

MATERIALITY AND THE MACHINE. MAXIMISING MATERIAL EXPERIENCES IN THE AGE OF AI

Ceri ALMROTT, Keith COLTON, Mark ENNIS and Ina O'CONNOR
Technological University Dublin, Ireland

ABSTRACT

Artificial Intelligence (AI) and related technologies are expected to significantly impact the future of design, but traditional design methods are still important. Material Intelligence (MI) is crucial for product designers, and a structured four-year approach to undergraduate design education centred around experiential learning through MI is presented. The approach emphasises hands-on experimentation, integrates MI into the core curriculum, and prioritises interdisciplinary collaboration to produce innovative, functional, and sustainable design solutions.

Keywords: Studio culture, design education, material intelligence, product design, experiential learning

1 INTRODUCTION

Artificial Intelligence and its associated technologies are set to play a significant role in the future of design [1][2]. They will emerge as powerful tools that prospective designers can harness to develop innovative artefacts[3]. However, we view AI, much like CAD and digital visualisation, as a complement to, rather than a replacement for, traditional design methodologies.

Despite the rise of AI and digital tools[4], product designers still need a deep understanding of the materials and processes they work with. This understanding, known as Material Intelligence, is crucial for designing physical objects[5]. This paper will present a structured approach to undergraduate design education that allows and enables this competency.

Similar to Emotional Intelligence, Material Intelligence requires customized educational support to develop the necessary skill set in learners. Educational interventions need the appropriate contextual groundwork to maximize success[6]. A semi-structured, investigative, and peer-supported approach that draws on real-world tasks and interactions is an integral part of this support framework [7].

As educators, we must maintain our understanding of the roles and abilities of any emerging technology and any that could lead to paradigm shifts within our field. AI has already impacted the discipline through developments such as Generative Design in CAD[8]. Still, it will become more embedded within the discipline as technologies develop[9]. As with all new tools, we see AI offering the potential to enhance the skills of the designer rather than supplant them [10].

For this reason, we must not overcorrect our approach to teaching and must take a cautious approach to adopting and integrating these tools. Their role is undoubtedly important and should lead to a reflection on our approach to education. Still, we must continue to develop competencies within our students, allowing them to function effectively as designers, no matter which tools and methods they adopt in their practice.

Material Intelligence (MI) was, for a time, a core tenant of the design of physical objects. Still, with the professionalisation of the discipline and the emergence of additional considerations, such as a greater focus on emotional intelligence [11], the role of MI within the field has lost its vogue. Furthermore, with the additional push to find cost and efficiency gains within the University Sector, it is a relatively simple accounting choice to reduce the role of the workshop and the high expense of materials and tools in favour of softer skills or adoption of digital-only representations rather than physical, and many design programmes have adopted a less hands-on approach to the design of tangible objects for this reason.

2 TECHNOLOGICAL EVOLUTION OF DESIGN EDUCATION

Product Design has historically been a discipline where students learn through hands-on studio and workshop practices, allowing them to engage with the physical reality of their work[11]. This

educational paradigm has roots in the Bauhaus tradition, which influenced the development of many design programmes in the latter half of the 20th century[12]. The practice-based studio approach is inherent in the way most design courses operate and speaks of the importance of practice that is seen in design education paradigms. [13]. One of the most prevalent ways of material expression in a traditional mode is through practical design activities, which involve model-making and prototyping in workshops. Recently, "FabLab" style spaces have emerged, offering accessible digital manufacturing approaches such as 3D printing and other CNC tools.

The development of these digital manufacturing approaches has led to an increased focus on the importance of digital design and manufacturing. This is often a core component of design education and has been for many years. [14]. For the most part, 3D CAD skills have replaced traditional drafting skills, with an increased emphasis on digital rendering and visualisation over more habitual marker rendering approaches to envisaging and presenting design concepts; even this has been augmented by the high adoption of graphics tablets and iPad-like tools. This digitisation of the design sketching toolset and a reduced cost of entry into this space have allowed design students to transition from the more physical proprioceptive skill to an alternative skillset augmented through digital processes[15].

Within the prototyping and modelmaking area of design education, the availability of digital manufacturing tools, such as affordable additive manufacturing equipment that many students own, through to digital plotters, laser cutters and CNC machines have provided opportunities for students to again augment their skills but often with the misplaced idea of being able to "CTRL + P" CAD work. This presents a risk that students will miss out on critical learning opportunities, fundamental to their core process through lazy and ill-considered prototyping approaches.

Education across design programmes has had to adjust to allow for a shift in expected technological interventions. As digital tools are more prevalent in early-stage education and broader society, students are taking design courses expecting to work with these ever-increasingly established toolsets. With a rigid amount of time for instruction on any programme, some traditional learning must give way to allow for their introduction. This is not necessarily bad, but implementing and integrating requires careful consideration to maintain core and necessary learnings [16].

3 UNDERSTANDING MATERIAL INTELLIGENCE WITHIN CONTEXT

Gardner posits that intelligence is not a single concept but a diverse set of abilities that allow different information types to be processed and understood [17]. Gardner suggests that individuals may combine different mixes and levels of these intelligences to contribute toward a person's cognitive ability and that educational interventions should recognise and nurture a diverse range of them.

While Material Intelligence may not fit neatly into Gardner's original multiple intelligences framework, it can be viewed as a multidimensional construct that draws on cognitive, sensory, and experiential elements gained through interactions. Emotional Intelligence also does not fit neatly into Gardner's model. Still, as educators, we are likely to be inherently more comfortable with the concept as its relationship to intrapersonal and interpersonal intelligence is often a core part of our pedagogical frameworks. As we have realised and refined our programmes to focus on the multidimensional nature of human behaviour, we have looked to educate and instruct our students in this model [11].

Designers with high Material Intelligence deeply understand different materials and their potential applications. They can visualise how various materials will look and feel in a product, enabling them to create aesthetically pleasing, tactile and visually coherent designs. By doing so, they can develop designs that are not only beautiful but also practical and efficient. This type of intelligence can only be acquired through hands-on exploration, experimentation, and manipulation of materials.

4 A PEDAGOGICAL FRAMEWORK FOR DEVELOPING MATERIAL INTELLIGENCE

Emphasising the unique approach, lecturers at [the program] have developed a pedagogical pathway that recognises the paramount importance of Material Intelligence as a fundamental skill for undergraduate design students. This pathway guides learners from a basic level of proficiency to a point where it becomes an indispensable and natural component of their skillset upon graduation. Integrating into the core curriculum, this multi-year approach compels students to actively engage and refine their design practice by incorporating opportunities to develop Material Intelligence.

Staff acknowledge that Material Intelligence is one of many competencies that learners are required to master. When presented to students, material-intelligence-based lessons are always a technique for exploring design practice alongside other critical aspects of the skillset, such as problem-solving, technical knowledge, and integration alongside digital tools in design and manufacture. Importantly, in a largely constructivist approach to developing learning interactions[18], students are not just encouraged but empowered to understand and engage with a range of approaches, blending these competencies as they shape their unique design identities.

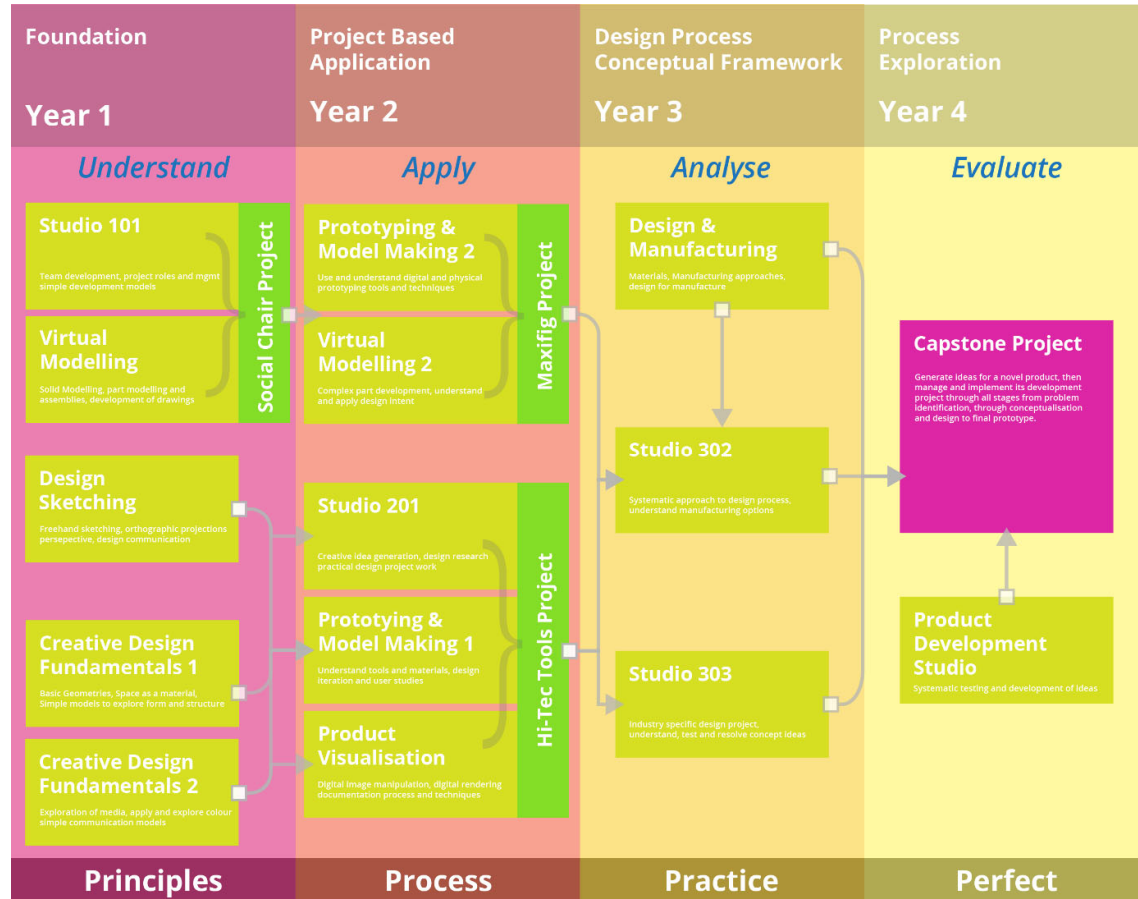


Figure 1. Educational Framework for developing competencies in Material Intelligence through practice-based experiential learning

The approach to developing competency in Material Intelligence is divided into four phases, aligning with the programme's four years. In the first phase, which aims to build foundational knowledge (*principles*), learners are encouraged to understand how materials can be interacted with to express design intent and explore simple ideas. Students are provided with some taught knowledge, but the core focus is on experimentation and hands-on application (as happens across many modules in this framework). The learning outcomes for practices in these activities are designed to align with Bloom's Taxonomy, specifically focusing on the cognitive domain of gaining understanding.

The second phase of interventions aligns with two cross-module projects that run during each of the two semesters of the programme. Here, learners are encouraged to understand and build on the core competencies first explored in phase one and apply these skills in a more developed and well-rounded design practice. In this second phase, students are encouraged to examine the design space using and through practical work. The overall educational focus of this year of the programme is the importance of *process*, and the project-based application of material knowledge is critical to this learning mode. Within Bloom's Taxonomy, students are encouraged to Apply learning from lectures in taught and adjacent modules to advance and explore their responses to the design briefs. This year of the

programme also includes the most direct education into workshop practice and the “traditional” modelmaking and prototyping skillset.

During Year 3 of the program, learners are encouraged to take ownership of their design approach and develop their *practice*. This is facilitated through a series of design studio modules, which provide a scaffolded environment for exploring the design space. These modules are intentionally less structured, building on the peer-supported studio culture developed in the first two years of the degree. The Material Intelligence pathway also adopts a more hands-off approach during this phase, with teaching staff creating opportunities and a safe space for learners to analyse and experiment with materiality in their design practice. Advanced technical instruction in design and manufacturing is delivered through a hands-on approach, exploring product teardowns, and tooling design and providing students with ample opportunities to engage with materials and processes within the classroom. These classes analyse good and bad design practices by deconstructing case study examples.

The fourth year of the programme and final year of the pathway are focussed on delivering the final capstone project. This project runs for two semesters and allows learners to exhibit the culmination of their learning across the degree. Within the framework, this year provides the space to intimately explore the materiality of their practice and evaluate it within the educational studio. In other classes in this year, the learner is asked to reflect on their understanding of design and their approach and appreciation of it. To assist in delivering the Capstone Project, learners are provided with a Studio Module and teaching and material resources to help them engage with the material aspects of their design solutions. Students are encouraged to take a scientific approach to using physical and material interventions within their work to evaluate and define their design solutions' critical and technical aspects. This work is assessed separately from the Capstone Project and is focussed more on process and intent than on outcome.

5 CROSS MODULE PROJECTS

A core aspect of the framework is the ability to engage in design projects that are not contained within a single module. This allows for specific skill-based learning outcomes to be realised in discreet areas while allowing students to apply their learning through a consistent output.

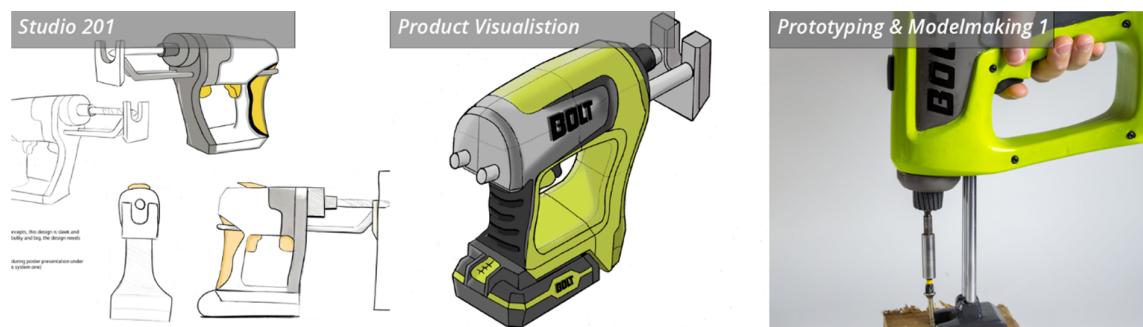


Figure 2. Outcomes from a Cross Module Design Project from Year 2, Project Based Application

The examples above and below illustrate how a student has participated in different graded assignments throughout the semester, each aimed at teaching distinct skills such as design research and problem framing, digital rendering, and exploration of design through modelling and prototyping.

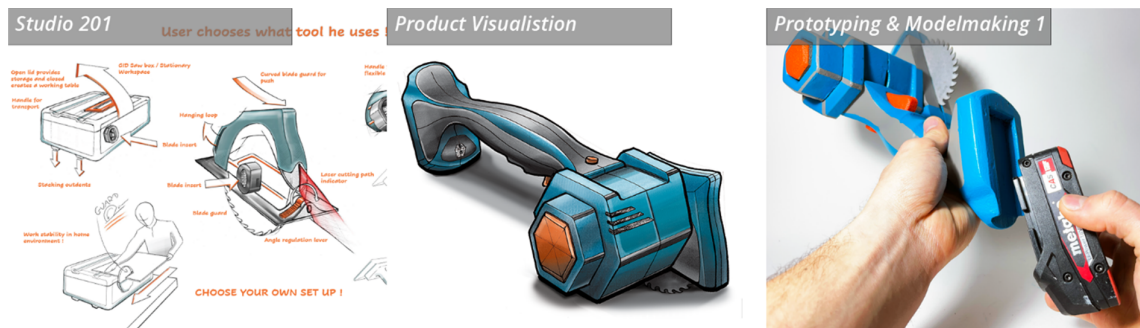


Figure 3. Outcomes from a Cross model Design Project from Year 2, Project Based Application

This approach allows the students to explore, comprehend and apply various tools being taught while providing a scaffolded context for their work. It also offers flexibility in pedagogy for different competencies and tutors. While some assignments require a more rigid and instructional approach, such as the visualisation assignment, students can still engage in the more exploratory and accessible approach needed in the design studio and prototyping process.

The delayed opportunities for access to workshops and studios for a cohort of students due to the COVID-19 lockdown further reinforced the importance of early and phased competency development in Material Intelligence. On returning to the studios, these students initially needed more confidence in exploring design through modelling and prototyping as part of their process. It took until their capstone project to develop an appreciation and better understanding that Material Intelligence-related skills were as essential and within their grasp as their digital skills, which were not as evidently missed out on in the early stages of their development.

6 CONCLUSIONS

The discourse surrounding the integration of Artificial Intelligence and digital technologies within design education has underscored their potential as powerful tools for innovation, sparking optimism about the discipline's future. While AI offers unprecedented opportunities for enhancing designers' skills, educators must ensure a balanced approach that preserves the foundational principles of Material Intelligence, instilling a sense of continuity and stability and resisting a move towards an over-reliance on digital tools at the expense of tacit knowledge development.

Material Intelligence, essential for designers working with physical objects, has faced challenges amidst technological advancements and cost considerations within educational institutions. However, its significance in informing design decisions, developing valuable and significant solutions, and fostering hands-on learning experiences remains paramount.

Howard Gardner's theory of multiple intelligences recognises diverse cognitive abilities. Educators have developed pedagogical frameworks that prioritise Material Intelligence alongside other essential competencies. Through structured, multi-year approaches integrating experiential learning and studio-based practices, students are equipped with the skills and knowledge needed to navigate the complexities of the design field effectively.

Design education can empower students to develop innovative, functional, and sustainable practices that address real-world challenges by emphasising hands-on experimentation, peer-supported learning, and interdisciplinary collaboration. As educators continue to refine their approaches, it is crucial to maintain a holistic perspective that values both technological advancements and the timeless principles of Material Intelligence in shaping the next generation of designers.

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