The Future of Teaching Post-COVID-19: Microlearning in Product Design Education

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***Abstract*—The recent COVID-19 pandemic has placed a huge strain on higher education institutions and educators around the world, which has included the closure of campuses, removal of face-to-face instruction and a shift to remote teaching and learning. However, this situation has also created unique opportunities and conditions that can foster innovation in teaching and learning practices and content delivery. One such innovation gaining traction is Microlearning, which offers learning opportunities through small bursts of training materials that learners can comprehend in a short time, according to their preferred schedule and location. This paper explores the potential of Microlearning within design education and how it can be implemented into the Product Design & Manufacture programme at University of Nottingham Ningbo China to support teaching instruction and enhance the student learning experience post-COVID-19.**

Keywords—COVID-19, microlearning, design engineering, higher education, teaching innovation, product design, mixed reality environments, online teaching, remote teaching, OER

I. Introduction

Design, particularly in the context of China's growth, is increasingly recognised as a value-adding link between cultures and products, services and experiences, and businesses and customers [1]. Increasing numbers of businesses are using "design thinking" (a creative problem-solving process developed and used by designers) to drive growth and innovation: 75% of organisations self-report having engaged in design thinking [2]. Design Council UK have found that design can directly and significantly improve sales, profits, turnover, and growth: for every £100 a business spends on design, turnover increases by £225 [3].

Due to the increased importance of design, higher education institutions (HEIs) now offer an array of design degrees. However, since the outbreak of COVID-19 and the resulting switch to online teaching and learning (T&L), many HEIs have faced challenges, especially in teaching practical and skilled-based subjects such as design and engineering [4].

"Microlearning" (ML) is a recent T&L innovation that has the potential to alleviate some of the challenges faced in online T&L, particularly post-COVID-19. We propose a new T&L method incorporating ML that aims to enhance learning experiences and improve the effectiveness and efficiency of teaching and training. We report on applying the method to the Product Design & Manufacture (PDM) programme at University of Nottingham Ningbo China (UNNC).

II. Microlearning

In today's working environments, employees are constantly challenged to learn, respond to new situations, and meet new demands [5]. The essence of ML can be thought of as a response to the increasing needs of these employees, often referred to as "knowledge workers" [6], who need to have knowledge on hand to meet their work (and other) requirements [7]. With the recent advances in technology and subsequent learning demands in the modern workplace, knowledge workers have neither the time nor the attention span [8] for traditional lengthy T&L methods, which can be considered expensive, outdated and time-consuming [9].

E-learning, such as electronic, online or digital learning, is learning with the use of a computer or similar technology. It is traditionally delivered in a "macro-learning" format, using fixed/linear learning approaches, such as instructor-led classes and massive open online courses (MOOCs). ML can be, but does not have to be, e-learning; it is more adaptive in nature and utilises a "just-in-time" (JIT) approach to learning [10]. Because JIT focuses on learning specific, immediately applicable skills or information [11], it has been used in industry to provide employees with information they need in a focused and concise format that is accessed directly before completing a task. This approach results in training that is delivered in bite-size chunks, and is available where and when it is required, rather than in long, out-of-context blocks.

Thus, ML is learning that takes place in small steps. It is "learning that fits" the learner, the goal, delivery method and the task at hand [12]. It often happens outside of traditional arenas [13], and can be seen as a response to the fragmentation of information and learning [14]. Hug [15] has suggested that it should be focused, self-contained, use multiple forms of media, and support all learning approaches. ML sessions should ideally be relatively short (6 to 10 minutes [16]), and available on-demand.

Industry has been using ML for compliance and safety training for several years, partly due to its flexibility and ease of access [17]. Delivering training through a smart phone allows companies to save time and money [18]. Walmart, for example, used e-learning vendor Axonify to create an ML Health, Safety and Environment (HSE) training programme, using 3-5 minute competitive games that reportedly improved employee knowledge, retention, and engagement with safety practices while allowing feedback and tracking [19].

Buchem & Hamelmann [20] found that ML can help facilitate self-directed learning, as short activities can be integrated into everyday activities. They also found that information delivered in short, focused "nuggets" was easier to comprehend and recall than the same learning delivered in a longer, more comprehensive format. The Rapid Learning Institute (RLI) found that 94% of learning and development professionals reported that their learners preferred ML over traditional e-learning courses [21]. RLI also reported that 65% of learners described the typical e-learning class as presenting too much information, and attempting to achieve too many learning objectives. In contrast, ML content is facilitated by

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bite-sized classes where one learning objective is addressed per class, often described as "micro-content." Micro-content can be designed in three main ways: as a single or separate learning task; delivered concurrently to existing material; or integrated into other activities [22]. However, ML is not simply splitting a larger e-learning or traditional course into smaller nuggets: Content should be aligned to a specific learning outcome and should trigger the learner to act [23].

The basic premise of ML is that people can learn more effectively in an easier, more enjoyable manner, if information is broken down into smaller units, and if learning takes the shape of small steps, available whenever and wherever necessary. This form of "bite-sized" education creates opportunities in design education, especially for assisting and re-enforcing theories, skills and knowledge taught throughout design education programmes. ML enables students to access information on-demand, as opposed to (or supplementary to) traditional lecture-based content or traditional e-learning.

Post lockdown, classes at UNNC are being delivered in a mixture of face-to-face and online formats, with pre-existing content being live-streamed or recorded during class. These methods have been highlighted as not best practice [24], which leaves room for online ML to be implemented and positively impact current T&L delivery. Instructors can either create supplementary content to reinforce learning that students can progress through at their own pace, or restructure existing content to be aligned with the principles of ML. For example, content could be delivered through short videos (5-10 minutes), branching in nature, single learning objective focused, aligned with learning outcomes, and reinforced with either in-class activities or online games/quizzes. This would increase interaction and be useful for both learners and teachers, especially when applied to practical/skill-based subjects [25].

The experimental and practical nature of design can cause difficulties for design students to link theoretical insights during their practical design assignments [26]. Taking advantage of distributed and JIT [27],[28] approaches to learning, ML has the potential to provide immersive and holistic learning experiences that bridge the gap between theory and practice. Moreover, when compared to other forms of e-learning, ML is well-suited for use in design education, as the learning method promotes a self-directed and needs-based educational model, much like the process of designing itself.

III. COVID-19 Impact on Education

At the end of 2019, the World Health Organisation (WHO) was informed of cases of pneumonia with unknown causes in the Chinese city of Wuhan [29]. By January 31, 2020, the disease had 9720 confirmed cases and 213 deaths in mainland China [30]. On February 11, WHO officially began calling the new disease COVID-19 [31]. By March 11, WHO was deeply concerned about the spread and severity of COVID-19, and by the level of inaction by the international community. The WHO then declared COVID-19 a pandemic [32].

Since the virus was previously unknown, highly contagious, and with no vaccine, measures were taken to slow the rate of infection. These measures included social distancing, limits on event sizes, and home quarantine when necessary [33]. As a result, education had to react, suspending face-to-face T&L and rapidly adopting e-learning, whereby T&L was undertaken remotely and on digital platforms. The sudden closure of schools worldwide disrupted the education of around 1.6 billion children and young people, as of April 20, 2020, according to the United Children's Fund (UNICEF) [34]. Audrey Azoulay, Director-General of the United Nations Educational, Scientific and Cultural Organization (UNESCO), stated that "the global scale and speed of the current educational disruption is unparalleled and, if prolonged, could threaten the right to education." [35].

This period has thus been extremely challenging for education institutions, educators and students alike, impacting course schedules, attendance, T&L delivery, examinations and assessments, and student progression. Despite these challenges, the crisis has also provided opportunities for innovations in T&L that make greater use of online learning, distance learning and digital devices and tools.

In response to the outbreak of COVID-19, UNNC reacted quickly to ensure that T&L quality was maintained, aiming to have students still meet requirements to progress or graduate by the end of the academic year. On February 14, 2020, UNNC announced a 2-week delay to the start of the semester [36], allowing the institution to make the switch to online T&L. With restrictions on travel both within and external to China, many staff and students were unable to return to campus. By March 16, UNNC was delivering 469 modules online to about 8000 students, 9% of whom were outside of mainland China [37]. In May, most students returned to campus and UNNC began delivery of a mixture of face-to-face and online T&L.

The main challenges faced by UNNC staff during the online T&L period included developing online content with limited training or experience, dealing with insufficient bandwidth, and having limited time to prepare before online T&L delivery commenced. In addition, those faculty members teaching practical and skill-based classes found it especially difficult, often choosing to delay laboratory sessions and fieldwork until a return to campus [4]. This particular challenge highlights the opportunity for greater use of ML and digital tools within the online T&L provision.

IV. Product Design Education at UNNC

The role of product designer has been evolving [38], shifting from designing functional and beautiful products to creating immersive and intuitive user experiences. This shift has changed the skillset that a product designer needs to have.

Due to this evolution, and the availability of new technologies and digital devices, many techniques and methods taught in HEIs are often unchanged from traditional methods of product design [39], and are outdated. Design teachers are challenged to modernise the class content and implement new ways of learning and executing design tasks.

The PDM programme is aligned to the way the design process is conducted in industry. Students develop their critical thinking, problem-solving, communication and design skills in conjunction with engineering knowledge, to ensure that products are innovative and suitable for manufacture.

The programme combines human-centred design (HCD) with design-thinking approaches to problem solving. Famous design consultancy IDEO is often credited with inventing the term "design thinking" [40]. IDEO has been practicing HCD since 1978, and adopted the phrase "design thinking" to describe elements of the practice that they found most learnable and teachable. These elements are: empathy, optimism, iteration, creative confidence, experimentation, and an embrace of ambiguity and failure [41]. PDM uses a project-based learning system, combining a variety of learning models with complimentary classes to scaffold the learning of relevant skills and knowledge. The T&L methodology emphasises "experiential learning" [42], which means learning from

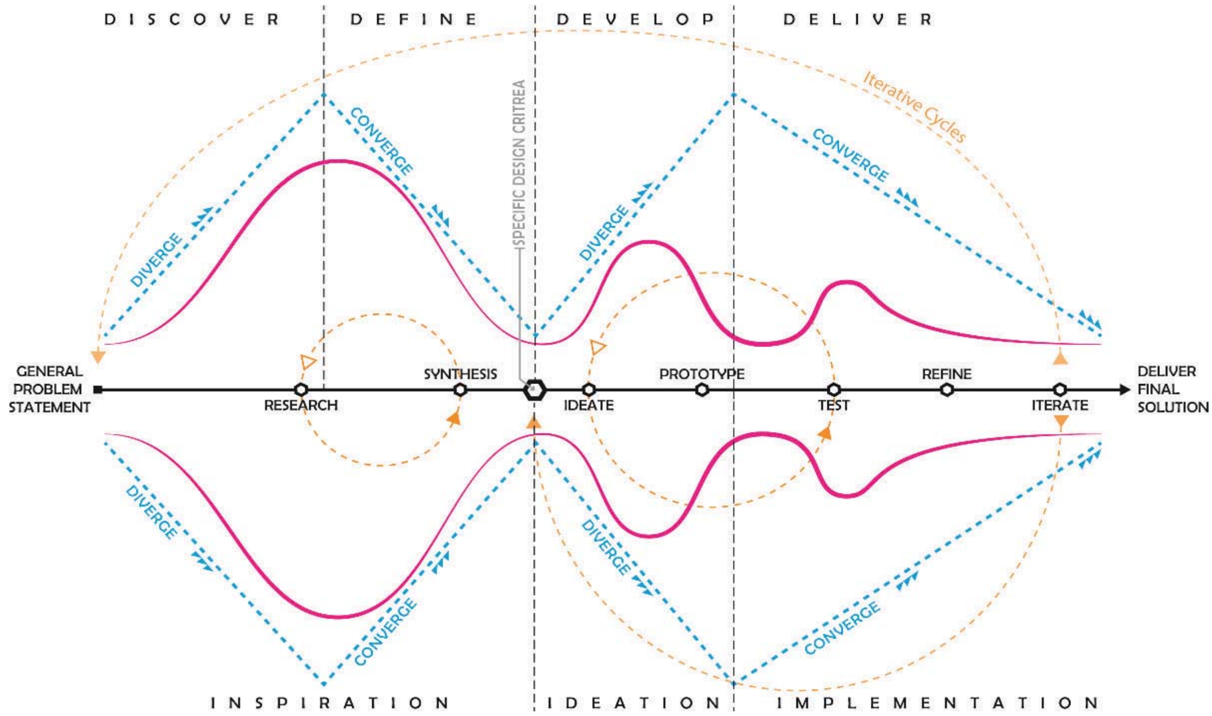

Fig. 1. PDM Design Process

experiences resulting directly from one's own actions, as opposed to learning from watching or listening to others [43]. Therefore, design project classes are at the core of the programme, with the final year including a capstone project worth half of the entire year's credits.

Central to all design project classes is the "design process," a systematic approach for breaking down a large project into manageable chunks. The design process is regarded as a creative problem-solving process [44], made up of a series of iterative phases, which lead from initial concept to realisation. There are many design processes, starting with research to define the problem and establish the design goals, from which innovative ideas can be developed.

As Fig. 1 shows, the design process used within the PDM programme combines the four generic stages of the UK Design Council's Double Diamond design process (Discover, Define, Develop and Deliver [45]) with IDEO's three distinct HCD phases (Inspiration, Ideation and Implementation [46]). To allow students to apply the design process more easily, it has been simplified and broken down into manageable and easy-to-comprehend phases. These phases, as shown in Fig. 2, are: Brief, Empathise, Define, Ideate, Prototype, Test, and Deliver. The phases are integrated with knowledge components [47], in the form of weekly individual tutorials and critiques, which allow the teachers to communicate the key components for each phase, monitor the student's progress, and provide formative feedback before summative assessment takes place.

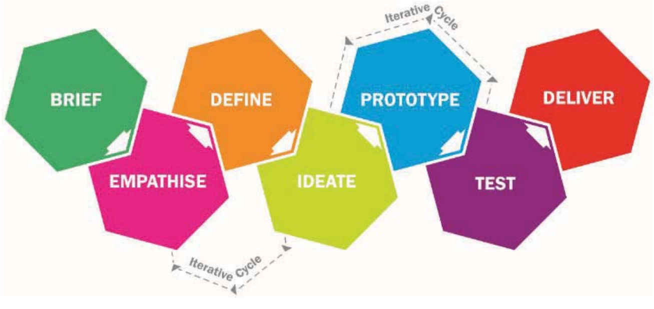

Fig. 2. Simplified PDM Design Process

With multiple approaches available in each phase, design teachers face the challenge of how to introduce the large number of techniques, methods, and skills that can be used. This is where ML has the potential to positively impact on knowledge and skill acquisition by assisting teachers with delivery.

V. Microlearning in Design Education

ML was informally piloted at UNNC during the online T&L phase in the second semester of 2019-20, as part of a year-long class that teaches 2-point perspective sketching and basic marker rendering techniques, and is assessed via coursework. Before COVID-19, the class was taught face-to-face, with the coursework assignments submitted through weekly 1-hour in-class tests. The sketching and rendering techniques were demonstrated twice weekly.

After switching to online T&L, the class format had to adapt, as it was no longer possible to conduct in-class tests or give demonstrations in person. This led to the pilot test, where pre-recorded videos replaced the live demonstrations, and the in-class tests switched to online submissions. ML principles were applied when creating the video demonstrations, resulting in videos with concise explanations, focusing on a single technique. Students could them view on-demand, and re-watch multiple times — something not possible with live demonstrations. As a result, the quality of student submissions was significantly higher than in previous years, and students gave positive feedback regarding the video content, through UNNC's "student evaluation of module" surveys.

Learning from this positive implementation of ML, and using PDM's simplified design process as a basis, we decided to explore potential areas where ML could be implemented to increase the T&L effectiveness and efficiency within the design programme. We identified two key areas within the design process where ML could make an impactful difference to benefit both staff and students: the Empathise (research) and Prototype (model-making) phases.

HCD is premised on empathy, on the idea that the people who are being designed for are the roadmap to innovative solutions. Empathy is a key research phase of any design project, requiring students to interact with and understand end users, to gauge their insights and experiences, and to identify the real needs of the users and overall problem. A challenge in this phase, from the teacher's perspective, is the number of different research and thinking techniques available (including brainstorms, observations, interviews and questionnaires, ergonomics, market research, product analysis, challenge maps, personas, scenarios, storyboarding, reverse engineering, brand analysis, SWOT analysis and creative thinking techniques [48]). Due to time constraints, teachers are typically not able to explain the methodologies and benefits of all possible techniques. Students, therefore, typically need to explore resources independently, often with limited guidance, while concurrently working on their design projects. This situation can result in simplistic and generic techniques being used, often leading to weak research outcomes.

Selection of the most appropriate techniques depends on the project brief, the needs of the student, and the nature of the project itself. ML and adaptive learning [49] can be used in an Open Educational Resource (OER) [50] to create an interactive research method toolkit. The combination of adaptive learning and OER has previously seen success at Bay Path University, where they reported on a large-scale implementation that personalised learning while recognising academic diversity [51]. They also reduced the long-term cost usually associated with maintaining an OER system.

Our proposed toolkit would contain branching scenario activities, flash card guides, interactive videos and quizzes, with each research and thinking technique categorised. Each technique could be broken down into an interactive step-by-step guide, supported by demonstrations and case studies, culminating with a quiz or game. Techniques could be presented in the form of a stand-alone mobile application or embedded in the university's virtual learning environment, using a diagnostic tool that uncovers the student's needs and goals, and directs them to the techniques best suited to their needs. In addition, if some learners want to explore a technique more deeply, the toolkit could make this easier for them by linking supporting articles, videos, or case studies, which would benefit and supplement the teaching content, and give a deeper on-demand explanation with rich examples, helping students to understand how to apply techniques in their own work and how to produce stronger research outcomes.

Students often have difficulties visualising a structure from drawings and may overly trust computer analyses [52]. Model-making is, therefore, another vital part of the design process, and can quickly produce tangible results [53]. Producing a physical prototype has been shown to help students bring their ideas into the real world, enabling them to test and share them with the users, stakeholders and markets [54]. Models help them to understand the scale, shape, ergonomics, product architecture, user interaction, material selection and manufacturing processes, while also helping to refine and improve the design.

Although 3D printing is an option in model-making, students are encouraged to make rapid prototypes or "sketch models," which can be made in a variety of materials. This phase is challenging for teachers as there are many model-making techniques available that are not standard in design curricula.

Compounding the challenge of introducing the large number of techniques and materials, there is also a shortfall of skilled technicians at universities [55]. A lack of practical examples can lead to graduates lacking in practical skills, and being underprepared for the job role [56]-[58]. ML could alleviate some of the pressure on technicians and teachers, and play a pivotal role in providing students with rich, specific and concise instructions and tutorials, as and when needed.

ML also has the potential to provide equipment training on-demand, which can reinforce, supplement and refresh introductory training. A typical university workshop might include a large range of equipment, from manual tools to automated machinery. All equipment requires basic training to ensure it is used safely and appropriately. Furthermore, between equipment updates and teachers and technicians being occupied, there is a need to make the right information available to students, in the right place, and at the right time. This can be achieved with ML through mobile devices.

To implement training for a design workshop setting, a mobile application combining augmented reality (AR) with JIT learning methods [59] can be developed. In AR, the environmental setting is real, but can be extended with additional computer-generated information and imagery applied by the AR system, in real time [60], [61]. Users can access it through screen-based devices, such as phones and tablets, by using AR markers as triggers. Through combining AR and JIT, training and instructional content can be placed directly into the workshop, be specific to needs, and made available as needed. AR markers directly on the tools and machinery with embedded JIT content (including safety requirements, tutorials, and links to advanced information) provide access to specific content immediately before completing a task. This information can be highly focused and culminate with a quiz or task to evaluate whether or not the learning has been successful.

ML also has the potential to support the model-making T&L process, and alleviate some of the pressure on teachers, technicians and institutions. A video library of model-making techniques could be created, where students could access concise and content-rich instructional guides on-demand, through their mobile devices. These videos would bridge gaps in student learning when a teacher is unable or unavailable to do so. The video library could demonstrate specific techniques, be categorised by material, advise best practices, and suggest possible materials, mechanisms and manufacturing processes suitable for production. Taking inspiration from existing fabrication laboratories [62] and open source resources, this video library could initially be developed at UNNC, by PDM staff (and students), after which it could be converted into an OER and shared with others, including the teaching community and industry.

VI. Conclusions

This paper has discussed the application of ML initiatives with a specific focus on two key phases within the PDM design process at UNNC. As design education can cover many different disciplines — including art, business, engineering, electronics, history, psychology, philosophy, maths, physics and sociology — it can be very difficult to provide all the knowledge and skills within the available class time. ML however, has the potential to provide support, reinforce and scaffold T&L in design.

In today's dynamic business environment, employees are tasked with constantly upgrading and updating their skills. For this reason, organisations have been turning to ML to create efficient, flexible, and on-demand training courses. In education, ML has already been applied in other skill-based subjects with promising results [63]. ML can enhance design education at UNNC post-COVID-19, and benefit students, teachers and the PDM programme. By restructuring or supplementing existing content with micro-content, that utilises emerging T&L methodologies (such as visual learning, gamification and JIT) and emerging technologies, (such as smart phones, tablets, AR/VR and OER), to produce innovative, immersive and interactive learning experiences. Grounded with the principles of ML, this micro-content should be, single learning objective focused, delivered in short bursts, accessible at student's request, and able to be experienced through their perosnal mobile devices, allowing for autonomous learning without restriction.

As stated by Johnson *et al.* [64, p. 21], "AR has strong potential to provide both powerful contextual, on-site learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world." Before COVID-19, technology was underutilised in higher education. In the Post-COVID-19 future, ML could provide the catalyst needed for HEIs to embrace educational technological affordances as a sufficient means for blended learning. This could support the evolution of pedagogy, and better engage the students of tomorrow. We recommend that HEIs reimagine current pedagogies, and design them to embrace the modern (and future) student. Future education should reflect students' cognitive and collaborative learning styles, while utilising their own (mobile) devices to enhance learning through technology-driven T&L methodologies. ML should not be viewed as a stand-alone intervention, but should instead also reinforce and support classroom-based learning. With ML and AR already being used in industry, for immersive learning experiences and knowledge transfer [65], is it important for HEIs to follow suit and prepare students for their future work environments.

In our future work, we will develop the theoretical approaches and methods discussed in this paper further with the aim of implementing ML in both face to face and online T&L formats, within the PDM curricula at UNNC. Empirical data of student experience will be obtained through controlled and comprehensive studies that include large sample sizes and validation instruments, to measure efficiency and evaluate the potential impact of ML in design education. Additionally, exploration of current and emerging technologies will need to be conducted to better understand their capabilities and how micro-content can be developed within them, to create unique learning experiences that add educational value. The analysis from these studies could inform T&L theories and help generate content-design principles to guide ML instructional design, and perhaps even provide value to pedagogical techniques beyond this field.

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