Material Practices in Transition: From Analogue to Digital in Teaching Textile and Fashion Design

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Abstract
The transition to digital design tools challenges the craftsmanship of textile and fashion designers as part of the product value chain, opening for reflection on how textile craftsmanship should be taught in education due to the current trend of digitalisation. By looking at new forms of craftsmanship, this research expands on the idea of teaching students transdisciplinary methods which connect analogue and digital tools within textile and fashion design education. Based on analysis of a number of case studies, we propose a framework of different strategies for teaching textile craftsmanship in the digital design age, with the aim of integrating textile-specific digital environments — which have been designed primarily to maximise the efficiency of industrial processes, rather than to enhance design development with regard to artistic expression — and non-textile digital tools on the basis that these are exploratory in nature and open to more creative design practices.

Keywords
Material practices
Teaching
Analogue craftsmanship
Digital tools
Textile and Fashion Design

The Role of Haptics in the Age of Analogue Craftsmanship

Prior to the age of digitalisation, the haptic dimension and analogue tools were generally employed in teaching fundamental skills in design education programmes. Compared to the role of visual observation in the design process, haptic perception informs about the physical features of materials that refer to characteristics such as roughness, compliance, coldness, slipperiness (friction), and weight (Tiest, 2010). Complementary, Zuo et al. (2014) make a clear distinction between the physical features of material textures based on the structural arrangement of the constitutive elements and how the texture is experienced and communicated based on sensorial perception. Moreover, haptic discovery connects the understanding of the material's physical and sensorial properties and communicates the necessary adjustments in forming and material craftsmanship. In referring to the quality of craftsmanship, Manzini (1989) associates the role of direct interaction with the medium of creation with modes of learning technical knowledge and selective processes leading to the refining of skills.

The first foundational examples for teaching textural qualities were developed at the Bauhaus, where the richness of haptic perception and importance of teaching multidimensional forms of expression by connecting the visual to the tactile were understood, and employed in the training of students. The exercises were based on material discovery, facilitating direct interaction with a large variety of textures and materials and experimentation with a diverse range of textural qualities and media of expression, including wood, metal, and textiles (Itten, 1975). Hence, the use of the descriptive language of material characters and properties was considered insufficient for enabling complex creative processes in texture studies.

Following the same line of thought, Groth (2016) stresses the importance of nowadays education through direct tactile and bodily experiences in craft and design. Physical prototyping supports cognitive and sense-making processes by connecting an ideal mental vision of a desired design to a possible reality, and enables the creator to communicate the qualities of the artwork to the user.

For textile designers studying, basic exercises in textural design have a fundamental role in integrating the sense of touch alongside visual expression in the processes of selecting materials (yarn qualities, printing materials) and textile techniques (weaving, printing). Addressing haptics as a sensorial dimension in the design process allows the designer to work with complex processes, connecting materials, tools, textures, and forms through direct experience with the artefact and understanding of the physical properties of materials.

Haptics in the Age of Digital Craftsmanship

Today, the increased influence of digitalisation on the creative processes of the artistic fields challenges the role of haptic knowledge and analogue environments in teaching and acquiring basic design skills. Thus, the extended transition away from analogue methods and towards digital tools in most design education programmes has moved the focus in teaching from haptic to visual media of expression and has challenged the use of conventional design methods (Kretzer, 2021). Consequently, digitalisation has lessened the importance of experiential knowledge and tactility in the process of artefact-making by amplifying the importance of vision and digital craftsmanship within creative processes. Digital media of expression offer the possibility to generate highly expressive digital surfaces, which are solely visual in nature and constituted by digital textures that utilise mediations of analogue characteristics (such as colour, transparency, dullness, and lustre) and digital variables (including reflection, refraction, specularity, and luminosity). In analysing the differences between analogue and digital craftsmanship, McCullough (2006) describes the direct manipulation of objects in real-time as one of the fundamental characteristics of digital craftsmanship, as the digital medium allows the designer to achieve similar artistic goals in less time.

Reflecting on the transition from analogue to digital design methods, Malins et al. (2007), discuss the positive tension that occurs in teaching design when transitioning from educating for traditional haptic skills to the digital medium emphasising the gain of a transdisciplinary dimension of knowledge that crosses the traditional borders of the established design professions. This hybrid knowledge synthesises traditional form-making processes based on the diminishing importance of material craftsmanship and experiential knowledge as compared to abstract digital creative processes based on logic and generative complexity. Gross and Do (2009) refer to educating for a new maker culture defined by cross-disciplinary creativity and openness to combine the established knowledge domains in digital and physical tools and processes.

The transition to digital tools and cross-disciplinary workflows has been widely established in object-based fields such as product design and architecture (Carpo, 2017). In the textile field, teaching methods for digital modelling and digital manufacturing techniques are at an early stage (Kwon et al., 2017). Subsequently, in material-based fields such as textile and fashion design the haptic dimension of material-making remains a quintessential aspect of teaching and learning textile structural techniques or fabric manipulation methods. However, the role of textile and fashion design as part of the product value chain faces large challenges at present that open for reflection on how textile craftsmanship should be taught due to the current trend of digitalisation of tools. This influences industrial manufacturing, the development of complex workflows, remote modes of production, assessment of sustainable material life cycles, and customisation of textile products. Moreover, the pandemic forced designers, teachers, and students to teach and to work on physical artefacts remotely, utilising digital tools and equipment in innovative ways and studying how they can be used to replace physical prototyping (Özdamar et al., 2021; Carpo, 2022). Today, a slow but progressive return to physical, in-person approaches means that the solutions found during difficult times are no longer replacing the old ones but opening up new opportunities. Thus, the field requires suitable methods of teaching complementary digital skills for material simulation to be established, and creative processes of structural design that can complement traditional haptic skills and the craft of hand manipulation and use of analogue equipment.

Exploring a Textile Perspective on Digitalisation: Research Approach

This research expands on the idea of teaching transdisciplinary methods that connect analogue and digital tools in textile design education to develop new forms of craftsmanship that emerge from the use of advanced digital fabrication methods, both textile and non-textile. Using a practice-based approach, the aim was to outline a space for digital textile craftsmanship that would expand the existing knowledge on analogue textile tools and material crafting in relation to digital environments. Knitting was selected as it allows the practitioner to work with the processes of material construction, object forming, and surface-texture design so as to link the material to the product. The aim was to broaden specialised knowledge of textiles by connecting craftsmanship to the use of the most advanced digital tools, such as digital environments for virtual sampling, and highly specialised machine-control software. The purpose of this was to generate suitable methods for textile- and fashion-design education programmes that would complement existing analogue skills with digital ones and add value to manual craftsmanship. This research opens up for reflection on a new profession that combines textile design training with current modes of connectivity in production, communication, and collaboration that are specific to Industry 5.0, the current industrial model (Nahavandi, 2019).

In the field of knitting design there already exist highly specialised digital environments for working with structural programming, surface imagery, materials, and three-dimensional visual sampling and customisation of textile products. These include SDS-ONE APEX for industrial machines such as the Shima Seiki and M1Plus for Stoll knitting machines, both of which can be used with garment-simulation software such as VStitcher and Clo3D. These digital environments require access to highly specialised software and machines and advanced knowledge of textile craftsmanship and technical programming. Exploratory creative processes that make use of these environments are generally assisted by a technician as they require special training in technical skills that are usually not provided by design training. Complementing these are non-textile digital environments such as Rhino 3D and Blender, which allow the designer to start with a basic three-dimensional drawing of textile structures, simulate and animate three-dimensional textile forms. These require knowledge of CAD software and facilitate work with more general-purpose, affordable tools such as 3D-printing and laser-cutting machines. As compared to specialised textile-design software and industrial-scale machines, which are constrained by textile and fashion industry workflows, non-textile digital tools provide an exploratory character to design processes and open up for a more direct relationship with product design and architecture.

The case studies presented constitute four scenarios and ways of interaction between the haptic dimension and digital environments for textile and knitting design. A two-fold approach was used:

- First, from a practice-based research perspective using the designer's standpoint, interactions were explored with regard to expanding the range of tools and design processes to generate new methods to teach new forms of hybrid craftmanship.
- Second, from a pedagogical standpoint, how interactions can enhance the teaching and learning process was explored, as was the generation of updated tools and methods to improve the learning experience and obtaining of both manual-haptic and digital skills.

A Framework for Teaching Textile Craftsmanship by Mixing Analogue and Digital Tools

As result, we propose a framework of methods Fig. 1 that relate analogue and digital craftsmanship to specialised textile and non-textile tools in design processes. The purpose of this is to elaborate on and offer different strategies for teaching textile material practices in the digital age, with the aim of integrating textile-specific digital tools — which have been designed primarily to maximise the efficiency of industrial processes, rather than to enhance design development — and general-purpose digital tools, which provide an exploratory character to design processes and open up for perspectives from a diverse array of fields.

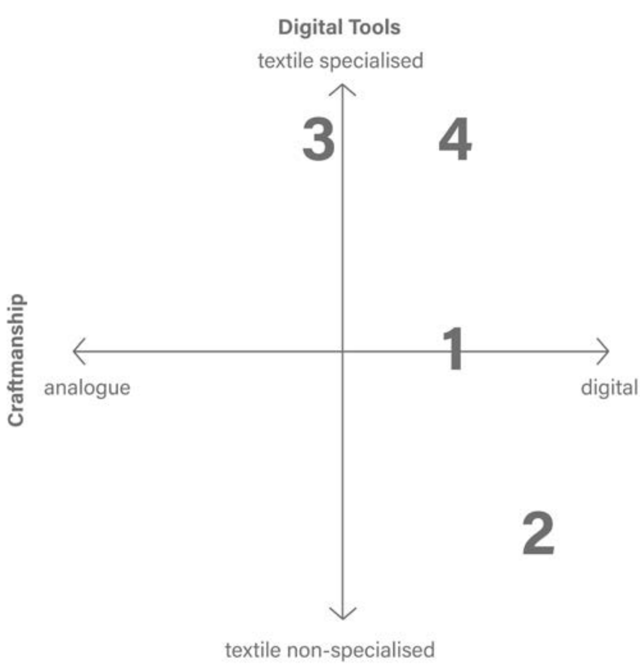

Fig. 1
Position of the case studies according to the type of necessary craftsmanship skills and type of modelling environment used, by Authors.

1 Implementing digital craftsmanship in specialised digital textile environments and non-textile digital environments. This method involved two approaches to combining digital tools and material-fabrication methods using a specialised digital textile environment for knitting design (M1Plus) and non-textile digital environments such as Rhino 3D and Grasshopper for 2D and 3D pattern-generation and simulation. These 2D patterns were printed on textiles using three-dimensional filament-printing technology and applied to a previously produced knitted base, which was prestressed. The result was a hybrid collection of three-dimensional textile composites with self-folding and -forming behaviours Fig. 2. The advantage of combining these two approaches in teaching was that it facilitated work with haptic qualities of textiles such as feel, weight, and elasticity and 2D surface design and the formation of a complex three-dimensional forms in a digital environment. This led to the development of forming skills relating to the combining of soft and stiff material behaviour (Dumitrescu, 2021), and simplified the knitting process so as to achieve complex textures by adding a new technology, resulting in three-dimensional textures and forms.
The process emerged from a dialogue between:

- the haptic experience of knitted structures;
- material hybrid fusions to generate self-folding and -forming behaviours;
- 2D pattern design and forming of textures in a digital environment such as Rhino 3D;
- acquiring new craftsmanship skills in a non-textile fabrication method: three-dimensional filament-printing technology.

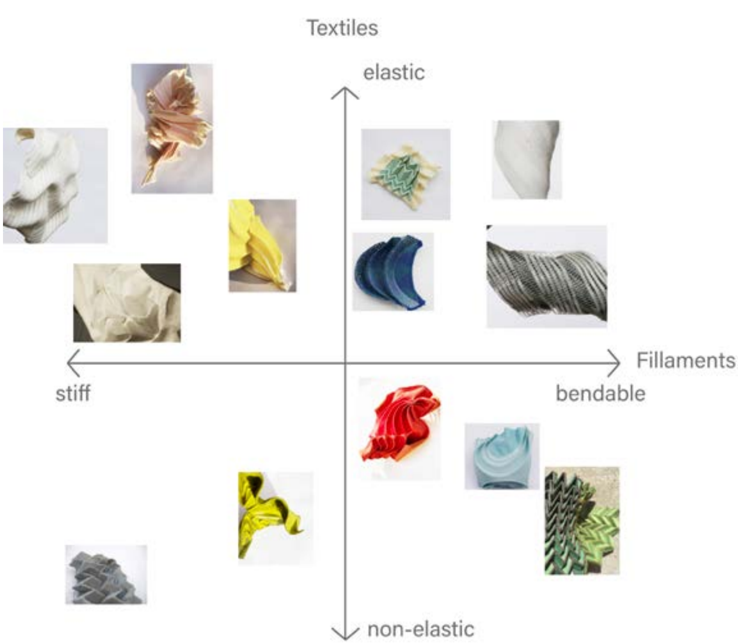

Fig. 2
A diagram for structuring samples for teaching hybrid materials based on form and material behaviour according to the textile elasticity and the flexibility of the 3D printed layer, by the author.

2 Implementing haptic knowledge of textiles in non-textile digital environments to generate digital textile expressions-
This method references the process of transposing physical textile craftsmanship into a non-textile digital environment and modifying it to alter conventional textile expressions, facilitating creativity in the digital environment Fig. 3. The diverse array of actions challenged the flat expression of textiles, resulting in novel, three-dimensional interpretations with enhanced haptic visual expressions.
The case uses background knowledge of knitting using analogue and digital tools to generate different structural designs. The aim was to translate reality-based images that could then be manipulated into new textural forms through non-textile digital tools. A method to animate cloth in Blender was used to explore the dynamic forming by draping of digital textiles; this exercise focused on the explorative process of surface, environment, and form. The digital draped fabric forms which were created in Blender were translated to Rhino 3D. Here, the forms were further explored as volumetric textures by applying the digitalised knitted samples. The process enabled the creation of complex coloured textural forms that could later be 3D printed.

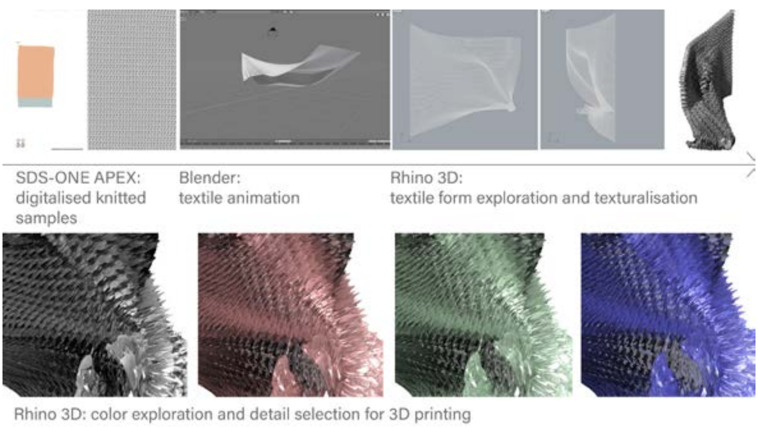

Fig. 3
A workflow diagram illustrating the different steps of the design process, by Author.

3 Implementing analogue craftsmanship in specialised digital textile environments.
This method used haptic and analogue experience and specialised digital tools to improve the learning process in terms of both analogue and digital knowledge. During the process of learning knitting skills, understanding knitted structures and physically touching materials are fundamental. This knowledge has always been obtained through touch and making hundreds of analogue samples, developing the ability of practitioners to predict the physical features of a final outcome. Today, digital environments for knitted textiles simulate what has been programmed using coding for industrial machines. In this case study students were asked to work in both physical and digital environments, following a series of steps during which they:

Designed and produced a physical knitted sample.
- Programmed the same sample in the SDS-ONE APEX3 software package.
- Simulated the sample by inputting all of the information regarding yarns, structure, and colours into the digital environment, using the skills learned as a result of manual experience.
- Knitted the simulated sample to create a second physical version, and compared this to the one made manually during the first step.

This process Fig. 4 taught the students how to use digital tools to predict analogue results and to use analogue experience to work in digital environments, generating a cyclic enhancement of both domains of knowledge.

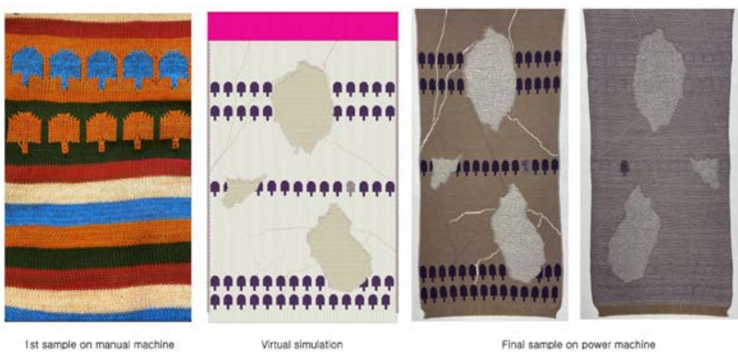

Fig. 4
The evolution of samples from manual to electronic machines, through the virtual simulation. Design and production by Ida Belli and Lorenzo Costanzini.

4 Using specialised digital textile environments to implement understanding of analogue processes and structures.

As is discussed above, learning how to knit is a process that requires an understanding of structures, namely how the yarn becomes a three-dimensional fabric. The more the yarn interacts with the needles in different ways, the more varied and complex the structure becomes, generating endless design possibilities. This learning process has always been a "learning-by-doing" process, where the understanding of what is achievable happens through trial and error.

Today, the software used to program machines has a feature that simulates the machine while it knits the structure that has just been programmed, showing all of the movements of yarn feeders, needles, and yarns Fig. 5. This dynamic virtual simulation makes it possible to observe what happens inside the machine, where the needles are usually hidden far from the eye and safety mechanisms prevent direct intervention. The tool, which was originally designed to allow technical specialists to check the program, was transformed into a learning tool for design students of both basic and advanced levels.

The tool allows beginners to:
- Observe how the yarn can be used to make basic structures.
- Understand how needles and yarn feeders work.

- Identify correspondence between manual and industrial machines.

More advanced users can use the tool to:

- Understand complex structures.
- Expand their knowledge of structures through exploration and experimentation with machines.
- Anticipate and understand possible errors, quickly and with less material wasted.
- Explore a wide variety of design possibilities.

Discussion

The case studies exemplify diverse ways of approaching the teaching of material design in textiles and fashion field, wherein haptic knowledge is combined with digital media, and show four possible paths that practice and processes within textile design can take; these extend out from the creative core of the research presented and encompass the digital technologies available. These can be used to generate new forms of textile craftsmanship, wherein haptic textile knowledge maintains its importance and is worked with in a systematic way in the digital realm. The results of each case study were improvements in terms of both design outcomes and skill development, and assessments of different positioning within the framework show that there are multiple pathways for further research and practices that could be positioned anywhere between the four axes of the framework in terms of finding new ways of helping the haptic and physical craftmanship to interact with the virtual and digital tools. The results of each case study exemplify the positive impact of a cross-disciplinary approach, and the benefits of combining tools in terms of both design outcomes and practitioner development.

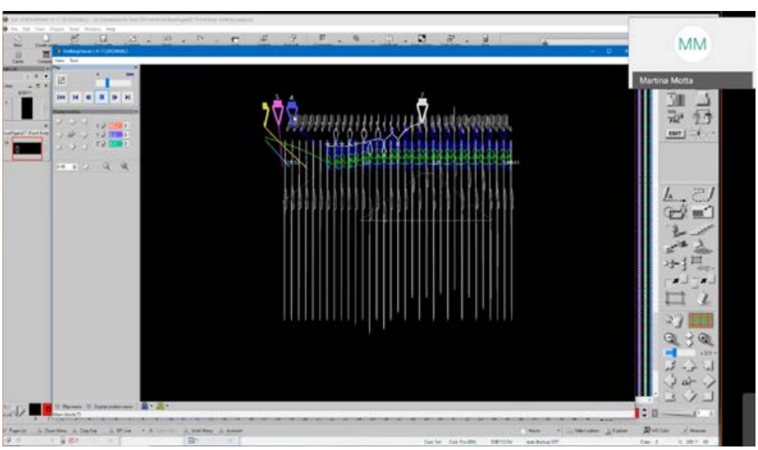

Fig. 5
A screenshot of Shima Seiki Apex3 interface showing the virtual simulation of how the machine performs the programmed knit sample including the movement of yarns, needles and yarn feeders. Produced by Authors.

Digital environments are increasingly supporting the rapid changes in approach to industrial production that we are experiencing: after a decade of Industry 4.0 we are now approaching Industry 5.0, which is centred on symbiosis between human and machine (Longo et al., 2020; Xu et al., 2021) while maintaining respect for the planet and workers' wellbeing (Breque et al., 2021). Here, shared workflows and cross-disciplinary practices complement an integrated perspective on the product value chain, extending from material to product and end-use (Gloy, 2021). Designing, teaching, and learning about hybrid material-based practices, as takes place in the field of textiles, requires new tools and methods with higher levels of digitalisation, and so there is a necessity to implement holistic perspectives on processes relating to design and textile-making which transcend conventional professional boundaries that are based exclusively on analogue and digital craftsmanship and tools, and which will ensure responsive innovation paths.

Textile and non-textile digital tools are of equal importance when teaching textile design, as both enable the development of creative processes and provide knowledge and skills with which to realise design visions. This research sought to emphasise the design possibilities afforded by each, and to reflect on the need to teach students about the diversity of digital environments to ensure the development of sustainable textile-based practices.

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