Crafted Identities

Technological Transformations in Textile Design

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Recently a number of emerging technologies have been integrated into the field of textile design. Specifically, these have included advances in physical computing, 3D fabrication, artificial intelligence, and digitization, which have contributed immensely to the industry in the form of e-textiles, novel materials, personalized experiences, and virtual simulations. The limitations to be physically present during the Covid-19 pandemic have accelerated this evolution of textile technologies with digital simulations replacing physical prototyping, and the emergence of virtual showcases.[2] Essentially, these digitized and automated emerging technologies speak to the accessibility and ease of production that is possible in textile design processes. For instance, through digital looms and virtual simulations, one can create instant fabric replicas, modify colors, adjust weaves, or remodel drapes with more time and material efficiency, as compared to physical production processes. However, while eliminating the embodied making processes for the sake of efficiency, these technologies are moving away from the crafted origins of textiles, and materiality. A textile or any craft, is a representation of numerous factors related to the culture of the creators. So, are the emerging technologies eventually moving away from the textiles' identities for the sake of automation? Or, are they still being preserved and even evolved through these technologies?

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1 The New School, India/US.

2 The Business of Fashion and McKinsey & Company, "The State of Fashion 2020 Coronavirus Update," April 8 2020, https://www.businessoffashion.com/reports/global-markets/the-state-of-fashion-2020-coronavirus-update-bof-mckinsey-report-release-download.

With continuously emerging novel technologies being a significant part of everyone's lives, textile designers and practitioners are deliberating over the traditional and evolving identities of textile crafts and communities in presence of some of these technological transformations.

Craft Philosophies and Influences of Emerging Technologies on Textiles

Material culture studies place objects and belongings at the center of one's environments. As George Kubler quotes in his book, *The Shape of Time: Remarks on the History of Things*, "The history of things is about material presences which are far more tangible than the ghostly evocations of civil history."[3] One's relationship with one's belongings is reflected in their self and their identity, which can eventually translate into one's contribution to the advancement of the society. And the role textiles and crafts play in shaping and defining cultural identities, is no revelation. Crafts, and specifically textiles, have strong roots in narration and representation of identity, whether it is of an individual self, a community, a culture, or a geography. Textiles are represented by their maker's stories, and the materials that they are made of. Weaves, prints, and knits are embedded with traditional knowledge and sediments of cultural evolution. For instance, a brocade fabric in India that was initially made out of real gold and silver, transitioned into being made out of imitation gold and silver due the weaver community's changed socio-economic state, Jacquard motifs evolved into being less intricate with time due to commercialism and the transition of production from handlooms to power looms. The evolution of textiles is a reflection of the cultural, economic, political and technological transformations, amongst others, and vice versa. Arguably, the onset of the fourth industrial revolution has brought forth "a fusion of technologies that is blurring the lines between digital, physical, and biological spheres."[4] So, how are these multidisciplinary textile practices impacting the future?

This chapter explores some of the recent technological transformations in the textile and apparel industries. These transformations have resulted from multidisciplinary practices and the use of emerging technological applications

3 George Kubler, *The Shape of Time: Remarks on the History of Things* (New Haven: CT: Yale University, 1962), 72.

4 Schwab, "The Fourth Industrial Revolution."

in the field of textiles such as e-textiles and wearable technology, artificial intelligence, novel and bio-fabrication, mixed realities, multi-dimensional fabrication, and applications powered by blockchain technologies.

Delving deeper into each of these applications, electronic textiles or "e-textiles" are a fitting transition into a dialogue about traditional and technological crafts. Demonstrating the versatility of textiles, e-textiles combine textiles with electronic components such as lights, sensors, and microcontrollers, enabling outcomes such as active heating and cooling, data capture and transfer, and haptic, visual and aural sensations, among many other purposes and end results.[5] The incredible ability of textiles to be designed out of any material, to be spatially adaptable, not to mention being one of the most accessible and routinely used products, makes them a well-chosen partner to this kinship. It is not just the field of electronics and physical computing that is revolutionizing the practices of textiles, but textiles are influencing the transformations in electronics as well. For instance, Leah Buechley's initial research and explorations around wearable technology gave birth to the LilyPad Arduino e-textile technology kits—a novel sewable microcontroller used for integration with textiles. Buechley's initial explorations and innovations helped to energize an era of Do-It-Yourself electronic textiles in the early 2000s.[6] Through the last couple of decades, the field has witnessed some creative and critical experiments with thermochromic, electromagnetic, photosensitive, motion sensitive, and touch sensitive systems being incorporated with textiles, resulting in outcomes like the wearable computer,[7] knitted radio,[8] thermochromic tapestries that change

5 Gernot Ehrmann and Andrea Ehrmann, "Electronic Textiles," *Encyclopedia* 1, no. 1 (2021), 115, https://doi.org/10.3390/encyclopedia1010013.

6 Leah Buechley, "Roadtrip Nation Interview," *Roadtrip Nation*, accessed June 30, 2022, h ttps://roadtripnation.com/leader/leah-buechley.

7 Steve Mann, "Wearable Computing," in *Encyclopedia of Human Computer Interaction*, ed. Mads Soegaard and Rikke Friis Dam, 2nd ed. (Interaction Design Foundation, 2014).

8 Irene Posch, Bundeskanzleramt Österreich, and Land Steiermark, "The Knitted Radio (2014)," *Ebru Kurbak*, June 25, 2014, https://ebrukurbak.net/the-knitted-radio.

color in response to WiFi signals,[9] a wearable suit that senses and informs the wearer of signals from IoT platforms,[10] and countless others examples.

A textile circuit with sewable LED Matrix.[11]

Looking at these progressions, it appears that textiles and their end-products are being recognized for their functions, in addition to how they look, who they belong to, who they are worn by, or where they come from. In the short span of a couple of decades, the identity of textile crafts went from being recognized for its cultural significance, to being recognized for its functionality. Instead of looking at a fabric and thinking whether an *ikat* fabric is from Indonesia or India, naturally dyed or made with synthetic dyes,

9 Ali Morris, "Thermochromic Tapestry Changes Colour in Response to Wi-Fi Signals," *Dezeen*, November 22, 2017, https://www.dezeen.com/2017/11/22/thermochromic-tapestry-changes-colour-response-wifi-signals-richard-vijgen-dutch-design-week.

10 Sophia Brueckner and Rachel Freire, "Embodisuit: A Wearable Platform for Embodied Knowledge," in *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '18 (New York: Association for Computing Machinery, 2018), 542–48, https://doi.org/10.1145/3173225.3173305.

11 Nishra Ranpura, textile circuit design, 2022.

one now wonders whether it will light up, move, make a sound, or heat up. However, e-textiles, like traditional textiles, are still being identified by what they are made of and what their purpose is. What e-textiles are missing is a sense of belonging and identity that comes with history and nostalgia. The direction of the field of e-textiles going forward, is likely to set the tone of this sense of belongingness. This incites the question of where e-textiles are headed.

While e-textiles have grown tremendously in the last couple of decades, recent developments and speculative innovations in the field are projected to "revolutionize the applications around climate crisis, remote healthcare, athletics and sports, thermoregulation, space investigation, and sensorial experience in real life and the virtual worlds."[12] Thermoregulating textiles have the potential to address the need for energy efficiency, adjusting to extreme weather patterns and combatting increasing energy prices.[13] Heating and cooling textiles can effectively regulate temperature in a localized part of the body, which, when applied against the body's movement, can address the need for self-powering technologies. Studies are also being done to incorporate micro solar panels and piezoelectric materials into textiles to mitigate the need for an external power supply.[14,15] In addition to incorporating components into textiles, the discipline of e-textiles is seeing the creation of fabrics that act as electronic components. "Project Jacquard" by Google's Advanced Technology (ATAP) Lab has developed a collection of conductive threads for weaving touch-responsive textiles like clothing, tablecloths, rugs, or any fabric-based product.[16] The jacquard mechanism makes it flexible enough to incorporate conductive threads onto localized areas, and create a soft circuit during the production process itself. The age-old Jacquard mechanism that inspired modern computers might be laying the groundwork for more revolutionary applications.

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12 Kunal Mondal, "Recent Advances in Soft E-textiles," *Inventions* 3, no. 2 (2018), 23.

13 Yunsheng Fang, Guorui Chen, Michael Bick, and Jun Chen, "Smart textiles for personalized thermoregulation," *Chemical Society Reviews* 50, no. 17 (2021), 9357–9374.

14 Seyyed Alireza Hashemi, Seeram Ramakrishna, and Armin Gerhard Aberle, "Recent progress in flexible–wearable solar cells for self-powered electronic devices," *Energy & Environmental Science* 13, no. 3 (2020), 685-743.

15 Joshua Edimison, Mark Jones, Zahi Nakad, and Thomas Martin. "Using piezoelectric materials for wearable electronic textiles," in *Proceedings. Sixth International Symposium on Wearable Computers*, 41–48. IEEE, 2002.

16 "Jacquard by Google," accessed July 1, 2022, https://atap.google.com/jacquard.

Some textile designs are becoming hybrid and driving how technology advances. Some examples of textile functionality that drives innovation can be witnessed in health and wellness industries. Localized tracking has tremendous applications in medical fields, and we are already in the midst of an era where fitness trackers and smart watches are widely used. E-textiles that are converted into biofeedback-tracking apparels, have the potential to play a significant part in improving and maintaining health and wellness.[17] Commercial developments of these applications are already underway. E-textile based washable socks can prevent diabetic foot ulcers by monitoring foot temperature.[18] Wearable point-of-care systems can monitor an array of health conditions by tracking ECG, blood pressures, respiration rate, and oxygen saturation.[19] One can basically create a 3D visualization of a body in real time through trillions of data points, by embedding sensors in apparels as a cipher mesh.[20] Similar applications surrounding haptic technologies are also a gateway towards more immersive experiences. In addition to reading feedback from one's body, e-textiles can, more interestingly, provide outputs which signal physio-psychological changes in the form of haptic sensations to make one feel sensations like a hug, a gunshot, anxiety, or a caress.[21]

While it is understandable that commercial applications of e-textiles often place "function" over feelings, form, or fondness, the discipline is not devoid of them altogether. As mentioned earlier, developments with e-textiles are likely to establish a novel culture of hybrid textiles. Researchers, practitioners, and designers such as Laura Devendorf, Leah Buechley, Irene Posch, and Lisa Nakamura have curated a mindful culture around e-textiles that is not just

17 Guorui Chen, Xiao, Xun Zhao, Trinny Tat, Michael Bick, and Jun Chen, "Electronic textiles for wearable point-of-care systems," *Chemical Reviews 122, no. 3* (2021), 3259–3291.

18 Alexander M. Reyzelman, Kristopher Koelewyn, Maryam Murphy, Xuening Shen, E. Yu, Raji Pillai, Jie Fu, Henk Jan Scholten, and Ran Ma, "Continuous temperature-monitoring socks for home use in patients with diabetes: observational study," *Journal Of Medical Internet Research* 20, no. 12 (2018), e12460.

19 Chen et al., "Electronic Textiles For Wearable Point-Of-Care Systems," 3259–3291.

20 Christopher Assad, Michael Wolf, Adrian Stoica, Theodoros Theodoridis, and Kyrre Glette, "BioSleeve: A natural EMG-based interface for HRI," In *2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pp. 69–70. IEEE, 2013.

21 Cati Vaucelle, Leonardo Bonanni, and Hiroshi Ishii. "Design of Haptic Interfaces for Therapy," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, (2009), 467.

about the electronic function of the textiles, but essentially speaks to the essence and values of crafting. Some discourses explored by these pioneers through their research and practice include thinking about craftspeople as technical collaborators,[22] thinking about making e-textiles accessible to people who are differently abled,[23] looking at indigenous cultures' values and roles in early electronics manufacturing,[24] being mindful about the culture of new tools and machines that are being developed as a result of multidisciplinary practices, and considering the role and history of gender and race in the fields of both textiles and electronics while curating innovations and setting precedents.[25]

The universe of textiles is diverse with different crafts, embodying a myriad of different philosophies. In addition to the processes and materials, craft philosophies are about the cultural and socio-political history, generational knowledge, embodied emotions of struggle and accomplishment experienced by the makers themselves, and the reception of the craft by the users. With e-textiles, it is difficult to hold on to some of the roots of traditional textiles, since functionality is a driving force and that requires major transformations to traditional textile practices, especially in the way textiles are fabricated. Granted, the fabricating process is a significant aspect of a textile's identity. However, whether e-textiles are moving away from the textiles' conventional origins or not, they are certainly on track to developing an identity of their own.

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22 Laura Devendorf, Katya Arquilla, Sandra Wirtanen, Allison Anderson, and Steven Frost, "Craftspeople as Technical Collaborators: Lessons Learned through an Experimental Weaving Residency," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (New York, NY: Association for Computing Machinery, 2020), 1–13, https://doi.org/10.1145/3313831.3376820.

23 Emilie Giles and Janet van der Linden, "Imagining Future Technologies: ETextile Weaving Workshops with Blind and Visually Impaired People," in *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition*, (New York: Association for Computing Machinery, 2015), 3–12, https://doi.org/10.1145/2757226.2757247.

24 Lisa Nakamura, "Indigenous Circuits: Navajo Women and the Racialization of Early Electronic Manufacture," *American Quarterly* 66, no. 4 (2014), 919–41, https://doi.org/10.1353/aq.2014.0070.

25 Rebecca Stewart, Sophie Skach, and Astrid Bin, "Making Grooves with Needles: Using e-Textiles to Encourage Gender Diversity in Embedded Audio Systems Design," in *Proceedings of the 2018 Designing Interactive Systems Conference*, DIS '18 (New York: Association for Computing Machinery, 2018), 163–72, https://doi.org/10.1145/3196709.3196716.

And, it is only with time and retrospection that one will be able to see where the craft philosophies of e-textiles situate them among textile crafts.

The reliance on time is not only true for emerging textile craft disciplines, but is something that is inherent to textile design. The interrelationship of past and present developments, and relevant future predictions, has a significant part of the commercial textile design industry. It is the reason the majority of textile manufacturers, and home and apparel brands develop and launch seasonal collections. It takes thorough research, analyses and observations, often referred to as trend or forecast analysis, to understand where textile design and the related industries are headed. This space of research largely sets the tone of the future of the textile industry. And the nature of this research space that greatly revolves around analysis has naturally attracted applications associated with artificial intelligence (AI).

AI is usually related to machine-based, computational intelligence. As AI technology becomes increasingly sophisticated, it is penetrating the areas of commerce related to trend analysis, customer services, shopping experiences, and sales analysis. Textile design is also moving into an arena where data-based AI applications are common and creators are looking at a new definition of craftsmanship, one that combines traditional crafts and manual skills with digital intelligence and contemporary manufacturing practices.[26] [27]

Through the intriguing combination of AI and crafts, we have seen developments like robot-made potteries based on machine learning and genetic algorithms,[28] the creation of an "ideal" recipe for a "perfect" India pale ale (IPA),[29] and "The Ultimate AI Masterpiece" where 900 years of art history was projected onto a car, using it as a canvas.[30] With regards to fashion and textiles, AI has been heavily used in digital commerce tools such as wardrobe curation, fit engines, and customized collections based on AI generated trend

26 Barbara Silvestri, "The future of fashion: How the quest for digitization and the use of artificial intelligence and extended reality will reshape the fashion industry after COVID-19," *ZoneModa Journal* 10, no. 2 (2020), 61–73.

27 Amit Zoran, "Hybrid craft: showcase of physical and digital integration of design and craft skills," in ACM SIGGRAPH art gallery, (2015), 384–398.

28 Charlotte Nordmoen, "HumanMADE," accessed July 2, 2022, https://www.cnordmoen.com/humanmade.

29 Brauer AI, "Brewing is Science and Art," accessed July 2, 2022, https://www.brauer.ai

30 "Creativity Meets AI: BMW 8 Turned into a Work of Art Using Artificial Intelligence," BMW.com, accessed July 2, 2022, https://www.bmw.com/en/innovation/creative-ai-bmw-8-gran-coupe-art-with-artificial-intelligence.html.

analysis, through a collaboration of fashion brands and technology companies, that involve, but are not limited to Tommy Hilfiger, Gucci, Google, and IBM. This AI based "phygital artisanship" seems like just the beginning.[31] By largely relying on AI for trend forecasting, as opposed to solely relying on traditional methods of market observation and getting insights from the designers and influencers, we are moving toward a future filled with accelerated information updates.

Traditionally, textiles and crafts are a representation of cultural, economic, and political histories of a community. Can AI generated textiles do a better job at representing these histories? After all, it is quite convenient to feed large amounts of information into an algorithm and get accurate outcomes. Perhaps, it is more efficient than traditional and generational crafts. Or, are the embodied experiences of temporalities and materialities more important to the making process than the final representation? What constitutes an embodied making process? There is certainly a growing discourse around automated and virtual crafts.

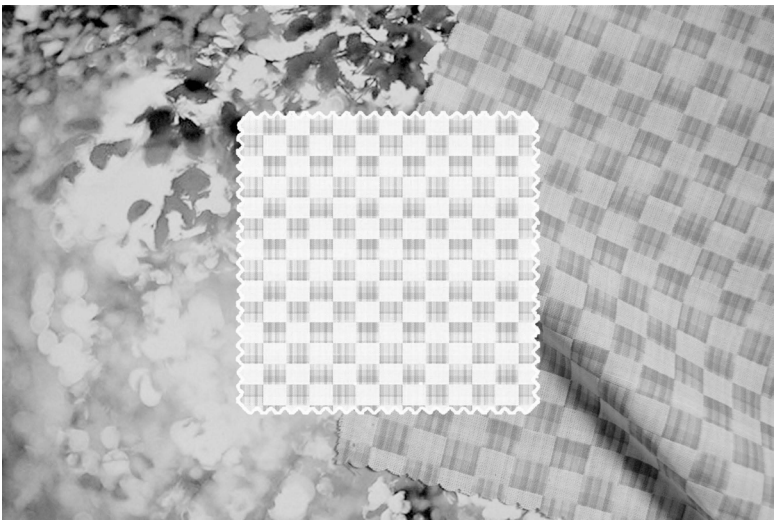
Kerry Murphy, the founder of the Fabricant, asked, "Should we continue to listen to those voices that say only the physical has merit, that only stuff made from other stuff counts? Or do we move towards new expressions of worth that accept that innovation, creativity and uniqueness can exist in many forms? What we decide now will become our reality."[32] With textile fabrication processes such as weaving or knitting, the time and labor spent on them are substantial parts of their identity. And when it comes to traditional textile dyeing methods like ikat, the skill and efforts involved are necessary for the quality of the craft, and are something that can be difficult to be replicated through automated mediums. In the evolving and overlapping universe of art, craft, design, and technology, where does one place computational textiles?

Digital or simulated textiles, for instance, have been a significant part of textile fabrication processes. In reality, simulated textiles are not a novel concept. Since decades ago, in industrial settings, the technical specifications of textiles have been made on different computer aided design (CAD) software

31 IBM Institute for Business Value, "Rethink, reimagine and reinvent the retail store," IBM, accessed March 01, 2023, https://www.ibm.com/downloads/cas/YVLPNBA1.

32 Micky Larosse, "Data: The New Raw Material," *The Fabricant*, accessed July 2, 2022, https://www.thefabricant.com/blog/2019/6/3/mtn2njedjvd120angslmhzrybrnm52.

that visualize the textile or a replica of it, on screen, while being designed.[33] In addition, the simulated look of the textile has often been used for the design and production purposes. Over time, CAD software has been redesigned and updated to reflect a more realistic look of a fabric. Beginning with simple digital line interlacements showing color and weave, the software capabilities have evolved into simulating different feels and finishes, such as linen, slub, brushed looks, or coated finishes. And today we can find 3D versions of these materials that don't just look realistic, but emulate the real-life physics of material behavior.



A computer aided design (CAD) simulation of a double-cloth (two-layered) fabric along with the actual fabric and its visual inspiration.[34]

However, these programs are not always easily accessible, as licenses cost thousands of dollars, and can generally be only purchased by well-established textile manufacturers. Researchers and developers, such as the Unstable

33 Ashis Mitra, "CAD/CAM solution for textile industry: an overview," *International Journal of Current Research and Academic Review* 2, no. 6 (2014), 41–50.

34 Nishra Ranpura, digital textile design, 2016.

Design Lab[35], are developing open-source digital looms to build accessible technical textile specifications with novel user interactions (since conventional CAD software has been made with industrial use cases and settings in mind). The awareness around ownership and distribution rights on digital platforms have encouraged more accessible versions of digital looms. And just like that the value from inherited or acquired knowledge and skill shifts towards accessibility and pedagogy.

In addition to their contribution towards the functional aspects of textile fabrication processes, computational applications have undoubtedly been playing a significant role in redefining the aesthetics of textiles as well. AI's close relationship with generative art and algorithmic patterns is contributing to the aesthetics of textiles in terms of novel weave, knit, and pattern generations. This is creating its own digital world of simulated, often unreal textiles that seem to be textiles on screens, but structurally and physically they might not always fabricate an actual textile. Are we headed towards immaterial materials, which are merely the citizens of virtual worlds unable to exist in the real one?

Given the way the world is experiencing reality in the present times, not much can be said about which materials are supposed to be deemed as more real, the physical or the virtual ones. We spend more time exploring the colors and textures on a screen than in the physical world around us. Perhaps, the immaterial materials on screen, in the various simulated realities, are indeed more real than the tangible ones around us.

X-reality, which encompasses virtual, augmented and any other form of mixed reality simulation, is in a convenient position to thrive, with the metaverse opening gates to numerous trade and commerce opportunities. With actual translations of people's lives into a digital world, and curation of several virtual worlds, x-reality is not only creating representations of one's self, but has given birth to new life forms—"digi-sapiens" and "digi-twins." And an entire generation which is to come is named "generation M" after the "metaverse." Hence, undoubtedly, the world of technology is innovating every day to develop software and applications that best represent the physical materials and lifestyles through their digital counterparts, and that includes fashion and textiles. Whether it is via attempts at accurate fabric simulation through CAD software, or precision in drape and fit through 3D modeling and rendering software, we are close to a stage where there is not much visual

35 "Unstable Design," accessed March 1, 2023, https://unstable.design.

difference between the virtual and physical. And when one adds the haptic and other sensorial e-textile applications to it, one could have an exact replica of a fabric made up of pixels, light, and data instead of fibers, dyes and weaves or knits– 'an immaterial material'. A fabric in x-reality is merely a simulacrum. Is a simulacrum an identical representation or a contradiction of the original identity? What is the simulacrum adding to the original fabric, and what is it taking away from it?

The x-reality platforms have opened dialogues around sustainability in the milieu of crafting and making. With limited consumption of energy and resources, easier reproducibility and more efficient modification processes, virtually simulated 'immaterial materials' are getting their own seat at the table. Especially during the COVID-19 pandemic, commercial manufacturing industries have found novel ways of representing their products through digital means, such as digital mapping, virtual showcases, and photoshoots. And while digital versions of products, and especially textiles, are proving their benefits, there are drawbacks as well. While sensorial applications are progressing towards realistic experience, there is still much space left for further developments. Hence, from the ability to familiarly feel, smell and hear an actual fabric, to experiencing how it falls, wrinkles, ages or deteriorates, the digital counterparts of textiles are not a match yet, although they are certainly getting there.

Games such as Minecraft are embodying the crafting essence and exploring the materiality and temporality of making in their own hybrid sensibility and application. Whereas, games such as League of Legends, Fortnite, and Roblox are turning towards expressing representation through in-game customizable and curated digital avatars.[36] Metaverse fashion shows, branded products being sold for the digital avatars, and skin-tone representations in the digital world are redefining the notion of identity.[37] In addition to making hyper-real virtual identities of textiles, can we also give life to them, such as growth, deterioration, wear and tear, and death?

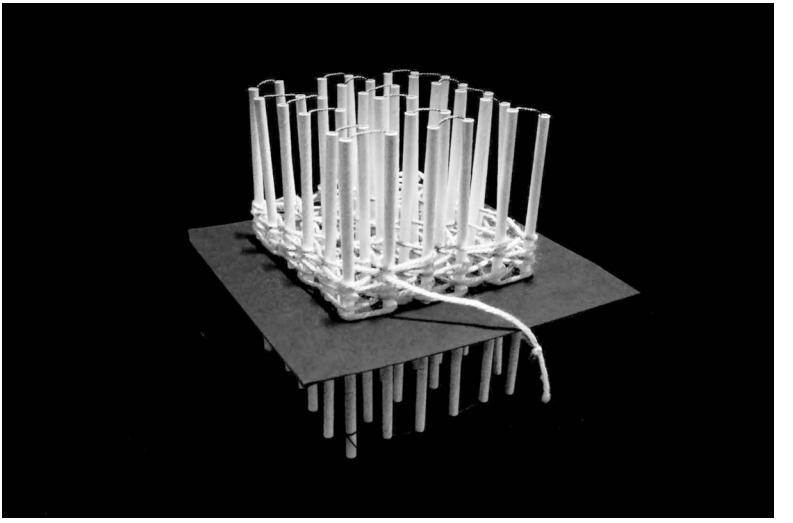
The worlds of x-realities, with multiple versions of existences, are bound to raise provocations around experiential philosophy, and crafted materials,

36 Sensor Tower, "Fortnite Mobile Revenue Hits $1 Billion in Two Years," accessed March 01, 2023, https://sensortower.com/blog/fortnite-launch-revenue.

37 Maghan McDowell, "Race, Gender and Representation: The Grey Area of the Metaverse," *Vogue Business*, September 28, 2021, https://www.voguebusiness.com/technology/race-gender-and-representation-the-grey-area-of-the-metaverse.

and textiles are no exception to these provocations. And interestingly, these provocations are not just limited to the simulacra of the x-realities. Just as the x-realities are trying to imitate the physical realities, the physical realities are undoubtedly manifesting the digital and computational data into tangible forms as well. The innovation in the field of 3D modeling and printing is one such example where the physical world gets its forms from the intangible world of computation and simulation.

The advent of 3D printers has made great strides in the realm of 3D fabrication. It opened avenues for customization, sustainability, on-demand production, and structural innovation.[38]



Explorations of 3D lattice interlacements on a handmade 3D loom.[39]

38 Nurhalida Shahrubudin, Te Chuan Lee, and R. J. P. M. Ramlan, "An overview on 3D printing technology: Technological, materials, and applications." *Procedia Manufacturing* 35 (2019), 1286–1296.

39 Nishra Ranpura, 3D lattice interlacements, design, 2021.

3D printing started to rise in the world of fashion and textiles through the works of one of the pioneers of the field, Iris Van Harpen, around 2010.[40] While electronic textiles are making great strides into creating the applications comfortable and practical as wearables, some artists and designers of haute couture fashion such as Iris Van Harpen and Behnaz Farahi introduced the potential of 3D printed textiles and kinetic wearable fabrication. And the application of 3D fabrics extends to knit machines that can create finely detailed seamless garments from yarns in a short amount of time.[41] The efficiency in terms of resource consumption, waste reduction, time, and labor seems quite promising, which is why research is being carried out in terms of different materials and weave/knit structures to test strength, movement, and durability. From 3D printed tissue engineering,[42] 3D printed organs for product testing instead of animal testing, to 3D woven structures being strong and flexible enough to be used for outer shoe soles, the potential for interlaced dimensional fabrication is enormous.

Dimensional fabrication also holds an interesting space between virtual and physical materials—a hybrid space driven by crafting through automation. Autonomously fabricated 3D materials speak volumes about one's understanding of the concept of evolution of materials—a material crafted by machines. What does it mean to have an "embodied machine experience"? Can there be other forms of embodied experiences that are devoid of humans?

While thinking about novel means of fabrication, it is important to note that technologies are not just restricted to man-made, and machine-oriented applications. The future (or perhaps already the present) is seen as a collective. "Collective Intelligence"—multiple forms of knowledge, whether human, technological, or ecological—is opening new ways of thinking, and eventually making. The truth about the planet not belonging to the humans is dawning on us as we realize the presence of and learn from the intelligences of the machines that surround us and are made by us, and the nature that

40 Helen McCormick, Ran Zhang, Rosy Boardman, Celina Jones, and Claudia E. Henninger. "3D-Printing in the Fashion Industry: A Fad or the Future?" *Technology-Driven Sustainability: Innovation in the Fashion Supply Chain* (2020), 137–154.

41 James McCann, Lea Albaugh, Vidya Narayanan, April Grow, Wojciech Matusik, Jennifer Mankoff, and Jessica Hodgins. "A compiler for 3D machine knitting," *ACM Transactions on Graphics* (TOG) 35, no. 4 (2016), 1–11.

42 Mohsen Akbari et al., "Textile Technologies and Tissue Engineering: A Path Toward Organ Weaving," *Advanced Healthcare Materials* 5, no. 7 (April 6, 2016), 751–66, https://doi.org/10.1002/adhm.201500517.

has always been around, will be around even after we are gone, and that we so blatantly overlooked. While we attempt to situate ourselves amidst multiple intelligences to understand our identity here, we are simultaneously learning from and collaborating with these intelligences.

With Anthropocene anxiety, we are turning towards more conscious textile fabrications. Bio-fabricated textiles are cultivated from mycelium, living bacteria, yeast, algae, and plant-derived materials under engineered conditions.[43] Ecovative, Bolt Threads, MycoWorks (US), Mycotech Lab (Indonesia) are some of the leading innovators in the field of bio-fabricated textiles today. We are already looking at mycelium leathers,[44] leathers and cotton made in labs that do not harm animals and consume less resources,[45] fine mycelium bags using biotechnology, and fruit waste fabrics.[46] Mycelium is already becoming a vegan alternative to leather, and is impacting not just consumer mindset but also the economy. The DNA of textiles and fabrications is being transformed. In addition to mycelium, leather made from collagen brewed from fermented yeast,[47] lab-grown cell-based fur,[48] recombinant silk made by adding silk genes into yeast and bacterial via fermentation,[49] and nanocellulose "tree-free" rayon from fruit waste are some examples of bio-fabricated materials aimed to be used as textiles.

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43 Valentina Rognoli, Bruna Petreca, Barbara Pollini, and Carmen Saito, "Materials biography as a tool for designers' exploration of bio-based and bio-fabricated materials for the sustainable fashion industry," *Sustainability: Science, Practice and Policy* 18, no. 1 (2022): 749–772.

44 Simon Vandelook, Elise Elsacker, Aurélie Van Wylick, Lars De Laet, and Eveline Peeters, "Current state and future prospects of pure mycelium materials," *Fungal Biology and Biotechnology* 8, no. 1 (2021), 1–10.

45 Amber Dance, "Engineering the animal out of animal products," *Nature Biotechnology* 35, no. 8 (2017), 704–708.

46 Eldy S. Lazaro Vasquez and Katia Vega. "Myco-accessories: sustainable wearables with biodegradable materials" in Proceedings of the 2019 *ACM International Symposium on Wearable Computers*, 306.

47 Vasquez and Vega, "Myco-accessories: sustainable wearables with biodegradable materials," 306–307; "Modern Meadow," Modern Meadow, accessed July 2, 2022, https ://www.modernmeadow.com.

48 Vasquez and Vega, "Myco-accessories: sustainable wearables with biodegradable materials," 307; "Furoid," CellAgri, accessed July 2, 2022, https://www.cell.ag/furoid.

49 Vasquez and Vega, "Myco-accessories: sustainable wearables with biodegradable materials."

"The Weaver," an installation visualizing the embodied motion of back-and-forth weaving.[50]

Biotechnology has, of course, always been a part of the textile design processes. From dyes extracted from plants and flowers, to yarns extracted from animals and insects, biotechnology has inherently been part of the fabrication process even before modern technology. These bio-fabrication applications provide some elegant examples of evolution in textiles. The remarkable developments in the fields of microbiology, and nanotechnology, have only furthered the established practices of biotechnology in the textile industries. It does make one wonder how subjectivity impacts one's notion of identity. If one is adjusted to the idea of textiles being made of plastic, animal and even human hair, or silk from an insect, mycelium or yeast-based textiles simply seem like another step. On the other hand, the notion of digitally simulated textiles being considered as textile crafts raises debates, due to a little less exposure to that provocation. And this philosophy also resonates with the essence of the crafting process—the repetition and variation. Whether it is the act of weaving where the shuttle moves back and forth repeatedly with variations to form different weaves, or the act of sewing where the

50 Nishra Ranpura, photograph of installation, 2022.

needle repeats the same process of going up and down at different points, the act of repetition creates fondness and the instances of variation preserves curiosity. Whatever the thought might be that lets one situate emerging textile crafts' identity, the technological transformations are not only influencing and evolving the textiles directly, but indirectly as well by contributing to the systems of textile design and production.

Speaking of production systems, blockchain technology is the next in line of these many applications impacting the traditional definitions in the field of craft and textiles. Blockchain technology is proving to be a useful tool, for the purposes of transparency and traceability. It provides an opportunity to "show the work" while considering the raw materials used in the process of making. The process of tracing and tracking in a production and supply-chain cycle provides an agency to the materials involved. It certainly gives accountability to the participants as well. One can know from which farm the cotton of their shirt has been produced, or which community assembled the denim jacket they have been wearing. Furthermore, digital signatures can be a useful tool to give the artisans a space to claim ownership as creators, rather than merely be anonymous producers in the fabrication process. However, there are certainly drawbacks to the use of blockchain technologies including but not limited to environmental concerns of data mining, privacy, accessibility, speed, and scalability.[51] Regardless of the shortcomings of blockchain technologies, aside from contributing to the logistical and transactional operations, can blockchain technology create a significant difference in textile and craft industries? In which ways can blockchain technology and digital signatures prove to be a source of security for ownership?

How are these emerging applications, at large, influencing, reaffirming, and challenging our understanding of textiles crafts? From questioning the shift in embodiment within the making processes, to embracing novel materials and tools, the deliberations over how technological transformations take the textile crafts forward could be never ending.

51 Koppiahraj Karuppiah, Bathrinath Sankaranarayanan, and Syed Mithun Ali, "A decision-aid model for evaluating challenges to blockchain adoption in supply chains," *International Journal of Logistics Research and Applications* (2021): 1–22.

Is there a conclusion?

While the thoughts shared and questions posed throughout the chapter are not simple or easy, these are necessary provocations to consider as we move forward into a time where lines between different disciplines are blurring. It is not just the identities of humans that are overcoming the binary notions, but the identities of our creations as well. The journey of textiles and technologies often go hand-in-hand, providing us with new mediums, inspirations, guides, and tools, along with challenges, lessons, and failures. The process of crafting textile identities involves multiple parties: designers and makers, consumers, materials, tools, and their narratives. Eventually, it is up to us to determine whether emerging technologies are moving away from the identity of textiles, or whether they are being preserved and evolved through these technologies.[52]

52 This is a brief exploration of the effects of emerging technologies in the field of textiles, and is in no way exhaustive. There are countless discourses around these technologies and multi-disciplinary practices (inside and outside the scope of this chapter) worth thinking about but not included here, such as reuse and recycle challenges of e-textiles, lack of maker-bias in AI generated, dimensionally fabricated textiles, or pedagogical applications of digital looms, amongst others.