well as knowledge sharing initiatives for the fashion-tech community at large.

The project aims to provide insights to face the following challenges: supporting mechanism, human resources, environmental elements and financial challenges.

- **Supporting mechanism**

Mapping, establishing, and moderating networks of financiers and investors, incubators and accelerators already active and/or interested in supporting fashion-tech businesses.

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\(^1\) The EU programme for the Competitiveness of Small and Medium-Sized Enterprises (SMEs). It aims to support better access to finance for SMEs, access to markets for SMEs, entrepreneurship, more favourable conditions for business creation and growth.

\(^2\) Erasmus+ is the EU’s programme to support education, training, youth and sport in Europe. It offers opportunities for a wide range of organisations, including universities, education and training providers, think-tanks, research organisations, and private businesses.
Connecting ecosystem stakeholders and nurturing cross-sectoral and transnational collaboration, through a series of informational and networking events, bootcamps, entrepreneurial and financiers workshops, and dedicated digital channels.

Supporting a selected number of fashion-tech businesses through bespoke technical, business and investment readiness mentoring programme. Mentorship is mainly aimed at better understanding specific challenges and tailored support needed by fashion-tech companies, in order extract exploitable learnings and best practices for replication and transferability purposes.

- **Human resources**

  Stimulating the the ecosystem awareness around missing key competences and resources, valuable connections and partnership, through dedicated encounters with industry experts along the mentoring programme, bootcamps and investment readiness workshops.

- **Environmental element**

  Guiding selected start-ups to develop a consistent product-market-fit and competitors research, to discover novel technological and innovative solutions for their products/services, to target the right consumer and structure sustainable marketing strategies accordingly.

  Setting-up dedicated channels aimed at fostering knowledge sharing initiatives leveraging on the consortium partners and the fashion-tech community at large. Relevant events, incubation, acceleration and funding opportunities, as well as webinars, podcasts and article on the sector trends, enabling technologies, business insights, investment strategy tips, success stories and best practices are publicly shared for the benefits of the whole community.

- **Financial challenges**

  Supporting fashion-tech companies in getting investment ready through insights on the investors’ perspective, investment strategy development, pitching mentoring and investors profile identification.

  Helping expert and ‘novice’ financiers in identifying investment targets in fashion-tech and in (co)investment opportunities.

  Organising pitching sessions and investment forums where selected fashion-tech companies can connect with potential financiers, in order to facilitate matching and foster investment opportunities.

**WORTH Partnership Project** is a 4-year project funded by the COSME Programme, designed to foster transnational, cross-sectoral collaboration connecting fashion designers, creatives, manufacturing SMEs and technology providers. It is aimed at boosting the creation of
innovative and design-driven products through the codification of cross-disciplinary partnerships supported by an incubation programme, mentoring and access to funding.

The project tackles the following challenges: human resources, supporting mechanism, environmental elements and financial challenges.

- **Supporting mechanism**

Organising networking events and activities to encourage entrepreneurial collaboration and market up-scale.

Establishing tailor-made coaching and mentoring process for selected partnerships, to improve knowledge and skills linked to design, technology, manufacturing processes, business strategy, legal support and IPR management.

- **Human resources**

Matching complementary SME/start-up designers and manufacturers with technology providers from the fashion and consumer goods industry.

Promoting creative partnerships as a model to sustain the development of cross-sectoral innovative projects.

- **Environmental elements**

Raising awareness and sharing knowledge on Fashion-Tech industry key topics through webinars, interviews and lectures on innovative partnerships creation, entrepreneurship, internationalisation, marketing&communication, IPR, pitching, business strategy, fashion and technology trends, incubation support opportunities, success stories and best practices.

- **Financial challenges**

Providing direct access to financial support to selected partnerships going across the incubation process, so as to bring their projects and ideas to life.

**E4FT - Education4Fashion-Tech: Interdisciplinary Curriculum for Fashion in the Digital Era** is a 3-year project co-funded by Erasmus+ Programme - Strategic Partnerships for higher education. Its purpose is to answer the market need shaping hybrid professionals able to manage fashion, technology and entrepreneurial domains. One of the project’s output is an innovative fashion-tech higher education curricula to build up and progress skills and knowledge concerning smart textiles, wearables and digital manufacturing.

The project presents piloting experiences aimed at enhancing the awareness mainly on: supporting mechanism and human resources.

- **Supporting mechanism**
Mapping and sharing the state of the art of Higher Education programmes and other high-quality fashion-tech training experiences provided by public and private organisations.

- **Human resources**

Mapping subject specific fashion-tech skills at the intersection of design and multimedia communication; technology and engineering; and human, social, psychological, and economic context.

Developing teacher’s toolkits and flexible MA programmes as resources to support the implementation of fashion-tech interdisciplinary teaching and learning activities, validated and continuously updated thanks to short term educational pilots (hackathons and workshops) promoted in collaboration with research and development centers and fashion-tech companies.

Collecting and sharing course material, edited lectures and other contents developed from educational activities as MOOC-type materials to allow future engagement by a European-wide creative community.

**FTalliance - Weaving Universities and Companies to Co-create Fashion-Tech Future Talents** is a 3-year academia-industries partnership co-funded by Erasmus+ Programme - Knowledge Alliance. Its goal is to enable and facilitate the exchange, flow of knowledge and co-creation paths between universities and companies operating in the Fashion-Tech sector. The partnership aims to boost a twofold impact. From one side, enhancing students’ employability and innovation potential, equipping fashion and textile, design and engineer with updated fashion-tech competences. From the other side, supporting the competitiveness of and growth of the EU Fashion-Tech sector.

The project aims to mainly address the human resources challenge.

- **Human resources**

Designing and piloting a series of challenge-based design educational activities to boost creative encounters within the framework of a number of industry briefs, allowing beneficial and reciprocal exchanges between the student participants and companies.

Fine tuning a multidisciplinary fashion-tech curriculum integrating fashion, design and engineering with industry relevant challenges through open innovation and project-based learning methodologies.

Developing fashion-tech residency programme and co-creation opportunities to foster innovative concept development and products prototypes. Students are involved in hands-on innovation activities within fashion-tech companies, in order to let them benefit from the know-how, expertise, tools and channels of the host organization.
7. Conclusions

The necessity to embrace strategic partnerships and build networked ecosystem in constant dialogue seems to emerge as a valuable resource to tackle the novel challenges of the Fashion-Tech sector. The key activities when dealing with collaborative and distributed networks should be: understand the stakeholders needs, codify a common language, connect and match key players, and iteratively feed these relationships. As in the cases presented, universities and research centres should formalize long lasting partnerships to align educational curricula with the future needs of the job market. The vision should not be limited to contingencies, but it has to look at the impact of disruptive technologies in the medium and long term. Given the novelty of the phenomena, the evolutionary and dynamic nature of this emerging paradigm lead to the fact that new approaches to create value from 4.0 model are still in progress, and that value will spread as best practices are shared, laying the foundation for further adoption. In this regard, fashion-tech dedicated ecosystems of innovative enterprises, business support organisations, academic institutions and financiers network should grow and drive innovative paths, fostering networked and capillary cross-disciplinary knowledge sharing initiatives and creating awareness and common literacy on key challenges and successful approaches.

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Acknowledgements: This paper is the result of common discussion and framework, nevertheless, section 1 was edited by Chiara Colombi, and sections 2, 3, 4, 5 were edited by Chiara Di Lodovico.
The evolving role of prototypes in design research: a discussion on terms and meanings.

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Abstract | In this paper, we present the preliminary findings of an ongoing research project addressing the role of advanced prototypes in design research. The project aims at investigating the evolution of the role of the prototype in design research, given the recent advances in prototyping techniques and processes. In the first phase, we collected a diversity of definitions from literature, outlining both traditional and emerging traits of the use of prototypes. We observed that researchers tend to classify prototypes based on a variety of different purposes, which are tightly bound to the type of enquiry being carried out and the specific area of research in which they work. The emergent heterogeneity of terms and meanings shows that the definition of prototype is anything but univocal. This multiplicity of definitions led us to develop an overview of the assortment of terminologies and purposes that researchers use to describe the role(s) of the prototype.

KEYWORDS | PROTOTYPE, RESEARCH ARTIFACT, DESIGN RESEARCH
1. Introduction

1.1 The changing role of prototypes

Design is deeply rooted in the culture of making, being traditionally devoted to transforming ideas into tangible outcomes. This hallmark of design is currently undergoing a radical change due to a twofold counterror phenomenon. On the one hand, a profound process of dematerialization, which largely affects the world we live in (Moles & Jacobus, 1988). This process entails everyday objects losing their physical attributes and turning into either purely digital artefacts (e.g., bitcoins) or new types of product merging physical and digital features (e.g., smart objects, IoT, etc.). On the other hand, the emerging role of speculation – meant both as a means and as an end of the enquiry – in some areas of design research (e.g., design fiction (Bleecker, 2009; Dunne, 2013)). This shift makes tangible artefacts no longer an imperative stage of the design process, paving the way for a wider notion of both prototype and prototyping.

In other words, designers are still in charge of making things come into being, but regardless of their physicality. In the context of this paradigm shift, prototypes (both tangible and intangible) have come to acquire a crucial role in the process of knowledge production – mainly at the academic level – as they are considered carriers of meaning and, as such, means to conduct research. The terms of this new role are reflected in the preliminary findings we report on in this paper. Indeed, the proliferation of new jargons and terminologies in some areas of design research signals the attempt of giving a status to a changed role of the prototype.

1.2 “Advanced prototypes”: scope and limitations

As part of an ongoing research project addressing the “role of advanced prototypes in design research”, our findings shed light on the plurality of perspectives regarding the notion of prototype. From this plurality of views, besides the traditional understanding of what a prototype is (i.e., first unit of a product to be mass-produced), new conceptions emerge clearly, emphasising the theoretical and generative contribution that prototypes give to the research process. As an example, in the field of interaction design, prototypes are often employed to test the experience of users systematically, with the aim of producing knowledge to be shared with other researchers. In this field, prototypes are made mixing physical and digital features, sometimes relying on advanced manufacturing processes (e.g., PCB laser-cutting or milling). This peculiarity led us to term these types of prototype “advanced”. Because this way of prototyping, we believe, marks a significant shift in the way present-day design research contributes to the development of products, our project was named after this term. That being said, the true novelty in this field is that prototypes are conceived of as means of knowledge production, whether or not they are made by using advanced manufacturing processes. Indeed, this new role is played by other types of
prototype (and prototyping) as well – substantially intangible – which are gaining significance in design research (e.g., storytelling in design fiction – see section 4.1).

1.3 Focusing on the emerging role(s) of prototypes

Based on literature review, we found that prototypes in design research are used nowadays as means to produce knowledge (i.e., theory), throughout the research process. This innovation, we believe, is of great relevance for the understanding of the emerging role(s) of the prototype in design research. Indeed, the new role of prototypes as means of knowledge production extends beyond our notion of “advanced prototypes”, including intangible artefacts that are often unrelated to manufacturing processes. Therefore, the focus of our project shifted towards the evolution of the role of prototypes in design research, which is not limited to those artefacts made by means of advance manufacturing techniques.

This project is funded by the Department of Design of Politecnico di Milano and developed by nine affiliated researchers, working in different areas of design research. The research group brings together a wide spectrum of expertise ranging from product design to interaction design, fashion design and materials in design. In this plurality of specialisations, the joint interest is the design of products and its evolution. Indeed, the proposal at the base of this research project originated from directly observing the emerging role(s) of the prototype in our daily academic work.

2. Literature review

2.1 Phase 1: “Defining and Understanding”

As a first stage of the project, we collected a wide range of definitions of prototype circulating in different areas of design research.

Analysing the literature, we found that there is no consensus among authors regarding the meaning of the term prototype, even when referring to the context of design practice. Some authors use the traditional notion, which understands prototypes as refined artefacts ready for production (Pei, E., Campbell, I. & Evans, M., 2011). Others, in contrast, ascribe a wider role to prototypes, viewed as “design-thinking enablers deeply embedded and immersed in design practice and not just tools for evaluating or proving successes or failures of design outcomes” (Lim, Y., Stolterman, E., & Tenenberg, J., 2008; McElroy, K., 2016).

Despite this lack of consensus, recent studies address specifically the context of design research (mainly academic), where “prototypes are made for operationalization, validation and exploration, and these uses seem to fit in different research approaches. They can be done to test preconceived hypothesis or to reflect on open-ended exploration. Roles prototypes can play in research projects are to confront theories; to confront the world; to evoke discussion and reflection; to changing the world; to test a theory” (Stappers, P. J.,
2013). This idea of prototypes as means to carry out research extends to areas such as service design and design fiction, where they often consist of intangible artefacts (Kimbell, L., & Bailey, J., 2017; Kymäläinen, T., 2016).

The initial purpose leading the data collection was that of reaching a shared definition of the emerging role of prototypes in design research. Nevertheless, the heterogeneity of definitions that we found in literature led us to rethink the purpose of this stage, directing our efforts towards a mapping of the diversity emerged (section 4.2). Giving an account of this diversity, we thought, better responds to the underlying aim of the research project, i.e., understanding the emerging role of the prototype in design research.

3. Method

3.1 Selection and review of relevant sources

The term prototype is largely used nowadays in several areas of design research to describe unfinished and instrumental artefacts (McElroy, K., 2016; Wakkary, et al., 2015). This connotation revises and overcomes the long-established difference between model and prototype in the field of industrial design (see section 5.2). Furthermore, the notion of prototype currently used in design research (i.e., academic context) comprises a larger spectrum of categories of artefacts than the traditional one. For this reason, we decided to search for terms such as model and artefact, which the current notion of prototype seems to have gathered under the same umbrella-term (i.e., prototype).

Overall, the role of prototypes, their understanding and the terminology used to differentiate their purposes vary across the wide spectrum of design research, from engineering-based design studies to arts and crafts design research. Therefore, besides the terms model and artefact, we searched for definitions under the term demonstrator, mainly used in engineering-oriented design research.

3.2 Literature review process

Source finding
We started the literature review by collecting relevant sources, using keywords according to terminology (e.g., prototype and design), disciplinary areas (e.g., interaction design, product design, design research, etc.) and research areas (e.g., manufacturing techniques, product development, etc.). We made use of search engines and sharing platforms, such as Google Scholar, ResearchGate, Academia.edu, Mendeley, Online databases (library of Politecnico di Milano, ACM Digital Library).
Collection
We selected and sorted 95 publications among books, journal articles, papers, web articles and definitions from encyclopaedias. Hence, we extracted relevant content, consistently with the key topic of our research. Thereupon, we clustered the excerpts according to terminology, disciplinary area, and role played in the (design) research process. We identified eight clusters: prototype (49 publications); artefact (11 publications); culture and artefact (8 publications); design (encyclopaedia) (5 publications); model (5 publications); fashion (4 publications); product (design) (8 publications) and systems (design) (5 publications).

Document analysis using the Data Grid
We developed a grid to organise and review the excerpts systematically (Tab.1).

<table>
<thead>
<tr>
<th>DATA GRID</th>
<th>reference</th>
<th>general definition</th>
<th>extensive definition</th>
<th>synthesis</th>
<th>interesting aspects</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Artifact&quot;</td>
<td>Design Dictionary: Perspectives on Design Terminology Michael Erlhoff, Tim Marshall (Eds.), Birkhauser, Berlin (2008)</td>
<td>&quot;Quite literally, an artefact is an object that is the product of human skill and ingenuity. The term derives from the Latin artes (art or skill) and factum (made or done), and thus is a pivotal term to describe almost any designed entity.&quot; p.27</td>
<td>&quot;All products of design are artefacts of one kind or another, and a common definition of design is the organization of the interface between humans and the &quot;made world,&quot; that is, the interaction between people and our artefacts.&quot; p.27 &quot;Although usually understood to refer to a material object, artefact can also refer to designed spaces, images, [...].&quot;</td>
<td>The term refers to anything produced by humankind: the &quot;made designed world&quot;. Thus, the notion of artefact is not limited to tangible objects; rather, it includes non-tangible things such as software and environments.</td>
<td>The meaning of the term &quot;artefact&quot; is much wider than that of &quot;prototype&quot;, though sometimes they are used interchangeably in some studies.</td>
<td>Artefacts is often another word for prototypes; the fact that the term may refer to a diversity of things, much different from each other, raises the problem of the limitedness of the notion of prototype based on materiality. In other words, understanding and right enough, this term prototype can be applied to non-tangible things.</td>
</tr>
</tbody>
</table>


Organizing literature
The literature review was carried out over a four-month period. During this process, unfitting publications were discarded. On the other hand, new ones were included, relying on the references of those we had already collected. The number of publications collected was considered enough to gain a general understanding of what a prototype is and what roles the latter plays in today’s design research.
4. Results

4.1 Preliminary findings

The literature review carried out using the Data Grid (Tab.1) allowed us to gain a first understanding of the evolving role of prototypes in design research. We collected a wide range of definitions that describe what prototypes in research are meant by, under terms such as “demonstrator”, “proof of concept”, “sample” – just to mention a few. Such terms constitute a specialised lexicon used in specific areas of design research. Over the last ten years, a variety of new terms have been introduced, with the aim of defining some emergent types and uses of prototypes. One example is the notion of counterfactual artefact, developed by Wakkary et al. (2015), which encompasses critical design, HCI, interaction design and philosophy. Another example is the notion of diegetic prototypes by Kirby (2010), who investigates the narrative role of those prototypes that are used to influence cinema audiences. These neologisms signal the need to fill an ontological gap related to prototypes in today’s design research, beyond terminology. In other words, the proliferation of new terms used to describe the role of prototypes testifies a change of perspective in the field of design, where research has expanded its horizons. In particular, various strands of research in design have been turning their attention to theory and social phenomena, besides the development of products. In these strands, prototypes are used as means to conduct research and generate knowledge, which does not pertain to one or more specific products. In fact, the knowledge generated may be used at a later time by other researchers either to develop a product or to investigate relevant theoretical matters further. This understanding of the role of prototypes sets apart from the traditional view spread in industry, showing the occurrence of a shift in the way the very research in design is understood.

4.2 Prototype: from definition to role

Overall, we observed that the diversity of terms currently circulating are part of a jargon that design researchers use to classify prototypes, according to a variety of purposes deemed as most relevant to their specific research areas. As a result, terms and definitions vary according to the specific research contexts, questions and, sometimes, stages of the process. In this respect, the classifications are often based on the specific objectives or purposes to which the single prototype aims. Therefore, terminology is tightly bound to both the specific aim and the general purpose (i.e., role) that the prototype is expected to help achieve. Such a functionalist approach to taxonomy is widespread among researchers and led us to move our focus from the definition to the role of prototypes. We therefore reframed the Data Grid, highlighting the diverse roles and aims ascribed to prototypes (Tab. 2). Moreover, we revised the data collected according to the changes made.
The evolving role of prototypes in design research: a discussion on terms and meanings

<table>
<thead>
<tr>
<th>DATA GRID II</th>
<th>Role of the prototype in the interpretation of the author</th>
<th>Categorisation criteria: Aim</th>
<th>Author’s specific distinction(s) (to be highlighted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>Description of the authors’ interpretation of the role of prototype</td>
<td>Collection of information based on a set of criteria of categorisation</td>
<td>Notes about any author’s specific distinctions about the role of prototypes</td>
</tr>
<tr>
<td>&quot;Prototype&quot;</td>
<td>The role of prototype is to perfect items and processes of a design before implementing them on a large scale.</td>
<td></td>
<td>Prototype vs Fully working prototype (clear distinction).</td>
</tr>
</tbody>
</table>


Table 2. Data Grid II (revised version) for literature synthesis and analysis – example of the term “prototype” from Encyclopaedia of Science (Blackwell, A. H., 2015).

The new grid for analysing the literature allowed us to identify two main roles that prototypes have in design research. These roles differ substantially from each other. One, more traditional, consists of giving researchers the chance of gaining useful insights about the prototype itself, as part of the product development process. The other, unusual compared to the long-established role in industrial design, consists of enabling researchers to gain knowledge regarding phenomena that lie outside of the domain of design. In the latter case, prototypes work as instances, embodying ideas and theoretical concepts. In this regard, they can be used to generate new hypotheses, answering research questions, and envisioning new design propositions. This is the major innovation, we observed, regarding the role played by prototypes in current design research.

Regarding the specific aims of prototypes, we collected over 140 statements. After a process of review, we made a list of 34 primary aims and clustered them into 9 categories: Develop, Assess, Communicate, Represent, Comprehend, Research, Explore, Provoke and Envision (Fig.1). These clusters well represent the range of purposes for which prototypes are made in design research.
Later, we used this outline as a starting point to proceed with the next stages of our research. In this article, however, we focus on the insights gained by analysing the terminology and the definitions of prototypes currently spread in various areas of design research.
5. Discussion

5.1 The role of prototypes through terminology

Our shift of focus from definitions to roles of prototypes allowed us to pinpoint a major change of perspective in the field of design research, which has expanded its scope of interests, including theory and social phenomena related to material culture. In particular, our preliminary results show that prototypes have acquired the role of means for the production of theoretical knowledge, which complements the traditional role of testing aesthetic and technical aspects of the to-be-product. Moreover, drawing on literature, we were able to develop an overview of 34 primary aims for which prototypes are used, both in practice and research, defining 9 main categories.

It must be clarified, however, that the emerging role of prototypes – i.e., its evolution – in design research is tightly bound to the terminology used to describe them. That is to say, terminology defines the role of prototypes, highlighting the nuances related to their specific purposes. Indeed, through their discourses – i.e., fine-tuning terms and ascribing new meanings – the actors of research have constructed, conceptually, a new role to be played by prototypes, so influencing the practical dimension of the very research.

The classification of aims that we developed (fig.1) well shows the importance of terminology in the emergence of a new role of prototypes. Take, e.g., the two categories Develop and Research. It is clear that the aims that these categories gather refer to quite different paradigms, hinting at two distinct roles. Interestingly, other categories – such as Comprehend and Represent – gather aims that refer to both roles, traditional and emerging, reinforcing the idea that such roles often coexist in design research.

What is relevant about these examples is that the terms that we used to define the sub-categories (i.e., aims) are faithful to the claims made by various authors active in the field. That is why the lexicon used in design research to describe and frame prototypes is relevant to an enquiry into their emerging role in the field (see next sections).

5.2 Semantic overlaps

By mapping the definitions of prototype, we collected over 80 terms and related meanings. In this respect, we noticed that in some cases different meanings are ascribed to the same term (e.g., the term “prototype” is used to address both the provisional draft object that represents the concept of a product and a detailed object that represents the final product before production). In some other cases, the same meaning is described with different terms (e.g., the provisional draft object that represents the concept of a product in an early stage of development might be termed “model”, “mock-up”, “sketch”, “prototype” or otherwise). Therefore, the literature is riddled with semantic overlaps, which show a lack of a shared understanding among researchers of what a prototype is meant by.
<table>
<thead>
<tr>
<th>Area</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial design (traditional)</strong></td>
<td>In industrial design, “model” and “prototype” refer traditionally to two different types of artefact (Pei et al., 2011; Erhoff, M. &amp; Marshall, T. Eds. 2008d). In this interpretation, models and prototypes are developed and used in different stages of the product development process for different aims. Indeed, models come first for visualising and evaluating some aspects of the product, whereas prototypes come later for testing the performance of the product.</td>
</tr>
<tr>
<td><strong>Science and Technology</strong></td>
<td>In Science and Technology, the definition of model comprises the concept of prototype. Thus, “prototypes” are types of model (physical objects). According to this definition, they are “developed and used to help hypothesize, define, explore, understand, simulate, predict, design, or communicate some aspect of the original entity for which the model is a substitute” (Geller, E., et al. (Eds.) 2004).</td>
</tr>
<tr>
<td><strong>Design practice</strong></td>
<td>In the area of design, the term “prototype” is currently used in the widest sense. McElroy (2016) claims that “a prototype is anything that is testable and improvable” along the design process (from sketches to foam models, called mock-ups, etc.). Others go further conceiving any form of representation or media as prototypes (Houde and Hill, 1997; Schrage 2013). In this perspective, prototypes are not defined by their features, but by their purpose. Hence, models are a subset of prototypes.</td>
</tr>
<tr>
<td><strong>Design research (academic)</strong></td>
<td>In design research, the term “artefact” is largely used to refer to entities that may comprise models and prototypes and any other material or immaterial objects used in the design process (Erhoff, M. &amp; Marshall, T. (Eds.) 2008a). This term appears to have a wide connotation, which proves useful in design research to address open-ended research questions and to inform an exploratory stage. Thus, the term “artefact” in design research often appears to be synonymous of “prototype”.</td>
</tr>
</tbody>
</table>

*Figure 2. Interpretations of three widely used terms (i.e., artefact, model, prototype) in different areas of design research.*
To bring some clarity, we give an overview of the way three widely used terms (i.e., artefact, model, prototype) are interpreted in different areas of design research (Fig.2). In addition, we elaborate upon a further term coming from the field of engineering (i.e., demonstrator), also adopted in some areas of design research (see section 5.3). Finally, we discuss the interpretation of the term prototype in the field of design research (see section 5.5) and in fields other than design (see section 5.4).

5.3 “Demonstrator” in Engineering

In the process of selecting relevant publications, we extended our scope of enquiry to engineering-oriented areas of design research. In these areas, we found that the term “demonstrator” is often used as a synonym of prototype. Moultrie (2015) points out that “[usually] demonstrators are viewed as technological prototypes which are close to market”. In this respect, Moultry proposes a new conception, arguing that “by considering the broader development space, it is possible to explore the potential for other types of demonstrators”. This point of view assimilates the term “demonstrators” to many of the interpretations of the term “prototypes” used in design research.

5.4 “Prototype” in disciplinary areas other than design

It is worth noticing that the term “prototype” can refer to a diversity of artefacts, depending on the specific disciplinary area. This semantic dissimilarity may lead to misunderstanding, especially in the context of multidisciplinary teamwork, where designers collaborate with researchers coming from different fields. Therefore, as Hallgrimsson puts it:

“Product designers have to work with professionals from other disciplines where the term prototype could be used to describe many things that are not three-dimensional. Software designers use the term prototype in the context of code. Electronics engineers speak about prototyping printed circuit boards. [...] It is worthwhile becoming more aware of these semantic differences since product design has become inherently interdisciplinary.” (Hallgrimsson, B., 2012).

5.5 “Prototype” in Design research

In the field of design research, as in that of design practice, prototypes are understood generally as means to represent ideas, namely, give an intelligible form to undetermined and abstract concepts pertaining to design solutions. In other words, prototypes are deemed as practical instruments to advance the design process, moving from the typical vagueness that characterises the concept phase to the clarity that implementation and experimentation usually require.

This general conception is common to all views on the role of prototypes that dot the diverse landscape of design research. Whether practice-oriented research (e.g., R&D context) or academic research, prototypes in the field of design serve the fundamental need to make magmatic and conceptually embryonic ideas manifest through fathomable forms of representation. Unlike in the professional world, however, in design research, the guiding
principle is that of gaining and/or producing knowledge, often regardless and outside of market requirements. That is to say, the kind of ideas and concepts that research prototypes embody are part of a process of knowledge production, which is not directly related to manufacturing and marketability.

Although in all areas of design research prototypes are used to produce knowledge, their (claimed) role differs widely depending on both the scope of research and the approach adopted, leading to a diversity of terms and definitions. Notably, Wensveen & Matthews (2015) identify four main roles, highlighting different ways in which prototypes and prototyping contribute to generating design-relevant knowledge. Prototypes can be used either to “test specific hypotheses” (experimental components) or to conduct “open-ended explorations” (means of inquiry) or to embody/show concepts and arguments (research archetypes) (p.272). Moreover, the very process of prototyping can be “a means of enquiry, akin to a research method” (p.269). Each role is bound to a specific methodological approach that proves consistent with the kind of knowledge sought, and yet a single research project may include all of them, relying on several prototypes having different purposes throughout the process (p.271). Thus, not only is the role of prototypes in design research multifarious, but also its variations can be combined in the same project, if needed.

As Wensveen & Matthews (2015) clarify, besides contributing to the discussion on the use of prototypes in design research, their categorisation aims to show that the approach commonly referred to as Research-through-Design (RtD) brings together “a multitude of legitimate intersections between design research and practice” (p.263). In other words, making prototypes, as a distinct practice of design put to the service of research, can contribute to producing knowledge relevant for design in many different ways. This open-minded view, which embraces the heterogeneity that characterises the field of design research, leaves room for new conceptions of prototype and prototyping in emerging areas such as that of design for social innovation (e.g., Kimbell & Bailey, 2017; Blomkvist, 2014). In this regard, the attempt of settling an inclusive epistemology for design research, beyond typologies and segmentations around the definition of RtD, is openly expressed by several researchers who proposed the term Constructive Design Research (CDR) (Wensveen & Matthews 2015; Krogh et al., 2015).

Notwithstanding someone’s attempts of agreeing upon an inclusive epistemology, researchers active in different areas of design tend to emphasise their peculiar way of doing research, coining terms that aim to distinguish their conception from that of others. This need to stand out is also reflected in the understanding of the role of prototypes. To give an example, while Wensveen & Matthews (2015) discuss prototypes and prototyping, Frens & Hengeveld (2013), who share a similar background, prefer to use the term making (instead of prototyping). Krogh et al. (2015), who present a typology of methods used to produce knowledge in RtD, on the other hand, emphasise the activity of sketching (p.5). These few examples show how even strands of research that share the same methodology attribute
different roles to prototypes and prototyping in design research. Interestingly, they claim differences of substance by emphasising semantic nuances and using distinct lexicons.

All things considered, the plurality of views on the role(s) that prototypes and prototyping play in design research – included their terminological inventory – are held together by the common aim of producing knowledge relevant for the design field, besides developing products for the market. This common trait, we believe, is what can be generally viewed as the emerging role of prototypes and prototyping in design research, without detracting from the significance that the diversity of views on such role (i.e., its nuances) offers.

6. Conclusions

In today’s design research, a variety of terms are used to describe tangible and intangible artefacts playing the role of prototypes. The reason behind this diversity is that the notion of prototype is highly context and purpose dependent, i.e., varies depending on both the specific disciplinary area in which it is developed and its use in the research process as it is performed in that very area. Our preliminary findings show that prototypes are best defined by both their general purpose (role) and their specific aims. Furthermore, we found that the role of prototypes in design research has evolved from a traditional conception (i.e., the first unit of a product series to be manufactured) to a new and wider notion, which views them as means to investigate phenomena outside of the domain of design. This evolution reflects a widespread and influential perspective into vogue in various areas of design research today. According to this view, prototypes are no longer aimed exclusively at developing products, also serving the process of knowledge production in the context of academic research.

The contribution of this paper is threefold. First, we provide a classification of prototypes by aims (fig.1), based on the claims made by various authors active in the field of design, both research and practice. Second, we discuss the emerging role of prototypes in current design research, highlighting a change of paradigm regarding the way research is conducted. This change follows an expansion of the scope of investigation, which includes theory and social phenomena. Third, we show that the emergence of a new role of the prototype in design research depends largely on the definitions and discourses that are developed over this topic. In such discourses, terminology plays an important role, influencing the very practice of research.

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**Acknowledgements:** The authors would like to thank the team members: Alba Cappellieri, Manuela Celi, Venere Ferraro, Margherita Pillan, Lucia Rampino, Valentina Rognoli, Susanna Testa.
The Making of a Dress: Explicating the Implicit Processes

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Abstract | This case study aims to provide fresh perspectives on design culture through the examination of the (usually overlooked) human decisions, interactions and processes involved in the design and making of an occasion dress. Four areas - actors and networks, project and praxis, benefits and limitations of technology, and artefact and meaning - were explored to address the questions, "What were the requirements for this dress to be made?" and "What is the cultural significance of this dress?" Interviews and observations revealed the motivations, co-design, risk-management, negotiations, relational capital, tacit knowledge, resources, technology and processes required in the making of the dress. The imagery referenced in the design of the dress gave it symbolic meaning. The making of the dress represents cultural cross-pollination through networks, artefact, and craft. The findings suggest that aside from brand storytelling, post-industrial designers should consider how they are helping clients craft their stories.

KEYWORDS | DRESS-MAKING, HAND-EMBROIDERY, IMPLICIT PROCESSES, CULTURAL HERITAGE, CO-DESIGN
1. Introduction

What can the making of a dress, commissioned in Singapore, inspired by Mexican Tehuana traje, and hand-embroidered in India, teach us about design culture in this post-industrial age? In the 20th century, shopping was a means of warding off the unhappiness created by a loss of self and identity (Bocock, 1992, cited in Press and Cuswoth, 1997). In the 21st century, everyday people are increasingly dissatisfied with simply being “consumers” and want to be “creators” as well (Sanders, 2006). Sanders (2006) identifies four levels of creativity that people seek. These include, from the most basic to the most advanced – doing, adapting, making and creating. Hur and Beverly (2013) cite the construction of IKEA flat-pack furniture as an example of ‘doing’; the mass-customization of predetermined shoe styles by Nike as ‘adapting’; and the growing number of DIY craft and fashion micro-producers embracing co-design activities as ‘making’. The ground-up co-design of the dress in this study is presented as an example of ‘creating’.

Numerous studies, including Jha and Narang (2014), examine the symbiotic relationship between contemporary fashion designers and craft communities in India. However, the end user (customer) is rarely, if ever, in the picture. The implicit human decisions, interactions and processes so critical to the culture of making are, likewise, rarely explicated. The author, having connected the client and the designer, had the opportunity to witness this design project as both an insider and a neutral observer. Considering the investment of time, effort and money involved in the creation of this artefact, gave rise to two questions: “What were the requirements for this dress to be made?” and “What is the cultural significance of this dress?” Four key areas were explored to address these questions – actors and networks, project and praxis, benefits and limitations of technology, and artefact and meaning.

2. Method

This case study involved detailed, in-depth qualitative and relevant quantitative data collection from multiple sources of information (Cresswell, 2013; Yin, 2009). Research tools included observation, interviews, and analysis of relevant data, such as WhatsApp chat proceedings between involved persons. Some of the key people involved in the making of the dress were interviewed, including the client, the designer, and embroiderers.

3. Actors and networks

Culture is created and defined by people. This section identifies the actors connected to the making of the dress. The client, Circe Henestrosa, is a fashion curator and heads the School of Fashion at LASALLE College of the Arts, Singapore. The idea for the dress came about when she was contemplating what to wear for the opening of Frida: Making Herself Up at the V&A Museum scheduled for June, 13, 2018. Circe considered two options, "My debate
was whether I should wear the traditional (Tehuana) dress or a more modernized version of it.” Eventually, Circe had both versions made. She commissioned a Mexican designer to make a more traditional two-piece outfit and a Singapore-based LASALLE alumnus to produce a contemporary version.

The Singapore-based designer, Vikas Dayal, was born in India, but currently works and resides in Singapore as a permanent resident. His 2012 graduation collection stood out from his peers for his use of detailed embroidery and beadwork. A key advantage he possesses over other Singapore-based designers and arguably the main reason for his selection, was that he has his own embroidery workshop in India.

In New Delhi, Taufir and Mamu are Vikas’ “main sampling guys” for machine-aided embroidery and hand embroidery respectively. Having previously worked for a renowned Indian fashion designer, Taufir chose to work for Vikas’ workshop due to proximity to his home and higher wages. He was responsible for producing the first embroidery sample for this project. Together with five other embroiderers, Mamu was responsible for the hand embroidery used in the final dress.

Figure 1. The silk embroidery thread seller.
There is a group of supporting actors, largely overlooked in the literature, who enable the continuation of the craft of embroidery – merchants who supply the essential materials, tools and equipment used in the craft. A representative of this supporting network is an elderly embroidery silk thread seller who operates a hole-in-the-wall shop close to Vikas’ workshop (Figure 1). Vikas prefers to patronize this particular thread seller because he provides the special service of color matching. The different colors of threads are stored in cardboard boxes with only numerical indications. Customers simply hand him color swatches and he will find the matching threads from memory.

Vikas has only one staff back in Singapore due to the country’s restrictions on foreign manpower. His sample-maker, Chote, who is skilled in both pattern-cutting and sewing. Chote was responsible for making and altering the dress toile (prototype) for the fittings and assembling the final dress. Although Circe knew Vikas personally, she first sought the author of this paper, Adrian, for his opinion as to whether Vikas would be able to produce the dress she had in mind. Adrian was one of Vikas’ lecturers at LASALLE and they had remained in contact since the designer graduated. Having previously worked together on a number of custom-orders, Adrian could attest to Vikas’ dressmaking and embroidery capabilities. Circe also enlisted the help of another LASALLE colleague, Dinu Bodiciu, a fashion design lecturer, to plan the embroidery placement for the dress.

4. Project and praxis

The making of the dress took place between March and May 2018. On March, 28, Vikas had the first meeting with Circe and Adrian to discuss the design of the dress. He accepted the commission on Adrian’s recommendation and because it aligned with his schedule. Vikas usually returns to India two to three times a year to work on the production of his own collections. He was scheduled to fly back to India on April, 2, to prepare for a showcase of his work at the International Fashioner Week on April, 7. Work for the dress progressed quickly at the onset. Chote completed the toile for the first fitting on March, 31, and altered it for a second fitting the next day. On April, 2, Vikas flew back to India, on schedule, with the toile and a Manila shawl sample, from Circe, as reference for the embroidery.

Amidst preparations for the fashion show, Vikas discussed the work for Circe’s dress with his embroiderers. They estimated that the embroidery with all its colors would require at least three months to complete, making it “impossible” to deliver by the end of May 2018. They strongly advised him to drop the project.

When Vikas is not around, the workshop usually produces embellished ready-to-wear dresses for the domestic market. During my visit in October 2019, the workshop was producing such a design. A distributor wanted to order 80 units of that dress a month, but the workshop was only able to churn out about half that quantity. This was a good problem for them to have, with demand exceeding supply. The dress I saw in production was embellished with hundreds of glued-on crystals. Initially, I thought that this type of work
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could be what Mohsini (2016) refers to as ‘labor’. In fact, although the materials used differ from traditional embroidery and beadwork, the work still leverages the experienced hands and dexterity of the embroiderers. The making of these dresses utilized skilled workmanship.

Nevertheless, adopting Pye’s (1968) use of terminology, Vikas demands ‘craftsmanship’ for his own designs as opposed to ‘workmanship’. As a designer-producer, he is more than willing to make the distinctions between the two. His own designs require experimentation at the onset and close supervision during actual production. He told me, “If I’m not there, the work does not move.” Even when he is there, the embroiderers can be reluctant to take on new work. New designs require a lot of preparatory work.

Vikas’ own designs, with their higher price points, may not garner as many orders as the crystal-embellished dress, but he still secures multiple custom orders for some styles. Vikas also pays his artisans extra for the higher quality he expects for his work. Circe’s dress, however, came across as a time-consuming one-off piece involving a style of embroidery different from what they usually do. It was not technically difficult for them to adapt to, but they did not see potential return-on-investment for the time and effort that would be required for the dress embroidery. Therefore, dissuading Vikas from proceeding with the order was simply a matter of avoiding risk.

On April 22, 2018, Circe followed up with Vikas via WhatsApp. She negotiated with him, suggesting a compromise of making either a top or skirt with the embroidery if the dress could not be completed on time. Vikas actually thrives on overcoming challenges. Over one of their regular chai and biscuits breaks, Vikas tells his team that his reputation will be tarnished if he fails to produce the dress. For “brotherhood”, the embroiderers agreed to start work on the dress. Once the sampling started, Vikas had to commit to the investment in materials and wages. He incurred a financial risk even before the actual “workmanship of risk” (Pye, 1968) commenced. On April 24, Vikas sends images of the first machine-aided embroidery sample (Figure 2) to Adrian and Circe.

Figure 2. Images of first machine-aided embroidery sample at different magnifications
Apart from commissioning another dress with the Mexican designer, Circe’s decision to get Dinu to work on the placement of the embroidery after approving the machine-aided embroidery sample was also risk-management. Believing that the scale and placement of the embroidery motifs could “make or break” the outcome of the dress, she sought Dinu’s help to ensure that the embroidery on the dress would look right. This process delayed the start of the actual embroidery work. On April, 28, Vikas sent Dinu images of the dress pattern pieces and the first embroidery sample photographed with measuring tape for scale. With these images, Dinu prepared the embroidery placements (Figure 3) and shared them on May, 6.

Figure 3. Embroidery placements prepared by Dinu. Clockwise from top left image: front bodice, back bodice, sleeve, and skirt placements.
The same day, Vikas started drawing the embroidery pattern (Figure 4) on plastic sheets. Each completed section was handed over to Taufir to punch holes along the drawn lines using his machine. Once the holes were punched, the embroidery patterns were ready for use as stencils. In the workshop, these are called “kah-kah” which actually refers to the plastic material but is understood as the embroidery patterns. The artisans use a chalk solution and the kah-kah to transfer the embroidery pattern to the dress fabric which is stretched out on a wooden frame.

Figure 4. Hand drawn embroidery pattern, referred to as “kah-kah” in the Delhi workshop.

Dinu’s embroidery placements did not save Vikas any time directly, as the kah-kahs still had to be meticulously drawn from scratch. However, Dinu’s placements contained more negative space compared to what Vikas would have left on his own. Accordingly, this resulted in indirect time savings as less embroidery was required.

Mamu produced the first hand-embroidered sample which was followed by another embroiderer, Mona. Another four embroiderers, who worked on the actual dress together with Manu and Mona, would then "copy from the sample". Referencing Derek Sivers’ (2010) observation of the “first follower”, Manu played the role of the leader, establishing the instructions and standard for the embroidery. Mona played the crucial role of the first followers and showed that the standard Manu sets could be achieved. The other less-experienced embroiderers then proceeded with their work by copying the pattern that had been set for them.

Vikas’ responsibility was to ensure the timely completion of the work by assigning the right number of embroiderers according to the pace of the progress. Vikas revealed that there are two flowers in the dress which are more finely embroidered than the rest. These initial flowers were embroidered by Mamu according to the standard that Vikas usually demands for his work. However, with just under three weeks left to delivery, the progress was too slow and Vikas had to instruct the embroiderers to reduce the refinement and increase the speed of the embroidery.

Worried that his own embroiderers could not finish on time, Vikas tried to sub-contract some of the work to two other embroidery workshops, offering the same extra rate he pays his own embroiderers. They rejected his offer, judging the work to be too time-consuming.
Money alone was not enough to get the work done and Vikas did not have the same amount of relational capital to leverage with the external workshops as he had with his own embroiderers.

In total, the dress took 720 man-hours to produce, including sampling and work on the actual dress. On May, 25, Vikas flew back to Singapore with the embroidered panels of the dress. That same day, Chote sewed up and finished the dress. His work took place behind-the-scenes; cutting and sewing according to drawings, measurements, verbal instructions, and photographs provided by Vikas. He never met Circe in person throughout the process. At 2 pm on May, 26, Adrian accompanied Vikas to deliver the finished dress to Circe (Figure 5). In the evening, Circe messaged her thanks to Vikas for completing the dress and asked about the price.

While certainly not recommended practice, there were two reasons why the price was not established until the end of the project. Firstly, Vikas did not have a close-enough prior reference for this particular style of embroidery involving so many different colors. It was difficult for him to accurately predict the time and resources required for its completion prior to commencement. Secondly, the project was not merely transactional. There was a relational component and the need for trust amongst stakeholders. The client had to trust the designer to complete the dress on time. The designer upon accepting the commission had to trust that his team would help him complete the work satisfactorily and that the client would pay him for the finished work. Both the client and the designer shared the risk of the project. It was a coproduction in which failure was not an option.
Figure 5. Circe trying the completed dress for the first time.
5. Benefits and limitations of technology

In this digital age, we are surrounded by so much technology that it is easy to take it all for granted. Today, when people speak of technology, they are usually referring to computers, smart devices, robots, blockchain, artificial intelligence, and 3D printing etc. In this case study, examples of technology from the present digital age, the industrial age, and the pre-industrial age were observed. More specifically, the smartphone, the sewing machine, and hand embroidery tools respectively. In this section, we examine the use of technologies in the making of the dress.

Digital technology enabled communication between actors in different locations and across time zones. The mobile application WhatsApp was used for the majority of the communications between client and designer. They only spoke face-to-face during the initial design discussion, for the initial fittings, and when the finished dress was delivered. WhatsApp was used to share visual references, follow up on the progress, negotiate solutions, provide assurance and approval, etc. Embroidery placements shared by Dinu via Google Drive, a cloud storage service, were accessed by Vikas on his smartphone. Vikas also used his smartphone’s camera to capture images and take videos of the embroidery work at various stages. Images of the first embroidery prototype were sent to Circe for her approval. Subsequent images and videos of work-in-progress were used to keep her assured of progress. Vikas also provides his clients with videos of the work-in-progress as a guarantee of the “handmade”. Ironically, when the embroidery seems too refined, clients sometimes question if the work was really being done by hand or machine.

Machine-aided embroidery, an industrial age technology, is typically faster than hand-embroidery but has its limitations. The work area is limited to the clearance between the machine body and needle and the largest hoop used was about 15-inches in diameter.
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(Figure 6). Only one machine embroiderer can work on a dress panel at one time; continually repositioning the hoop after each section is embroideried. The embroidery, consisting of 17 colors (Figure 7) meant having to re-thread the machine many times for each hoop position. A final drawback is that machine embroidery tends to produce a stiffer, more rigid hand feel as compared to hand embroidery because the main fabric has to be stabilized with interfacing.

![Embroidery threads](image)

*Figure 7. The 17 colors selected for the embroidery.*

Ari hand-embroidery, utilizing tools from the pre-industrial age, was eventually used to complete the embroidery for the dress in 15 days. This embroidery produced a softer hand-feel as compared to machine-aided embroidery since the use of interfacing was not required. It was also the more efficient option as the larger embroidery frame allowed multiple embroiderers to work on the same piece simultaneously (Figure 8). In Ari embroidery, switching between different colored threads can be done more quickly compared to the sewing machine. Ari embroidery involves chain stitching with an awl. Without getting too technical, each stitch leaves two threads on the surface where the thread is looped and a single thread on the under-side. This results in a higher density of the face-side embroidery compared to the reverse (Figure 9).
Figure 8. Two embroiderers working on the front bodice of the dress.

Figure 9. Close up of Ari embroidery sample. Top of embroidery on the left, back of the embroidery on the right.
6. Artefact and meaning

As curator of the Frida: Making Herself Up exhibition, Circe had dedicated almost two years in preparation. The opening at the V&A museum was an important milestone for her. A regular off-the-rack dress would not be sufficiently commemorative. Her motivation to wear a version of Tehuana dress for this occasion stemmed from her research on Frida Kahlo's adoption of Tehuana costume in her everyday dressing. While Frida was from Coyocoan, Mexico City, she mixed various types of indigenous garments in her dressing. Circe felt personally connected to this research being Mexican herself and for the fact that her grand-aunt, Alfa Rios Henestrosa, provided Frida with some of the Tehuana garments she wore. In the footsteps of Frida, Circe’s choice of dress was consciously driven to fulfil the duo purposes of constructing identity and showing her appreciation for artisanship. The intention of the client, in this case, imbued the artefact with its meaning.

While the dress holds personal meaning for Circe, any cultural significance depends on how it is perceived by others. Today, there is a strong association between peony embroidered Tehuana traje and Mexican identity, thanks in part to Frida’s influence. Historically, the Tehuanas adopted the peony embroidery from the imported Manila Shawl. The Manila shawl, unlike what its name might suggest, did not originate from the Philippines but from China. For the Chinese, each motif used in the embroidery had a purpose and was a metaphor, but this symbolism was lost in time as the designs were adapted to suit the tastes of different markets (Arbues-Fandos, et. al., 2008). The indigenous people of Oaxaca (Mexico) changed the colors and increased the size of the peony motif embroidery in the Manila shawl. This style of embroidery was also applied to the Tehuana dress. This historical cross-pollination continues with Circe’s dress, bearing Manila shawl-style peony motifs executed in Indian Ari embroidery.

The making of the physical dress was accompanied by the creation of many digital artefacts; including images, videos and text. Arguably, these intangible artefacts contribute more to the construction of cultural significance than the tangible artefact itself. On the night of the V&A exhibition opening, Salma Hayek, who played the role of the titular character in the 2002 biographical film *Frida*, came dressed in traditional Tehuana traje. Her outfit was a close interpretation of a photo of Frida as a Tehuana that accompanied the 1948 Time magazine article entitled “Mexico: Fashion Notes” (Belnap, 2017). This same image was Circe’s initial reference for her dress. This outfit while so representative of Frida in our collective psyche was not found amongst her personal belongings in the bathroom of the Blue House. Should Hayek’s traditional rendition and Henestrosa’s modern interpretation be seen as reincarnations of a lost outfit or an immortalized image? In any case, the image of
Salma, Circe, and Frida’s Self Portrait, 1948 (Figure 10) posted on Instagram has become memorialized as a part of contemporary media culture.

Figure 10. (Left) Instagram post of Salma, Circe, and Self Portrait, 1948 by Frida Kahlo. (Right) Image of Salma and Circe at the V&A exhibition opening shared via WhatsApp.

7. Reflections

The following are some of my reflections on the findings of this study in response to the research questions.

*What were the requirements for this dress to be made?*

This dress would not exist without the initial vision of the client, Circe, who was not only the patron/producer but arguably the lead designer. The commissioned designer, Vikas, adopted different roles over the course of the project, including translator, tailor, middleman, negotiator, production manager, artisan, quality control, photographer, videographer, customer service, etc. Possibly due to the privacy of such arrangements, such examples of co-creation between end user and professional designer are uncommon in the literature. Understanding the motivations of clients and producers in the co-design process can be valuable in enhancing existing or even creating new design service offerings.

It is important to note that money alone was insufficient incentive to get the work done. Trust and relational capital were necessary to overcome the perceived risks of the project. The client made initial contact with the designer through the author, who shared a closer
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working relationship. The designer’s negotiations with his embroiderers took place during the workshop “ritual” (Sennett, 2009) of the tea-break. These seemingly trivial connections played their part in the realization of the dress.

The designer’s tacit knowledge was observed in other minute production decisions. Although Dinu suggested using French tulle at one point, Vikas stuck to a tulle he was familiar with because he could accurately gauge, from experience, the amount of allowance required to compensate for the shrinkage that occurs after releasing the fabric from the embroidery frame. During prototyping, he reduced the number of colors in the embroidery from the initial 21 that the thread seller picked out to the essential 17. He mobilized multiple hand embroiderers after realizing that the machine-aided embroidery would take too long. He made sure the embroiderers applied the right balance between refinement and speed. He personally oversaw the dry-cleaning of the embroidered panels and hand-carried them back to Singapore. Process management was also critical to Vikas’ workflow. Placing his pattern cutter/sample-maker in Singapore allows him to perfect toiles where his clients live and make final adjustments when necessary.

The flexibility of the artisans’ skill enabled the tangible embroidery work. Ari embroidery was adapted to mimic the single-needle embroidery found in the Manila shawl. The smartphone facilitated processes from design negotiations to confirmations, and providing assurance.

What is the cultural significance of this dress?

Jha and Narang (2014) state that the challenge of bridging the gap between traditional craft and fashion lies in harmonizing the local and global, the urban and the rural, tradition and modernity, creating new market potential in a way that is beneficial for all stakeholders. I believe that the making of this dress has bridged the gap between traditional craft and fashion quite successfully. In the precedent of Frida, this dress was a celebration of Circe’s cultural identity and personal affiliations. As a designed artefact, this dress was the result of centuries of globalization, from the Manila shawl trade routes of the 1500s to present day expatriation; reflecting the cross-pollination of cultural symbols, design sensibility, and craft technique. In this digitally connected age, the images of the dress extend cultural significance well beyond the artifact. However, what cultural significance would the image have without the dress and the intangible design decisions, craftsmanship, and cross-pollination of cultural heritage that went into its making?

8. Conclusions

By explicating the usually implicit processes involved in the making of this dress, we see how the meaning and value of the crafted artefact is ascribed by the collective of actors involved in the making of the object rather than a single author. In this age of multiple networks and connections, the handmade still has its place alongside industrial and digital technologies as long as people continue to value its expression.
The earlier industrial revolutions may have led to the redundancy of the craftsman’s workshop and craft guilds (Sennett, 2009) but the 4th industrial revolution can empower small craft businesses to once again thrive. However, as customers continually evolve, the designer’s work now involves catering to – with reference to Maslow’s hierarchy – “higher-order” needs. In cases like this, the client and designer are engaged as co-designers.

In this post-industrial age, quality and craftsmanship are important, but they increasingly only fulfill clients’ baseline expectations (Langer, 2020). From a behavioral perspective, the higher purpose of this dress was art – an “activity of making the things one cares about special” (Dissanayake, 1995, p.223). I suggest that while conventional wisdom emphasizes brand storytelling, contemporary designers should consider how they are helping clients craft their own stories.

References
The making of a dress: Explicating the implicit processes


About the Author:

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**Acknowledgements:** Circe Henestrosa for being a constant inspiration. Her passion for celebrating local craft practice and translating the “traditional to contemporary” was the catalyst for this study. Vikas Dayal for his generous help in recounting the entire dress-making process, taking me to visit his workshop and artisans in New Delhi, and providing many of the images used in this paper.
The shape of wellbeing: investigating an approach for the development of a design requirements framework for design for wellbeing projects.

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Abstract | Positive psychology and positive design are becoming increasingly important in contemporary design discussions. The previous research work provides inspiring approaches to reflect on the way how human wellbeing can be shaped by products and indicates to the importance of the creation of meaningful activities and experiences through design. However, the actual transfer of these theoretical approaches to design practice has not yet been widely researched. This paper deals with the question of how approaches from the research field of design for wellbeing can be implemented in design projects. Using the case study of planning an interior design semester project, the investigation of an alignment strategy of the process phases requirements engineering and design in form of a design requirements framework is presented. This framework could act as a guideline for the assessment of the technical-practical, aesthetic and symbolic design function in design for wellbeing projects.

KEYWORDS | DESIGN EDUCATION, DESIGN PROCESS, WELLBEING, REQUIREMENTS ENGINEERING, DESIGN RESEARCH METHODS
1. Introduction

The research fields of positive psychology, well-being and human flourishing have been increasingly taken up and addressed by the design community. For an interior design project, where students got the task to develop redesign-concepts for an existing public building in an urban environment, the decision was made to take up the approaches presented in literature on positive psychology and positive design and try to apply them in this project. For the project’s clients, it was particularly important to make sure that people feel motivated to linger, exchange ideas, have fun and are able to experience an overall feeling of wellbeing while being inside the building. In the course of the preparation of the project, the review of the related work in this research area showed that the design community is aware of the importance of this research area within design practice, but nevertheless its implementation is still in its infancy. Missing tools and methods, as well as no real alignment strategy for the subsequent design process phases are complicating its implementation process. It became clear that the approaches generated so far, focused on the question of how the user requirements engineering process can be informed by collecting positive social practices and meaningful experiences from people of the project’s target group. But how to proceed from there? How to implement design for wellbeing in a design project? This paper aims to contribute to the research realm of design for wellbeing, by addressing the design process structure for projects in this field. For the preparation of the interior design project, the decision was made to work on an alignment strategy that would make it possible to move from the requirements engineering phase to the design phase with concrete results. The following chapters describe, the approach taken and lessons learned in the course of this undertaking, as well as present a proposal for an alignment strategy in form of a design requirements framework, bridging the requirements engineering and design phase of a wellbeing project.

2. Related Work

Based on the psychological approaches on the subjective (Diener, 1984), psychological (Ryff, 1989) and social well-being (Keyes, 1998, 2002), as well as human flourishing (Seligman, 2012) different design disciplines have worked on translations of these approaches in order to use them in design practice. Desmet and Pohlmeyer (2013) address the issue of design’s possible contribution to the creation of subjective wellbeing of individuals and respectively their happiness and coin the term positive design as an umbrella term to describe all forms of design, design research and design initiatives which focus on the increase of subjective wellbeing of individuals. They propose their positive design framework with the three components: design for pleasure, design for personal significance and design for virtue. Brey (2015) investigates the question of how and in which way it is possible to design for wellbeing and mentions that four approaches exist to implement design for wellbeing in design projects, namely the approach of emotional design, the capability approach, the
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positive psychology approach and the life-based design approach. He sees a complementarity in the four presented approaches since they highlight different factors for wellbeing. The inclusion of the role of physical objects and the symbolic meaning of material possessions has also been discussed. The role of objects was examined by means of the question, how the use of physical objects, in combination with psychological interventions, could possibly support human flourishing (Desmet & Sääksjärvi, 2016). For the design of meaningful experiences, the decoding of social practices is seen as an interesting starting point from a design perspective (Klapperich et al., 2018). Referring to design strategies for the creation of symbolically meaningful objects and interactions the SIM toolkit has been developed, which was later on illustrated with product examples for the 16 symbolic meaning-focused design for subjective well-being directions in order to inspire their application in design projects (Cassais et al., 2016a, 2016b, 2018). In summary, these efforts have mostly inspired the development of meaningful actions and experiences (Diefenbach & Hassenzahl, 2017) and it can be stated that the topic of implementing the design for wellbeing approach in a design process has not yet been addressed sufficiently.

3. Design process and seminar structure

During the preparation of the interior design project the decision was made to use, due to the projects’ goal, a human-centred design process methodology. The choice fell on a revised presentation of the Human-Centered Design ISO Standard 9241: 210-2010 (International Organization for Standardization, 2019) with a focus on the product design aspects within the process (Dittenberger, 2019). This design process is divided into the phases Inspire, Collect, Design and Evaluate (Figure 1). In the process step “Inspire”, the focus lies on learning about the projects’ context. Methods of qualitative social research, such as observational and survey methods, are applied. Based on the results of these studies, problem areas within the project context can be identified and subsequently comparatively researched in literature. In order to investigate the identified problem areas in more depth, further methods of qualitative social research are used in the “Collect” phase, such as interviews, focus groups or cultural probes. After each method has been carried out, the aim is to focus the project on a specific problem as well as the target group and to collect for this the human, technical, aesthetic, symbolic, ecological and economic requirements. After the broad preparation of the requirements for the selected problem area, the results are evaluated and a specific aspect is selected. For its processing, a research question and a design briefing for the projects’ practical, aesthetic and symbolic functions is formulated which should be addressed in the following design phase. Furthermore, archetypal users, personas, are defined to ensure that the project focuses on the selected target group. The process phase “Design” is dedicated to the development of design approaches, the conduction of design studies and analog and digital model building. This process step also includes the active involvement and creative incorporation of feedback from the target group in the design development. The phase “Evaluate” represents the final
step of the process. Before the final prototype is built, the project gets finally evaluated by people of the target group to see whether the defined design briefing meets the requirements. In an iterative approach, the process is repeated until the evaluation results fulfil the defined requirements.

Figure 1. Human-centred design process (Dittenberger, 2019).
The project’s design process phases were divided between the seminars design research and design studio practice. The design research seminar had to cover the design process phases “Inspire” and “Collect-Input/Output” and the design studio practice seminar had to cover the process phases “Design” and “Evaluate”. Within the design research seminar, all framework conditions for this project had to be determined in order to use the findings to create the students’ individual design briefings for their semester projects.

Design research is instructed and trained as an integral part of a design process during students’ design projects, to understand the real wishes and needs of the people they are designing for. Teaching experience, gathered while working with the presented human-centered design process model, had shown, that it is essential to highlight the further use of the generated data of a design research study in order to be able to use the results for the next project phase, the design phase. It has been observed that after carrying out a user requirements study, students had great difficulty in formulating criteria for a design briefing from the results of such studies. But in order to design a human-centered solution based on real end-user needs, the results of a requirements engineering process should deliver detailed design related information to enable the creation of a design briefing.

From a design education perspective, we posed the question of how we could make the desired output of the process phases, in the form of a collection of criteria for the technical-practical, aesthetic and symbolic design function (Schneider, 2005), more clearly visible and thus more understandable.

4. Collection of building blocks for the design requirements framework

As mentioned before, by applying during a user requirements study mainly methods which provide information about the life context, the needs as well as how the lives of the target group could be improved by a particular product field, the problem occurs that there is a lack of information which would be needed in the next process phase, the design phase. In order to give the students an overview of the requirements that should be collected during the design research phase, an approach for a new design requirements framework, addressing the technical-practical, aesthetic and symbolic design functions, was created based on existing models. Since a design briefing defines parameters for the functions of the design which should be achieved, reference is made here to Schneider's (2005) subdivision of the functions of design. He suggests a division into three parts: technical-practical functions, i.e. the physical functions of objects, aesthetic functions that affect all communicative, informative and formal functions of objects, and symbolic functions that relate to the social or psychological aspects of objects. In order to visualize the students what information is required for a design briefing, Heufler's (2004) items for the creation of a design briefing and Pugh's (1991) items for the creation of design requirements were used.
4.1 Design Briefing

Gerhard Heufler describes a design briefing as a “concise description or list of all the factors, requirements and requests affecting product design” (2004., p. 185). For him, a design briefing has to define items in the categories application, target group and market; technical, economic demands; environmental impact; and schedule. The following Table 1 offers a detailed overview.

<table>
<thead>
<tr>
<th>Application, target group, market</th>
<th>Technical, economic demands</th>
<th>Environmental impact</th>
<th>Schedule</th>
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<td>Technical data (dimensions, weight)</td>
<td>Energy and raw material consumption in production and use</td>
<td>Development, design, construction</td>
</tr>
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<td>Decisive features</td>
<td>Environmental conditions (temperature, dampness)</td>
<td>Long life, repairable, retrofittable, removable, recyclable</td>
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<tr>
<td>Target group definition</td>
<td>Operation, maintenance, service life</td>
<td>Reduction in raw materials</td>
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<tr>
<td>Competition analysis, market situation</td>
<td>Process, action</td>
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<td>Type of construction, model assembly, packaging</td>
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<td></td>
<td>Requirements, standards, patents, product liability, quantity, price</td>
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*Table 1. Items for a design briefing (Heufler, 2004).*

4.2 Design requirements

To work on this identified challenge on the creation of a design requirements framework for the technical-practical, aesthetic and symbolic design functions, Stuart Pugh’s (1991) checklist of 24 items for the generation of design requirements was selected as a starting point. He argued in his publication *Total Design: Integrated Methods for Successful Product*
Engineering in support of the performance of participatory design for product design projects by transdisciplinary teams. The first part of his suggested total design activities consists of the six phases: user needs, product specification, conceptual design, detail design, manufacture and sales. The second part focuses on the product design specification in terms of design, manufacture and sales. The third part deals with information gathered from methods to inform the design core. The fourth part addresses the inputs needed from technology sources. The aspects addressed in the four parts were used to develop a checklist of 24 items for the generation of design requirements (Table 2).

<table>
<thead>
<tr>
<th>Number</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Performance (function)</td>
</tr>
<tr>
<td>2</td>
<td>Environment (use context)</td>
</tr>
<tr>
<td>3</td>
<td>Life in service (intensity of use)</td>
</tr>
<tr>
<td>4</td>
<td>Maintenance</td>
</tr>
<tr>
<td>5</td>
<td>Target product cost</td>
</tr>
<tr>
<td>6</td>
<td>Transport</td>
</tr>
<tr>
<td>7</td>
<td>Packaging</td>
</tr>
<tr>
<td>8</td>
<td>Quantity</td>
</tr>
<tr>
<td>9</td>
<td>Production facilities</td>
</tr>
<tr>
<td>10</td>
<td>Size and weight</td>
</tr>
<tr>
<td>11</td>
<td>Aesthetics, appearance finish</td>
</tr>
<tr>
<td>12</td>
<td>Materials</td>
</tr>
<tr>
<td>13</td>
<td>Product life span (duration of use)</td>
</tr>
<tr>
<td>14</td>
<td>Standards, rules &amp; regulations</td>
</tr>
<tr>
<td>15</td>
<td>Ergonomics</td>
</tr>
<tr>
<td>16</td>
<td>Reliability</td>
</tr>
<tr>
<td>17</td>
<td>Storage</td>
</tr>
</tbody>
</table>
Table 2. Checklist of 24 items for the generation of design requirements (Pugh, 1991).

4.3 Symbolic meaning-focused design directions

The approach of Casais, Mugge and Desmet (2016a, 2016b, 2018) was chosen to explain the meaning of the symbolic design function. They address the topic of material possessions and their corresponding happiness-related symbolic meaning by arguing that material possessions contribute to the individually experienced happiness due to memories we have with them, achievements they stand for or aspirations they remind us of. In their paper the authors present the SIM toolkit (Casais et al., 2016a), which means the design with symbolic meaning for user happiness, as well as a symbolic meaning framework including 6 happiness-related symbolic meanings and 16 design directions for it (Table 3). Based on Carol Ryff’s model of psychological wellbeing from the year 1989, consisting of the six basic elements: self-acceptance, positive relations with others, autonomy, environmental mastery, purpose in life and personal growth, they analysed narrations of personally meaningful objects concerning their happiness-related symbolic meaning. Afterwards, they started to develop concrete design directions for each of the six categories to be used during a design process. The result of this research work was the SIM toolkit.

<table>
<thead>
<tr>
<th>Symbolic meaning</th>
<th>Design direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive relations with others</td>
<td>Support meaningful affiliations</td>
</tr>
<tr>
<td></td>
<td>Embody characteristics of a group</td>
</tr>
<tr>
<td>Personal growth</td>
<td>Support active personal development</td>
</tr>
<tr>
<td></td>
<td>Embody personal growth</td>
</tr>
</tbody>
</table>
Support acceptance and growth form past experiences

Enhance memories

Purpose in life

Encourage positive change

Provide a sense of control

Keep track of progress

Environmental mastery

Support multi-sensorial communication

Provide a context for meaningful interaction

Autonomy

Destigmatize

Design for mindfulness

Redirect the user’s attention

Self-Acceptance

Allow shared transformation

Allow self-expression

Table 3. 16 design directions to design for happiness (Casais et al., 2016a).

4.4 Design requirements framework

This collected information was used to create a new overview table. The aim of this new table was to give the students a compact overview of which criteria of the technical-practical, aesthetic and symbolic design function are necessary to create a design briefing. As already mentioned in chapter one, past experience from teaching showed that it is important to show the students at the beginning of a project what results of a design research study are necessary to base their design on relevant data collected. Table 4 shows an allocation of the different items to the respective design functions.

<table>
<thead>
<tr>
<th>Technical-practical design function</th>
<th>Aesthetic design function</th>
<th>Symbolic design function</th>
</tr>
</thead>
<tbody>
<tr>
<td>= physically experienced</td>
<td>= sensually experienced</td>
<td>= socially experienced</td>
</tr>
<tr>
<td>Main functions</td>
<td>Shape (geometry, proportion, size)</td>
<td>Positive relations with others</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>Sign functions (delimation, grouping, surface texture, colour contrasts, orientation, endurance, stability, precision, flexibility/variability, operation, comprehensibility)</td>
<td>Personal growth</td>
</tr>
<tr>
<td>Handling and interaction</td>
<td>Material (warm/cold to touch)</td>
<td>Purpose in life</td>
</tr>
<tr>
<td>Size and weight</td>
<td>Surface (tactile properties smooth/textured surface)</td>
<td>Environmental mastery</td>
</tr>
<tr>
<td>Environment</td>
<td>Colour (signal/restrained effect)</td>
<td>Autonomy</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td>Self-acceptance</td>
</tr>
<tr>
<td>Standards, rules and regulations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation and initiation of use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reuse, recycle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Items for the design requirements framework.

5. Alignment strategy

After creating the design requirements framework, the project phases and thus the seminar structure were worked on. As already mentioned, the design process phases “Inspire” and “Collect” should be covered within the design research seminar and the phases “Design” and “Evaluate” within the design studio seminar. As experience has shown that the design research phase raises most questions among the students, special attention was paid to the structural planning of this seminar.
5.1 Study design

The students’ projects had to follow a qualitative research approach to answer their research question. The qualitative research process is oriented towards the understanding of the humanities and cultural sciences and regards the subject as the constructor of his reality. Already during the research process results are put into practice theories and hypotheses are generated. Flick (2009) describes the research process in non-standardized qualitative research through the steps of selecting a research problem, systematic literature analysis, formulation of the problem, development of a project plan, selection of appropriate methods, entry into the field of investigation, data collection (data documentation and data analysis) and discussion the results.

For the study design the approach of action research, which can be understood as comparative research, was chosen. Here, the focus is on research into the conditions and effects of social action as well as the reflected action within a design process. Although the course of an action research process depends strongly on the practical conditions, there are two steps that must be considered. According to Muratovski (2016), first a goal or a research question is formulated, followed by an action which is subsequently evaluated. The process is characterized mainly by the constant change and the repetition of information collection, analysis and processing. In several iterations, preliminary results are already being implemented and tested during the research process. Another criterion of action research is the equality of all involved, which is ensured by the constant exchange between researchers and persons of the target group.

In order to proceed with the preparation of the semester project, the next step addressed the selection of qualitative and design research methods to enable the collection of valid data for the creation of a list of design requirements regarding the aspects of technical-practical, aesthetic and symbolic design functions, after the conduction of a design research study.

5.2 Data collection of the technical-practical and aesthetic design function

A spatial analysis was planned to ascertain the collection of items for the technical-practical as well as the aesthetic design function of the project. For this the method “Photo and Video Diaries” (Milton & Rodgers, 2013, p. 24-25) was chosen. The aim of this method is to record the actual state of a situation, room conditions or product uses in order to identify potential problems.

In order to synchronize the step of data collection and the subsequent data analysis, the method “AEIOU” (Martin & Hannington, 2012, p. 10-11), meaning A - activities, E - environment, I - interactions, O - objects and U – users, was defined at the same time. The following Table 5 provides an overview of the criteria on which students should collect image material when using the Photo & Video Diaries method.
Table 5. Preparation of the data analysis grid.

The preparation of the results of the spatial analysis within the analysis grid enables a good overview of the identifiable problems or open questions within the project.

5.3 Data collection of the symbolic design function

The data collected and the problem areas identified from the spatial analysis should be used to obtain further information about the symbolic meaning of the rooms within the building. In order to ascertain the symbolic spatial function, a guideline interview with identified persons of the target group was planned. The development of the guideline questions should be developed in group work. Based on the 16 design directions by Casais, Mugge and Desmet (2016a), the focus was placed on the parameters "positive relations with others" and "environmental mastery" with regard to the project context. The students should develop questions with the aim of finding out which activities within the building generate joyful moments and which materials, lighting moods and colour worlds are to be found.

In addition, participants should also be asked about activities they remembered which put them in a joyful mood and what the material contexts of these situations were. The results of the guideline study should be included in the data analysis grid. In summary, the result of
the analysis grid should enable the definition of a research question, which should further be used as a basis for the redesign concept of each individual student’s project.

In order to show the students, the connection between the seminars design research and design studio as planned from the beginning of the semester on, respectively the start of the project, and thus also to point out the alignment strategy of the seminars, a visualization of the table for the items of the design requirements framework was created (Figure 2).

![Figure 2. Visualisation of the Design Requirements Framework.](image)

After the detailed preparation, it was also planned that the teachers of both seminars should lead the kick-off with the students at the beginning of the semester project. In the course of the semester, the lecturers should also come together for special input sessions in order to indicate the connection between the teaching content of the two seminars with a physical presence. In a first interim presentation, the students should present the results of their study from the design research seminar in the form of a design briefing for their design phase.

### 6. Discussion and conclusion

How to implement design for wellbeing in a design project? After the completion of the project it can be stated that the intensive planning work of the semester project supported the actual implementation very well. After the presentation of the semester project and the
semester planning, the design requirements framework was well received by the students. Within the design research seminar, the positive design literature and the existing project examples were discussed thoroughly. The topic itself and the examples were reflected very interested by the students.

Figure 3. Students filling the data analysis grid.

However, how this content should be used in their projects was not very clear to them. The fact that design for wellbeing focuses primarily on the creation of meaningful actions and experiences is understandable for students, but the actual translation of these approaches to their own projects is very difficult to grasp.

During the implementation of the design research methods, the Photo and Video Diaries and the guideline interview, the design requirements framework was repeatedly used as a guidance to maintain the focus of the survey on the goal.

In a discussion with the students after completing the design research seminar, how they felt about the alignment strategy and the design requirements framework, it was reported that the meaning and implementation of design research as an integral part of a design
process was now much more understandable for them. The goal was always clearly insight and so they didn't feel lost in a purely theoretical approach that needed to be physically translated.

Wellbeing will become an increasingly important factor in design projects in the future. Previous research in this area has brought valuable knowledge from the field of psychology and positive psychology into design. Nevertheless, it is important to continuously work on the actual applicability of the theoretical approaches in practice. The approach of the design requirements framework and alignment strategy presented in this paper, in the sense that the factors for the technical-practical, aesthetic and symbolic function of design should act as a guiding principle in all design process phases, has proven to be sensible and practically applicable and will be worked on in further studies.

**References**


About the Author:

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Weaving sequential changes – designing textiles with multiple embedded stages

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Abstract | The development of dynamic materials has changed the ways in which textiles are designed, but few research projects have investigated multiple sequential changes in textiles. This paper explores the design of textiles with the ability to undergo transformations involving multiple stages. Dynamic shrinking, hardening and dissolving yarns were combined in industrially woven structures to create a collection of five textiles, the texture, size, thickness, and number of layers of which were possible to change through heat and moisture. The fabrics were used in two workshops, and a series of prototypes was developed to explore potential application areas. The outcomes of the experiments show that textiles can transform in several stages through alterations to their properties, and that it is possible to embed this in their structures. Further research is needed on potential applications and how to better integrate textiles into product design processes.

KEYWORDS | WEAVING, MATERIAL, DYNAMIC, LIFESPAN, TEXTILE DESIGN.
1. Introduction and related work

This paper explores the design of textiles with the ability to undergo multiple stages of transformation within a sequence; these transformations can relate to changes in texture, size, thickness, and number of layers. Experimental work with dynamic materials, including shrinking, dissolving, and stiffening yarns, explored the concept of embedding irreversible changes in industrially woven fabrics.

The experiments presented build on the inherently changeable properties of various materials. There is a wide range of dynamic materials with various properties on the market, and these are used for a wide variety of purposes. The materials that were investigated are often used in industry within manufacturing processes, and are generally removed from the final product before it reaches the consumer.

1.1 Yarns with changeable properties

Polyvinyl alcohol (PVA) is a water-soluble synthetic fibre (Sakurada, 1985). When a piece of PVA thread is dipped in water, it shrinks, becomes rubbery, and eventually dissolves completely. Wet PVA can be formed around objects and becomes hard and translucent when it dries, losing its textile qualities. In the experiments presented in this article, a spun yarn with a dissolving temperature of 40°C was used. PVA is non-toxic and degrades into water and carbon dioxide, and is used within e.g. the food, pharmaceutical, and textile industries (DeMerlis & Schoneker, 2003; Kuraray, 2019).

The properties of PVA have been explored in several projects: Storey, Ryan, and Belford’s (2008) dissolvable PVA dresses comment on the current fashion system, while Valle Noronha (2017) uses PVA threads and fabrics to embed pre-determined alterations, such as changes in shape and details, in garments.

Grilon yarns are thermoplastic copolyamide and copolyester yarns with a low melting point, and are used to separate, bond, and reinforce [something] (EMS-GRILTECH, 2019). Grilon LT yarn, which was used in the experiments presented in this paper, melts, shrinks, and disintegrates at temperatures of above 85°C (Districo, 2019). Single threads of Grilon can be easily disintegrated using a hairdryer, but larger quantities need prolonged heating through e.g. ironing or steaming.

The properties of Grilon have been explored from a design perspective by e.g. Dumitrescu and Persson (2011), whose knitted materials responded to touch by warming up, causing the structure to break. Resortecs (2019) uses stitching in a heat-dissolvable yarn to separate fabrics, buttons, and zippers in relation to the disassembly, reassembly, repairing, and recycling of garments.

Comfil yarns are thermoplastic composites that combine a reinforcement fibre and a thermoplastic matrix polymer, and are used for e.g. vacuum and compression moulding (Comfil, 2019). The Comfil polyethylene terephthalate (PET) yarn used in the experiments
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presented in this article shrinks and stiffens when heated, and can be activated by steaming and ironing, for example. When combined with other yarns it creates shrinkage and texture, while the other materials allow the fabric to retain their soft and flexible qualities.


The changes in all of the dynamic materials used in the experiments presented in this paper are irreversible. The materials are not able to regain their original expressions, and instead their expressions are built up gradually (Worbin, 2010).

1.2 Designing textiles with dynamic yarns

The development of dynamic materials has changed the ways in which textiles are designed, in that various changes can be achieved in a textile’s structure and visual expression. Such materials can be used to make textiles with qualities that can be changed after production, affording alternative uses. However, the designer’s perspective on the material – whether it is central to the product idea or a detail chosen at the end of the design process – influences how closely the material design and product design processes are intertwined (Nilsson, 2015). A material’s inherent changeability influences the changes that occur, and as such they are central to the design of textiles with the ability to undergo multiple stages of transformation, as well as investigations of potential applications. Textile techniques and material properties define the qualities of textiles, as well as ultimately the qualities and uses of products.

Several projects in the field of fashion have explored embedding changes in garments: Riisberg and Grose (2017) explore the concept of designing garments that evolve over time, facilitating an extended garment life and thus the usage of fewer resources. Valle Noronha (2017) explores the embedding of pre-programmed temporary and permanent changes into garments for stronger person-product attachment in order to highlight the materiality of the garments themselves.

1.3 Lifespan thinking

Lifespan thinking could be embedded in fashion and textiles in multiple different ways. Products could, depending on their uses, have lifespans ranging from fast to slow, with flimsy, recyclable, or durable materials that match the intended lifespan (Fletcher, 2014). Longevity could be addressed from the perspective of two different ‘speeds’: products with short, fast lifespans with materials that go through multiple ‘loops’, and extended, long...
lifespans through emotional durability, repair, and up-cycling (Goldsworthy, 2017). Streamateria is a digital platform for made-to-measure, biodegradable garments with short, pre-defined lifespans, connecting designers to companies that work with renewable, biodegradable materials and processes to promote circular and closed-loop practices (Streamateria, 2019; Vinnova, 2019). Embedding multiple stages of transformation in a textile’s structure encourages a better matching of the lifespans of the product and the material that starts during the design of the textile material itself.

2. Experiments

Various experiments were conducted in order to ascertain whether multiple stages of transformation, involving changes in size, thickness, opacity, softness, texture, and number of layers, could be embedded in industrially woven textiles. Single-, double-, and triple-layered woven structures were made using the aforementioned dynamic, heat- and water-reactive, shrinking, dissolving, and stiffening materials (Table 1). As a result, a collection of five fabrics was developed; the structure of each was possible to alter through ironing, steaming, and machine washing.

Two workshops were organised with designers and product developers at IKEA of Sweden to investigate the possible applications that the qualities of the fabrics might suggest. Based on the workshops, six preliminary prototypes of everyday textile products were made in order to explore the materials’ changeable qualities and to adjust and change the products during their use phases. The project was carried out in collaboration with Linda Worbin from IKEA of Sweden.

2.1 The experimental setup and materials

The aim of the experiments was to explore how multiple sequential changes could be embedded in textiles. Heat and water were chosen as the main activators of changes due to their availability and the possibility of applying them to fabrics either separately (for example by ironing or washing) or simultaneously (through steaming or washing at a high temperature; Table 1).

The dynamic yarns were used as floats to create texture when they shrunk, as a binding weft between the layers of fabric to enable separation of the layers when they dissolved, and as stripes to shrink parts of the fabric in order to create texture. They were combined with more stable materials such as cotton and paper yarn to form the main body of the fabric. All of the experiments were undertaken using an industrial Jacquard loom for flexibility with regard to developing and altering the weave structures and proportions of the materials. All of the structures were woven in two variations to test how the choice of dynamic material influenced the function of the textile; one used water-reactive, shrinking PVA, and the other either the heat-reactive, evaporating Grilon or shrinking Comfil yarns.
Weaving sequential changes – designing textiles with multiple embedded stages

Table 1. The properties of the three dynamic yarns.

<table>
<thead>
<tr>
<th>Stimulus Yarn</th>
<th>Ironing</th>
<th>Steaming</th>
<th>Machine wash 30°C</th>
<th>Machine wash 40°C</th>
<th>Machine wash 60°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVA 40°C</td>
<td>-</td>
<td>Shrank</td>
<td>Shrank and melted</td>
<td>Shrank and melted</td>
<td>Shrank and melted</td>
</tr>
<tr>
<td>Grilon LT</td>
<td>Broke slightly</td>
<td>Broke slightly</td>
<td>-</td>
<td>-</td>
<td>Shrank slightly</td>
</tr>
<tr>
<td>Comfil PET</td>
<td>Shrank</td>
<td>Shrank</td>
<td>Shrank and melted</td>
<td>Shrank</td>
<td>Shrank slightly</td>
</tr>
</tbody>
</table>

2.2 The final fabrics

A collection of five materials was developed as a result of the experiments, and is presented below (Figs. 1–5). These weaves were chosen due to the variation with regard to the number of possible transformation stages of each, as well as for the variation in stages that the different fabrics offered as a collection.

All of the fabrics were systematically tested with treatments that included water, heat, and steam. The tests showed that the fabrics could each undergo differing numbers of stages. For some, but not all, of the samples, the order of the treatments affected how the materials changed. For example, first steaming and then ironing the wavy-textured paper and PVA fabric produced a different texture than first ironing and then steaming it (Fig. 2). The fabrics could be washed several times before their layers separated, and had to be steamed or ironed for a long time in order to effect a change in them. If the fabrics are used in their textured state over a long period of time, patterns of dirt may be formed.
Figure 1. The different stages of transformation of Fabric 1, as well as how these were reached and the structure and materials of the fabric.

The terry cloth fabric (Fabric 1) was a flat, smooth double weave in paper and cotton yarn with a binding weft in PVA between the layers (Fig. 1). Water and steam shrunk the PVA, making the fabric thicker and more roughly textured. When the PVA completely dissolved, the fabric separated into two parts. The fabric could be either shaped around objects or separated in specific places to create pockets.
Weaving sequential changes – designing textiles with multiple embedded stages

The wavy-textured fabric

Binding: Double weave with a binding weft floating on the reverse
Material weft: Paper yarn (white) and PVA (purple)
Material warp: Cotton

Figure 2. The different stages of transformation of Fabric 2, as well as how these were reached and the structure and materials of the fabric.
The wavy-textured fabric (Fabric 2) was a flat, smooth double weave in paper and cotton with a binding weft in PVA floating on the reverse side of the fabric (Fig. 2). Water and steam shrank the PVA, making the fabric thicker and wavier in texture. When the PVA had completely dissolved, the fabric separated into two parts. It was possible to move back and forth between some of the textured stages, depending on the stimulus applied to the fabric. The fabric could be either shaped around objects or separated in specific places to create pockets. The lines of the texture gave the fabric direction and support. Applying water to specific lines of floats could be used to make the fabric curl inwards on itself.

![Figure 2. The dividable double-weave fabric](image)

- **Binding:** Double weave with a binding weft floating on the reverse
- **Material weft:** Paper yarn (white) and Grilon (orange)
- **Material warp:** Cotton

Figure 3. The different stages of transformation of Fabric 3, as well as how these were reached and the structure and materials of the fabric.

The dividable double-weave fabric (Fabric 3) was a flat, smooth double weave in paper and cotton with a binding weft in Grilon floating on the reverse side of the fabric (Fig. 3). Heat and steam caused the Grilon layers to separate to different degrees (into pockets or channels, or completely). When machine-washed at 60°C the Grilon shrank and the layers partially separated.
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The dividable three-layer fabric (Fabric 4) was a three-layered fabric in cotton with a binding weft in Grilon between Layers 1 and 2 and a binding weft in PVA between Layers 2 and 3 (Fig. 4). The middle layer had a different colour and surface design than the others. Water shrunk the PVA, giving the fabric texture. Repeated machine-washing at a high temperature dissolved the PVA and separated Layers 2 and 3. Heat and steam caused the Grilon thread holding together Layers 1 and 2 to dissolve, dividing the fabric to varying degrees (into pockets or channels, or completely).

Figure 4. The different stages of transformation of Fabric 4, as well as how these were reached and the structure and materials of the fabric.
The texture-changing striped fabric

- Binding: Single weave with a striped pattern in PVA and Comfil yarns
- Material weft: PVA (purple) and Comfil (yellow)
- Material warp: Cotton

Non-textured fabric

Texture 1

Texture 2

Texture 3

Texture 4

Texture 5

Texture 6

Texture 7

Fabric with floats and texture

Non-textured fabric with floats

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**Figure 5.** The different stages of transformation of Fabric 5, as well as how these were reached and the structure and materials of the fabric.
The texture-changing striped fabric (Fabric 5) was a flat single-layer woven fabric in cotton, with a white-on-white striped pattern in PVA and Comfil yarns (Fig. 5). Heat and steam shrunk the Comfil, changing the size and texture of the fabric. Water and steam shrunk the PVA, which also changed the texture and size and created floats by dissolving the PVA completely. The fabric could be shaped around objects, and its texture could be changed several times within a sequence by alternating between washing and ironing treatments (Fig. 5).

3. Workshops

In order to explore the possible applications of the materials, Fabrics 2–5 were woven out and used in two one-day workshops at IKEA of Sweden in Älmhult, Sweden. Each had four participants, who were a mixture of product developers and designers. The collection of fabrics and their stages of transformation were introduced to the participants, who were able to explore them using spray bottles, hair dryers, and clothes irons. The main questions asked during the workshops were: 1) What challenges do you face in your projects in relation to textiles? and 2) what expressions or functions are you looking for?

The participants came from fields including design management, childrens’ textiles, and home textile design, and had different perspectives on the design process. Accordingly, the discussions involved a broad range of ideas for the materials and their applications. With regard to using dynamic materials in the product development process or embedding changeable qualities in products, understanding and communicating change were seen as the main obstacles. This likely stemmed from that fact that, from the perspective of a designer, one often starts with a problem or an idea for a product and chooses a material that fits the idea.

The ideas for using the changeable qualities of the fabrics in the production process included form-fitting fabric for a lampshade and shaping fabric onto furniture for easier upholstering and less work-intensive production processes. This latter could be achieved by adding shrinking yarn to a double weave and washing it to create a quilted effect, rather than using the time-consuming method quilting by sewing. Other applications included furniture upholstery in order to create up-to-date expressions, a baby blanket that can change size or be separated into several thinner blankets, curtains with adjustable lengths, and room dividers or wall hangings with optional storage pockets.

4. Prototypes

In order to further explore applications, some of the workshop ideas were created as prototypes; these included a bedspread, two lampshades, two curtains, and a pillow (Figs. 6–9). The pattern shop at IKEA of Sweden in Älmhult made the prototypes. The prototypes
explored changes in the function, form, and expression of everyday textiles by e.g. using the shrinkage of a fabric as an after-treatment when forming the textile, and using the shrinkage of a fabric to fit it to a product and adjust a textile product during its use phase.

The textured surface of the bedspread was created using the shrinking behaviour of PVA rather than the quilting technique; the pattern of the middle layer of the fabric defined the texture on the outside of the fabric (Fig. 6). The lampshades explored the idea of using the shrinking behaviour of PVA to fit fabric around a frame. A length of Fabric 4 was pre-shrunk with water and sewn into a lampshade (Fig. 6). Fabric 2 was sewn into roughly the right shape, then shrunk using water and fitted onto the frame (Fig. 7).

The curtains and pillows explored ways of forming a textile product after its production by adjusting its length and width using heat and water. The pillows could be adjusted in terms of size in stages through washing and steaming, while the curtains were not planned to change from one specific size to another; instead, they could be freely adjusted (Figs. 8–9). As most of the changes were irreversible, a potential user would need to learn new ways of treating and maintaining their textiles in order to take advantage of the different stages of transformation and prevent unplanned changes.

Figure 6. Two prototypes that explored the shrinking behaviour of Fabric 4 to create texture through machine washing: a bedspread and a lampshade.
Weaving sequential changes – designing textiles with multiple embedded stages

Figure 7. The process of fitting Fabric 2 around a lampshade.

Figure 8. Prototypes for pillows that can be adjusted in increments through steaming or washing: from bottom to top, non-treated, steamed, machine washed twice at 60°C, and machine washed at 30°C. All of the pillows had the same amount of filling.
The prototypes, while very basic in their scope, showed the importance of developing materials alongside products. Some of the ideas for prototypes were not possible to achieve with the developed fabrics. The details of the textile products, such as stitching thread, lining, and trim, would have to be matched to the planned changes. The original idea behind the bedspread was that it would be suitable for a single bed in its shrunken textured state and, after being washed at 60°C, would fit a double bed. This was facilitated by the textile, which shrunk by 50% at most, but was hindered by the fact that the trim and stitching would not have expanded with the fabric. Ultimately, the shrinkage of the fabric was effected through an after-treatment, giving the bedspread a heavy, textured surface before the material was stitched to create a more static prototype.

5. Discussion

The main question, which was explored from several different perspectives through experimental work with materials and weave structures, development of prototypes, and discussions with practitioners, was how changes or sequential stages of transformation can be embedded in the structure of a textile; a secondary aspect was at which stages of the design process textile materials can be utilised to achieve this, and what possibilities such changes open up for with regard to applications and designing several product lifespans in one textile.

Designing textiles with embedded changes means that the effects of these changes have to be considered when using the materials in different products or applications. Nilsson (2015)
argues that textiles can be incorporated into product design processes at several points, from constructing a new material to choosing an already existing fabric, and that their influence varies depending on where in the process they enter. Choosing a material based on an existing product idea was a common method among the participants of the workshops. The discussions highlighted a lack of awareness of the existence of changeable materials, and in some cases uncertainty regarding the need for them. The participants often started with a problem, came up with a product that solved that problem, then picked a material as the final step.

This method of choosing materials for products is challenged when it cannot be assumed that the textile will remain static after the production of a product. Changeable qualities invite a more active role on the part of textiles, wherein materials enter the design process at an earlier stage and their properties are developed alongside the intended expression and functionality of the product. This is a concept posited by Nilsson (2017). Such a method has consequences for the overall design and production process; for example, if a bedspread is designed such that its size can be adjusted through shrinking or a blanket can be divided into two thin shawls, the trimmings and sewing thread must be adjusted to allow for these changes. This suggests that there is a need for alternative ways of designing textiles and textile products that have such abilities, requiring textile and product designers to work in dialogue while developing both a product and its materials.

Textiles with embedded changes can propose alternative solutions to existing issues or be developed with a specific product in mind. Thus, time and the way a products is handled shape the exact changes that take place. Different properties of changeability lead to different types of change and various applications. For example, a fabric with the ability to gather and shrink in one direction suggests an alternative method of shortening a pair of curtains through shrinkage, which can later be reversed through washing. A fabric that can be separated into two fabrics, on the other hand, suggests an alternative method for hanging curtains by opening channels for the curtain rods, rather than sewing.

However, the design of such fabrics is challenging in that this will require users to learn new habits with regard to how they handle their textiles. On the other hand, methods such as ironing, washing, and steaming are familiar and easily accessible methods of textile maintenance. Using such methods to shape textiles opens up the idea of customising, adjusting, and taking a DIY approach to textiles without the need for advanced sewing, pattern-making, and textile construction skills and equipment. Another challenge is that consumers expect a product to maintain the same expression and function throughout its lifespan. They would thus have to understand the changeability of such textiles and ‘buy into’ the concept of change, and this would need to be communicated to them in a clear manner before a purchase is made.

Changeable qualities in textiles could also be used to replace more costly production processes. The fabrics presented in this paper were all woven on an industrial Jacquard loom for the purpose of flexibility in terms of development. They could, however, have just as
easily been woven in greater quantities on a shaft machine. If produced on an industrial scale, the intolerance of textiles to heat and moisture would require the preparation process and after-treatments to be rethought, as the materials cannot be washed without changes occurring. This could open up for reducing the amount of chemicals used in production processes.

6. Conclusions and future work

The textiles presented in this paper exemplify the idea that it is possible to design textiles that are able to undergo multiple sequential changes as a result of inherent changeability and the placement of materials in a textile structure. The number of stages of transformation did not automatically correlate with the versatility of the possibilities that were created in the fabric. Fabric 2, with its ability to change in terms of size, thickness, and texture and be divided into several layers, had multiple different stages. In comparison, Fabric 3 offered relatively few stages of transformation. However, when the possibilities of the materials were discussed during the workshops, an equal number of possible uses and applications were posited for both fabrics.

Using the inherent material property of changeability to design textiles could suggest alternative approaches to designing the lifespans of textiles, wherein a textile’s qualities are connected to the material’s properties and the material’s properties are better matched to the textile’s lifespan. The ability of a textile to undergo multiple changes in a sequence could open up for the design of several product lifespans using the same material, not by reusing the textile for a new product but by changing its structure and qualities. This would imply the need for textile and product designers to come together earlier in design processes in order to gain an improved understanding of the possibilities and limitations of materials and the requirements of the product. Further research is needed with regard to the various properties of changeability in materials and their uses and functions, and how to combine the knowledge of textile and product designers such that the development of textiles becomes an integrated part of design processes.
Weaving sequential changes – designing textiles with multiple embedded stages

References


About the Authors:

**Author 1** Riikka Talman’s PhD-research explores combining dynamic materials with textile structures to create textiles with an inherent ability change over different timespans, suggesting alternative ways of designing and perceiving textiles that accept change as one of their qualities.

**Acknowledgements:** This project was carried out in collaboration with Linda Worbin from IKEA of Sweden and it was funded by IKEA of Sweden.