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Designing furniture for the future: Integrating advanced digital technologies into the design process

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Abstract

This paper aims to evaluate how teaching and learning can better equip future designers by integrating advanced digital technologies into the design process. During the continuous unfolding of the Fourth Industrial Revolution (4IR) in South Africa, it is important to consider how to advance design curricula in order to prepare design students for an ever-changing working world. Both the South African Department of Trade Industry and Competition and the South African Furniture Initiative have shown increasing interest in cultivating our local furniture industry. This shows potential for re-imagining the pedagogical approach to furniture design, a traditional avenue within Industrial Design, for a local and advancing industry.

By using practice-based research as a method of generating new knowledge, this paper reports on a second-year student furniture design project undertaken at a leading South African design education institution. The student project focused on designing within the South African context while using advanced digital technologies to lead the design process and final product outcome. While the local context was considered by using available materials or incorporating traditional patterns, this paper focuses on how digital fabrication was used to create new pathways within the design approaches taken during the project. Examples of digital technologies used include 3D printing, laser cutting, and AI design generators.

By reflecting on the project outcomes, this paper aims to speculate on how new digital technologies can be effectively integrated into the design process while resulting in context-appropriate designs. The paper engages with questions such as *As digital technologies grow and evolve, how can they effectively be integrated into the teaching and learning of design? How can design include technological advancements such as AI-generated design while mitigating the problematic disruptions they bring? What opportunities does digital fabrication contribute to the process of design and making in a traditional Industrial Design field like the development of furniture?*

As the field of design evolves with the growth of 4IR, it will become ever more important to continuously question how new digital technologies can be converted into useful tools, while keeping social structures, context, and culture at the forefront of design decisions. By examining a student design practice project, this paper proposes new pathways in teaching and learning through practice-based research.

Keywords: 3D printing, artificial intelligence, design pedagogy in 4IR, digital fabrication, furniture design, laser cutting.

Introduction

The field of Industrial Design has continuously evolved as new technologies and social shifts have emerged throughout history (Ferrari 2017). As the Fourth Industrial Revolution (4IR) unfolds, it becomes increasingly important to evaluate how the role of the designer will shift again and how pedagogical approaches to design need to adapt to it (Adelabu & Campbell 2020). This paper unpacks ways in which South African industries have changed during the 4IR and explains how these shifts have been felt in a traditional Industrial Design industry: the furniture industry. As the country's interest in cultivating this industry visibly increases (dtic 2021), there is potential for re-imagining how higher education institutions engage with the teaching of design skills in order to accommodate the industrial shift that is felt during the 4IR.

With the perspective that practice-based research can offer new insight into how the design process is approached, this paper reports on a furniture design project undertaken in a second-year university Industrial Design course. This paper discusses three selected student projects that integrated a form of advanced technologies into their design process: 3D printing, laser cutting and AI-generated designs. Through the analysis of these projects, this paper aims to provide insight into how digital fabrication can contribute to the field of furniture design within the South African context. Alongside this, the intention is to reflect on how practice-based research provided opportunities to explore new pathways in teaching and learning.

Context

As a socio-technological field, Industrial Design is bound to evolve and shift as human development does through the industrial revolutions (Ferrari 2017). During the mid-18th century, the First Industrial Revolution harnessed the power of steam, and in the late 19th century the Second Industrial Revolution honed the power of electricity, both leading to the large-scale production of goods (Schwab 2017). These revolutions caused societies to shift from being predominantly agricultural to becoming industrial and capitalist (Schwab 2017; Ferrari 2017). During these revolutions, the field of design focused on expanding the uses of materials and manufacturing methods in order to develop mass-produced items suitable for mass consumption (Ferrari 2017). The Third Industrial Revolution marked the introduction of electronic and information technologies, shifting society once again (Schwab 2017; Ferrari 2017) and repositioning the role of the designer from being predominantly product-focused to being service-oriented (Ferrari 2017). As the Fourth Industrial Revolution (4IR) currently unfolds, it is relevant to imagine how the role of the designer may shift again and how pedagogical approaches within design institutions need to evolve for the societal shift that the 4IR causes.

4IR is described as the amalgamation of digital, biological, and physical fields (Schwab 2017). While examples such as smart home devices and AI chat-bots come to mind, it is important to consider another socio-technical shift, the impact of which is felt in the South African context: the de-industrialisation (Barnes 2019). De-industrialisation is described as a decline in industrial activity and a reduction in production quantities within a location or field (Debande 2006). The South African Department of Trade and Industry has identified various factors that contribute to such a decline, including “sub-optimal performance of state-owned companies, sharply escalating administered prices, logistical bottlenecks and other economic infrastructure constraints” (dti 2018). Alongside this decline, however, it is important to note the democratisation of technology, which is a promising advancement that has developed during the 4IR. The term “democratisation of technology” describes how quickly technology has become available, affordable, and user-friendly to general users (Urbanski

2000). Perhaps even more than the evolution and development of digital technologies, the newfound accessibility to these technologies is what is shifting societies. The democratisation of technology will arguably impact how design approaches evolve within traditional design industries, such as the design and manufacture of furniture.

The described development caused by the 4IR can be clearly observed within the South African furniture industry. During the late 1990s, the industry was dominated by large industries such as Ellerines, Bears, and Joshua Doore whose focus' fell on the mass-production of standard items (Ward et al., 2017). As the global furniture industry went through a significant shift during the 1990s, however, the South African market fell at a disadvantage (Ward et al., 2017). Through the rise of globalisation, Chinese exports of cheap and mass-produced furniture challenged the dominance of Anglo-Saxon industries that focused on small-scale, handcrafted, quality furniture (Ward et al., 2017). As a result of this industry shift, the approach towards furniture changed to become design-driven instead of craft-orientated (Ward et al., 2017). Innovation and adaptability became relevant advantages and through the democratisation of technologies, small-scale, machine-made batch production became the new approach to furniture design and manufacture (Dunne 2000). Globally, the furniture industry has been polarised into two areas where Italy, Germany, Scandinavia, and some parts of Eastern Europe lead the higher quality and price market, while China dominates the lower quality and price bracket (Walcott 2014). In comparison, the South African furniture industry fell at a disadvantage, lacking skilled labour and quality local materials, being in poor proximity to importers, lagging behind on international trends and competing in a well-established market (Dunne 2000). The large South African furniture companies were unable to complete, and reflecting the de-industrialisation, the majority of them have folded (dtic 2021). The current South African furniture industry is predominantly comprised of small and midsize enterprises (SMEs) (dtic 2021). While this does not mitigate many of the disadvantages the industry has, it does allow for adaptable and design-focused companies. Along with increased accessibility to new technologies, the South African furniture industry has many new initiatives supporting industry growth, such as the South African Department of Trade and Industry (DTIC), the South African Furniture Initiative¹ (SAFI) and Clout/SA² (dtic 2021).

With this industry change in mind, there is potential for re-imagining the pedagogical approach to furniture design, a traditional avenue within Industrial Design, for a local and advancing industry. In order to consider how this is done, it is important to engage with how the 4IR impacts teaching and learning within design institutions. The jobs that exist today may not exist in a few years' time and positions we cannot yet imagine will come into being (Harari 2019). Today's students will most likely not stay in a singular job during their lifetime and are instead more likely to change careers multiple times (Harari 2019). As the Fourth Industrial Revolution continues to impact and change the landscape of the working world, it is important for higher education institutions to engage with new technologies and speculate on how these will impact the methods and processes that are taught (Adelabu & Campbell 2020). Pedagogical experts have emphasised the need to shift content from training hard skills to including the teaching of soft skills such as communication, creativity, and problem-solving (Chaka 2020). While the necessary change in soft skills taught in higher education has been speculated on, it is also important to address how higher education institutions should engage with preparing students for the inevitable change in hard skills needed in industry (Chaka 2020). In a field such as

¹ South African Furniture Initiative (SAFI) is a joint initiative between industry, labour and government promoting the development and growth of the South African furniture industry (SAFI, 2023).

² Clout/SA facilitates collaboration between designer-makers and potential buyers with the goal of promoting South Africa's creativity, artisanship, and heritage (Clout/SA, 2023).

Industrial Design, research through practice and experimentation may be an effective method of preparing students for 21st-century skills (Chu et al., 2017), such as having to both engage with and potentially create new technologies and manufacturing methods. Therefore, the student furniture design project explored in this paper was undertaken through practice-based research.

Methodology

Practice-based research refers to a research approach in which research and practice act as complimentary processes for generating new knowledge (Candy et al., 2021). Practice-based research falls within the field of action research, which is a process that can be used for improving educational practice through action, evaluation and reflection (Clark et al., 2020). The intention of action research within pedagogy is to collect relevant information for improving practice (Clark et al., 2020). It is a collaborative process that is situated within the teaching and learning environment and new knowledge is created through action (Clark et al., 2020).

The project that informed this study was undertaken within a second-year Industrial Design practice module at the University of Johannesburg in 2022 with a class of 25 students. The students conducted a traditional furniture design project that focused on the South African context while having to integrate a form of digital fabrication into their design process. In order to conclude the project, students reflected on the potential that digital fabrication offers within the South African context and submitted their reflections on an online survey. Their answers were compiled and thematically analysed, similarities were identified, and any significant insights were highlighted. Along with these reflections, the students documented their project processes and outcomes within online portfolios, which were reviewed and the advantages and disadvantages that occurred during the integration of advanced technologies were documented. Three projects were selected in order to illustrate significant and varied methods of implementing digital fabrication and are discussed in this paper. Through this process, the research aim of this project was to identify potential ways of re-imagining the pedagogical approach to furniture design, a traditional field within Industrial Design, as the impact of advanced technologies becomes more prevalent.

Project brief

The project brief was adapted from the 2022 DTIC Furniture Design Competition requirements and read as follows:

The COVID-19 pandemic has caused significant disruptions to the global supply chain and highlighted the need for some level of self-reliance, as well as opportunities for import substitution and localisation. This also speaks to the importance of the sustainability of raw materials in manufacturing, and raising consciousness on where and how inputs are sourced. Businesses are therefore now forced to be more agile in how they react and adapt to crises in supply. Against this background, you are asked to design a furniture piece that will respond to these challenges and embrace localisation, celebrate the South African heritage, and portray South African identity.

Further design considerations were communicated, including the need to be innovative as well as integrate a form of digital fabrication into the design process or outcome. Students could choose from a variety of advanced technologies available within the department, including CNC routing, laser engraving, and CNC vinyl cutting. The three selected projects discussed in this paper made use of 3D printing, laser cutting, and AI-generated designs. The projects were chosen for discussion as they

offered interesting insights into the contributions digital fabrication can offer a traditional Industrial Design field such as furniture, particularly within the South African context.

Project outcomes

3D printing

The first student furniture design project discussed in this paper is a chair designed to be CNC cut from 18mm plywood and assembled through interlocking slots within the cut sheets (Figure 1). The design element that is focused on within this paper, however, is the leather strap seat that has a custom pattern design embossed into the material. The pattern embossing was created through a traditional technique of leather stamping, but as opposed to using a traditional tool, the stamp was 3D printed.



Figure 1: Student chair design (2022)

3D printing is an additive manufacturing technique whereby a 3D physical object is formed through the layering of material one slice at a time, as seen in Figure 2 (TWI 2023a). The 3D model that is printed is first created using computer-aided design (CAD) before being digitally sliced into horizontal layers, specifying the shape and structure of each layer to create a file that can be sent to a 3D printer (TWI 2023a). The 3D printer then builds the model layer by layer (TWI 2023a). Multiple methods of 3D printing exist including but not limited to fused deposition modelling (FDM), stereolithography (SLA) and selective laser sintering (SLS). Each of these methods has its own process and materials (TWI 2023a).

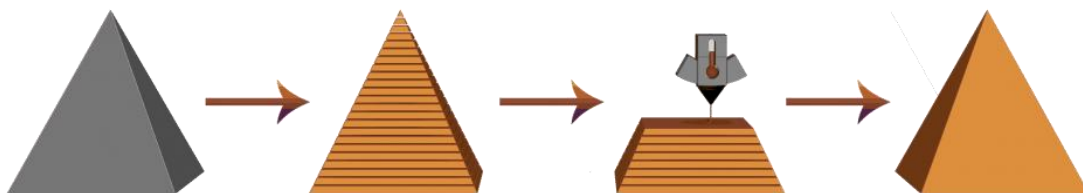


Figure 2: How 3D printing works in four steps (My3DConcepts, 2023)

Leather stamps are traditionally machined from brass or stainless steel, a subtractive manufacturing process that removes material until the inverted image of the stamp design exists as a debossed form. This tool is then knocked into the leather with a hammer, leaving the design embossed within the

material. In the discussed furniture project, the student alternatively 3D printed the leather stamping tool (Figure 3), revealing the advantages that using digital fabrication could offer within this more traditional, hand-manufacturing process.



Figure 3: 3D printed leather stamp (2022)

In its additive nature, 3D printing is a waste-reducing process, using material efficiently as an object is built (TWI 2023a). In addition to this, the digital manufacturing process used offers design flexibility. As a quick production method, 3D printing allows for rapid prototyping cycles and quick design iterations (TWI 2023a). It also allows for complex designs that would be challenging to produce using traditional techniques (TWI 2023a). Design is a key competitive advantage within the furniture design industry (Dunne 2000; Kraak 2017), making the use of technology that allows for the leveraging of design capabilities an important integration into design practice. Along with flexibility, 3D printing offers customisability and personalisation, two traits that are becoming increasingly necessary to remain relevant within the product design market today (Pallant et al., 2020). 3D printing has become more affordable and accessible, making its use possible within small businesses, by individuals and in educational institutions.

The use of 3D printing with the student furniture design project shows evidence of how new technologies can be integrated into traditional forms of manufacture without compromising the process or aesthetic result. As an added advantage, the use of 3D printing can allow for the affordable and accessible adaptation of designs within furniture.

Laser cutting

The next student project discussed in this paper is the design of outdoor seating made from a used oil drum and reclaimed pallet wood (Figure 4). The student made use of commonly found, used materials that are often re-sold at an affordable rate. Upcycling the drum and pallet wood referenced the idea of objects being used for purposes they were not originally designed for. This is an attitude that Adam Savage refers to in his book *Every tool's a hammer: life is what you make of it*, as being able to fulfil a need with what is available



Figure 4: Student outdoor seating design (2022)

(2019). This practice can be observed in the South African context, where numerous small-scale poverty prevention projects make use of upcycling materials into sellable products (Archer & Bjorkvall 2018), such as converting tin cans into toy cars or creating mats from used tires.

Laser cutting is a manufacturing process during which a high-powered laser beam burns, melts or vaporises a sheet material in order to create a precise and clean cut (TWI 2023b). It is a CNC (Computer Numerically Controlled) process, meaning that the cut file is created digitally, specifying the shape and dimensions of the cut (TWI 2023b). The power, speed and focus of the laser beam are then set according to the material and thickness being cut (TWI 2023b). The material is placed in the bed of the laser cutter and cuts can be controlled to be detailed and intricate (TWI 2023b).



Figure 5: Laser cut components (2022)

In the discussed student design project, the laser cutting of sheet metal was used as a method of modifying the oil drum. The resulting cuts were used to add storage space, drink holders, and aesthetic patterning to the furniture piece (Figure 5). Just like 3D printing, laser cutting is a customisable process making it easy to adjust dimensions to suit the object being modified. It is an affordable process that is suitable for batch production and is readily offered as a service within South Africa.

This student design project is an illustration of how digital fabrication can offer a method of reframing waste materials that are common within a context. As the practice of upcycling is frequent within South Africa, particularly in small-scale production (Archer & Bjorkvall 2018), laser cutting can provide a way of making upcycling an accurate and replicable process, while being able to customise designs to the objects being used within a product.

AI-generated design

Artificial intelligence (AI) is “a field, which combines computer science and robust datasets, to enable problem-solving. It also encompasses sub-fields of machine learning and deep learning” (IBM 2023). AI-generated work is becoming increasingly accessible in various formats, whether it is a language model like ChatGPT or an image generator such as Midjourney. As the complexity of AI-generated outputs grows and the tools become increasingly accessible to the public, it is important to consider what the evolution of AI will mean for the world of design.

Within the discussed furniture design project, students had the option of integrating AI-generated designs into their design process, specifically during their research phase. The project examined in this section experimented with making use of this method by prompting image-generating AI tools to design South African furniture alongside examining existing local furniture.



Figure 6: AI-generated stool designs (2022)

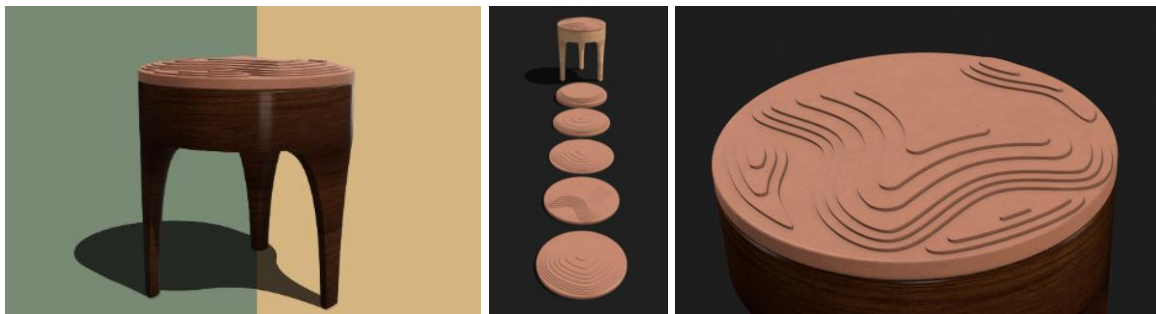


Figure 7: Student stool design (2022)

The integration of AI-generated designs poses an interesting contribution to design exploration. This phase of a project usually consists of investigating precedent designs as a means of researching what already exists as well as guiding the design direction of a project. Existing products form a foundation for creativity, which is defined as the process of creating novel ideas (Boden 1998). More specifically, “combinational” creativity is the process of merging existing ideas in a novel way (Boden 1998). It is also a place for students to gain an understanding of the context they are designing for and within. In this project, precedent studies were used to form an understanding and interpretation of what is considered local, as well as investigate the availability of materials and manufacturing methods in the South African context.

With the prompt of designing South African furniture, the image-generating AI tool simulates an amalgamation of South African furniture designs to generate something new. The tool is, by definition, being creative. However, the resulting images are difficult to contextualise. One cannot recognise what existing designs or objects the tool is drawing from, making the result an intentional reference to a widespread collection of ‘South African’ designs and artefacts. AI image generators are seemingly not refined enough to read into nuance and context, sometimes resulting in very literal and unusable design suggestions. The AI tool also has no reference to materials and manufacturing methods available within the context it is generating designs for. This means that the designs it provides cannot be taken directly to production. Therefore, in the following student furniture project, the AI-generated designs served as inspiration to develop a final design from that was aligned with the local context.

The final product designed using this process was a stool (Figure 7). The student picked up on the three-legged stool design (Figure 6) as it was comparable to a potjie pot, a three-legged cast iron pot that is commonly used to cook over a fire throughout South Africa (de Beer et al., 2022). The student selected SA pine as a material for the stool base, as it is locally grown and readily available. The contour lines that are visible on the top of select AI-generated stools were also developed further as a method

of referencing the topography of the South African Winelands (Figure 6 and 7). In line with this theme, the student chose cork as a material for the stool seats, referencing the cork used in wine bottling. This project is an example of an effective way of using AI as part of the inspiration phase within the design process, while still engaging with further product design development.

Since the completion of this project, students have integrated AI tools into their design process more frequently in order to explore its possibilities and identify its current limitations. Students have strategically prompted AI-powered chatbots to provide them with product design ideas. They have then plugged those suggestions into an AI image generator, which develops unique product designs, essentially eliminating their own ideation process. Furthermore, students have generated contextual product renders of their final design outcomes with AI tools in order to create product advertisements. While the outcomes of these explorations are still limited, AI-generated design can evidently be integrated into the design process. The translation of AI designs into manufacturable products within a specific context is not yet possible. It is, however, important to explore where AI tools can begin to be integrated into the design process as a method of aiding and inspiring designers who will compete in a rapidly changing world.

Student reflections

One of the students found the use of CNC processes enjoyable as it allowed for making easy adjustments to existing design files and speeding up the iterative design process. Being able to change files also meant that the customisation and personalisation of products were possible. Furthermore, it was found that digital fabrication could be used to imitate traditional handmade processes, such as the application of traditional patterns, while allowing products to be batch-producible and accurately replicable. Another student noted that making components through digital fabrication made their assembly process easier.

The business potential that digital fabrication offered small furniture enterprises was also speculated on. Students pointed out that businesses could decrease their turnaround time and production costs by replacing handmade processes with digital fabrication while also increasing the accuracy of product outcomes. In line with this a student remarked, “In an economic climate where small businesses and entrepreneurs are highly valuable and encouraged, digital fabrication makes furniture manufacturing a lot more manageable and accessible to small businesses”.

In general, students found the incorporation of digital fabrication within the furniture design project to be effective and beneficial. Practice-based learning was proven to be an effective way of learning new skills and exploring new methods of engaging with the design process.

Key findings and recommendations

The socio-technical field of Industrial Design has undergone significant changes throughout the industrial revolutions. As the 4IR unfolds, the role designers play and the pedagogical approaches in design institutions are impacted. The South African context has experienced the effects of de-industrialisation, as industrial activities and production quantities decline. However, as the democratisation of technology has increased throughout the 4IR, new technologies have become more accessible, affordable, and user-friendly, offering new possibilities in design approaches. These effects are visible within the South African furniture industry, which has undergone significant changes within the last three decades. The industry has transitioned from being mass-production-driven to

being dominated by small and medium-sized enterprises (SMEs). The democratisation of technologies could offer these SMEs an advantage in being both design-driven and adaptable.

With the rapid changes brought about by the 4IR, higher education institutions need to adapt their pedagogical approaches to prepare students for the evolving demands of the industry, leaving room to examine the approach to traditional fields such as furniture design. As a method of exploring that advanced digital technologies have to offer, practice-based research was used as a means of allowing new knowledge to arise from a second-year student furniture design project.

The student projects revealed that the integration of digital fabrication, such as 3D printing, laser cutting, and AI-generated design provided multiple advantages within the design process. 3D printing enables waste reduction, design flexibility, rapid prototyping, and customisation, which are crucial for staying competitive in the furniture design industry. Laser cutting allows for precise fabrication, customisation, and upcycling of materials, contributing to sustainable design practices. The integration of AI-generated designs into the design process opens up new possibilities for design exploration while highlighting the limitations of using AI tools.

The paper offers insight into how digital fabrication can offer support to the design of furniture within the South African context. The analysed projects illustrate how digital fabrication can aid in generating innovative and sustainable designs that are adapted to the local context. The paper also addresses the need to adapt pedagogical approaches to furniture design in order to accommodate the changes that 4IR technologies are causing within the industry.

It is recommended that students should be equipped with the skills to use digital fabrication technologies and critically engage with AI-generated designs as a means of generating new and creative solutions alongside research and ideation. In order to achieve this, it is suggested that students engage with digital technologies through the design process as a method of informing their design decisions. Furthermore, educators are urged to adopt a flexible and adaptable approach to teaching and learning in order to prepare students for the rapidly evolving working environment.

Through this student design project, it is evident that practice-based research is an effective method of introducing new technologies into the field of teaching and learning, as it allows for new knowledge to emerge through the practice of making. By integrating practice-based research into design pedagogy, we can explore and discover more about what advancing technologies have to offer.

Conclusion

Overall, this paper emphasises the importance of adapting and evolving Industrial Design pedagogy by integrating advanced technologies into the design process as well as exploring the possibilities that AI-generated designs offer. The furniture design student project discussed in this paper is evidence of how practice-based learning can reveal new design processes and manufacturing methods that can reimagine design approaches to traditional fields. The research findings of this project provide insight into how the pedagogical approach to furniture design in South Africa can be reimaged while considering the impact of the Fourth Industrial Revolution.

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