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Problem-based Learning in Institutional and Curricular Design at the New Model Institute for Technology and Engineering (NMITE)

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ABSTRACT

NMITE's Master's in Integrated Engineering (MEng) was created with a unique philosophy of integrating not only traditionally separate strands of engineering, but also of integrating engineering with other disciplines such as arts, humanities, and business. This broad and deep integration is made possible by adopting the principles and practices of problem-based learning (PBL) and embedding them within predetermined module challenges. In this way, each PBL challenge highlights and hones areas of engineering expertise and embeds liberal subjects whilst maintaining the integration intrinsic to the programme. Overall, this method supports the use of block learning with deep integration of employers and the community in the educational experience.

Keywords: Integrated Engineering; Curriculum Design; Engineering Education

INTRODUCTION

NMITE believes PBL can be a "change-agent" in a new model of engineering education, and that it can help open the engineering profession up to new and different kinds of thinkers and practitioners with the potential to achieve great things (Saven-Baden, 2000). Indeed, the creation of NMITE was motivated by the belief that engineering education, both in the UK and globally, can and should increase its potential, and that the current prevailing methods of educating engineers are not as effective as they could be (Perkins,

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2013; Perkins, 2019; Engineering UK, 2016; Wakeham, 2016). This new model has high-stakes implications: the need to educate passionate, curious, resilient, and agile engineers equipped with the skills and motivation to solve pressing problems may never have been more urgent. With a shortage of engineers entering the workforce and a surplus of "gigaton problems [that] need gigaton solutions" from climate change to clean water to resource scarcity, a change in engineering education is long overdue (Xu et al., 2020 p. 4037). At NMITE, the embedding of PBL within the pedagogical approach has a critical part to play in meeting this goal (Institution of Engineering and Technology, 2019; Usher & Sheppard, 2017).

To fully develop and test this approach, and prior to its first cohort in September 2021, NMITE utilised a year-long Design Cohort activity, based on Olin College's "Partners", that brought student co-design into plans for both the institution and the MEng programme (Miller, 2019). Learning with and from over 30 members of the Design Cohort has strengthened NMITE's PBL pedagogy and practice, expanding our conceptualisation and producing a truly innovative programme. By designing for PBL the programme enables students to become agile, intellectually curious graduates with the broad skillsets necessary for future employment.

BACKGROUND

NMITE is a new Higher Education (HE) provider in Hereford, England. As its first and therefore flagship programme, the MEng has been created using best practices used elsewhere in schools and HE, innovatively combining them to produce a unique pedagogical design, curriculum content and assessment approach. Revamping engineering education "requires commanding the whole problem, not just iterative efforts that barely strike a moving target."[1] It is not enough to make gradual, minor adaptations to existing educational models; rather, the change society needs requires a wholesale shift in mindset, pedagogy, and practice. The destination – graduating work-ready engineers – may be similar to that of other engineering programmes, but the NMITE road map is completely different. It has been drawn from scratch to take students on a journey whose landmarks include not only the achievement of technical skills, but also those of personal and professional development cited by recent governmental and professional body reports (RAEng: *Engineering Education systems that are fit for the future, 2018*) as necessary to 21st century engineering work. These include incorporating creativity into engineering (Awang and Ramly, 2008; Felder, 1988); broadening the diversity of students (Busch-Vishniac and Jarosz, 2004; RAEng, 2019); strong emphasis on project work (Grolinger, 2011; Savin-Baden, 2000; Perrenet et al., 2000); industry engagement in design and delivery (Burns and Chopra, 2017); experience of the workplace for students (Lee et al., 2010); and greater interdisciplinarity within and beyond engineering (Richter and Paretti, 2009). All this is accomplished on an accelerated timetable taking students from entry to Master's in only three years.

Beginning with a blank page has allowed NMITE to make these additional components integral to every landmark on the Master's pathway and to deeply embed them within the programme philosophy and design. Whilst still adhering to the high standards expected by the Engineering Council, the MEng learning journey will look different from the very first moment a student enters NMITE and uses a PBL approach through Engineering Sprints, multiple Community-Based Challenges and the completion of independent Bachelor's and Master's projects.

LEARNING APPROACH: INTEGRATED AND INTERDISCIPLINARY

An NMITE student realizes that engineering is at its heart all about systems and connections, and that the best engineers understand how economics, geopolitics, culture, technology, and values work together to enable it. Indeed, Popper states "We are not students of some subject matter, but students of problems. And problems may cut right across the boundaries of any discipline."[2] This is why NMITE's MEng uses PBL to integrate conventionally separate strands of engineering and goes still further – integrating engineering with other disciplines such as arts, humanities and business (Braßler, 2020; Navarro et al., 2016). Unlike traditional degrees where options to take outside subjects are available but not part of a coherent programme of learning, NMITE's integrated approach means these subjects are not isolated and all disciplines inform all learning at every stage. Engineering challenges are designed in such a way that the implications of other disciplines for engineering, and the interactions between technical and non-technical considerations, are fully woven into the learning throughout the degree. Indeed, liberal elements comprise 30% of the MEng programme. Communication and ethics are required components of every PBL challenge, and these concepts and skills are built upon with increasing complexity as students advance through the programme.

Using the strengths of a PBL approach, NMITE explicitly defines places within the curriculum where distinct professional behaviours and competencies are developed (Lucas and Hanson, 2016). The programme goes still further, deliberately embedding increasingly complex learning types across the Framework for Higher Education Qualifications (FHEQ) levels (which in the case of an integrated Master's is FHEQ 4-7), moving from passive to interdependent and directed to reflective learning as the programme progresses. This approach using PBL enables a natural and unobtrusive transition from extrinsic to intrinsic motivation (Talmi et al., 2018; Lam et al., 2009) and moves the student up the learning taxonomy from fundamental knowledge and application to synthesis, evaluation, and phronesis (Frigo et al. 2021). Ultimately, this educational model provides the basis for industry-ready engineering capability as well as the foundation for lifelong learning. To demonstrate this, Figure 1 provides a pictorial overview of the programme with details on competency and learning development; progression of technical techniques and professional behaviours; and awareness of social engagement and responsibilities.

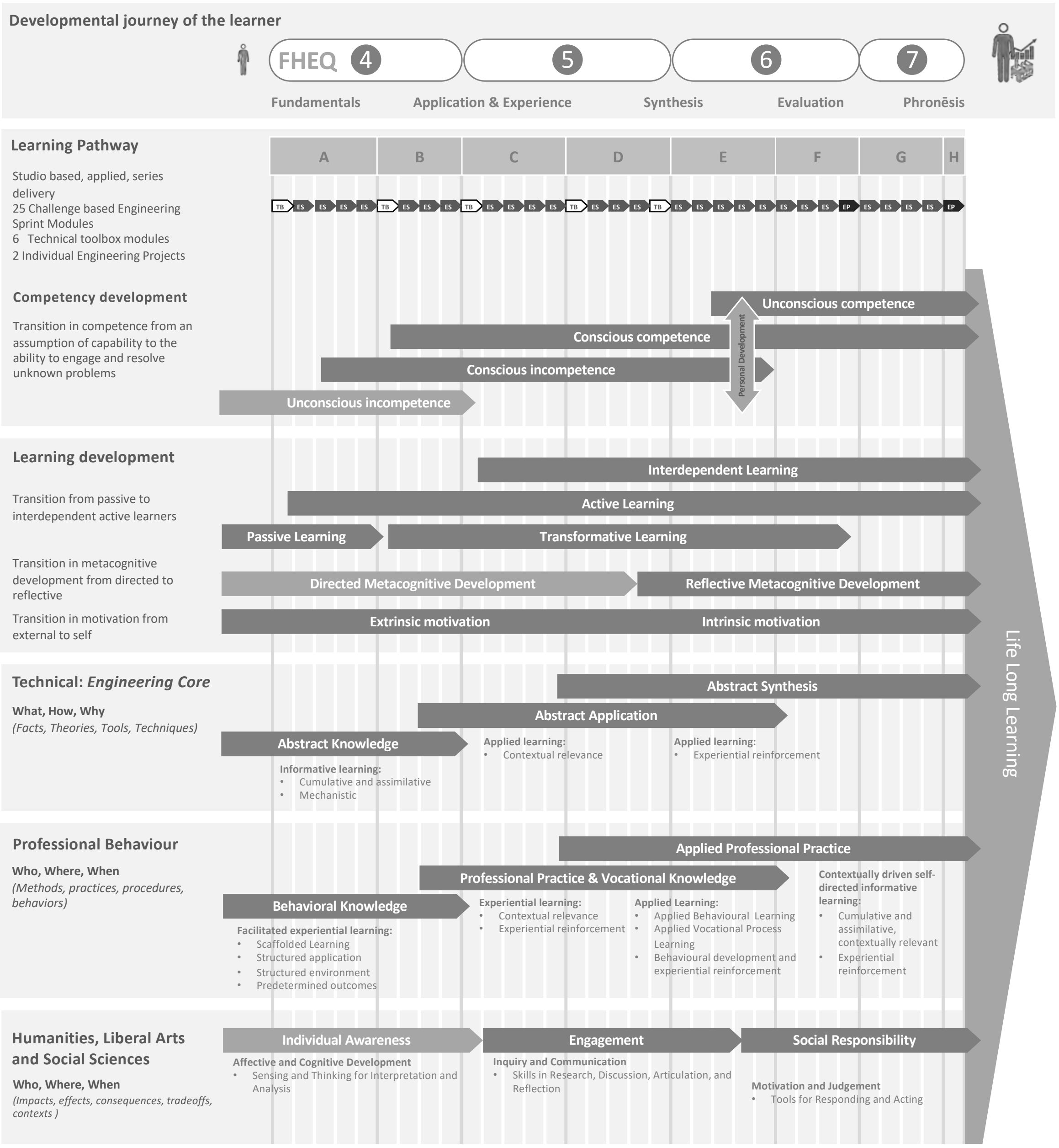

Figure 1. The NMITE educational model.

Thus, using a pedagogical approach made possible through the utilisation of PBL, NMITE has maintained a strong focus on the engineering discipline, while further enhancing it by including broad-ranging intellectual and personal discovery. Taken together, this integration of the technical and non-technical, the personal and the professional, enables learners to be both students and solvers of problems.

LEARNING STYLE: CHALLENGE-BASED AND ENGAGED WITH PARTNERS

NMITE is dedicated to the philosophy that education should integrate learning with experience, so the MEng content is always connected to real-world and tangible challenges. After all, "Having learned it is not as good as having seen it carried out; having seen it is not as good as understanding it; understanding it is not as good as doing it."[3] Therefore, educators and partners work collaboratively to develop PBL challenges that respond to specific problems and alongside specific stakeholders. Students will immediately understand that engineering does not happen in a vacuum: the need for engineered solutions arises because of problems situated within industry and communities. They will quickly come to know that a successful solution depends on stakeholder engagement, effective communication, and project management, and they will discover and practice multiple ways of achieving that success. By the time they finish their degree, they will have worked on over 26 real-world challenges, including examples such as flood-monitoring systems, wearable respiratory pollutant alarms and portable energy provisions.

At NMITE, the contextual nature of PBL also extends beyond the technical. Real-world partner engagement provides a pathway for exploration, awareness, and understanding of the economic, social, ethical, cultural, and political elements of engineering, for example the financial and ecological impact of a new transport route. In this way, these non-technical aspects become part of, rather than tangential to, engineering practice. The immediate and repeated exposure to and engagement with communities and industry enables students to gain and develop the professional skills and experience that often take years to develop in the workplace. This not only emphasizes the importance of effective communication and collaboration at every stage, but it also provides for a smooth transition from the world of school to the world of work and offers entry into professional networks long before graduation.

LEARNING COMMUNITY

The process of creating NMITE included significant stakeholder engagement with the aforementioned Design Cohort, industry, and community leaders. The Design Cohort product-tested and critically analysed and evaluated the effectiveness of PBL learning in a small community via seminars, tutorials and directed activities. They confirmed that an emphasis on teamwork, using contextualised challenges rooted in industry and community needs, mirrors a workplace setting. Furthermore, by including educators from areas outside engineering disciplines, NMITE's model enabled effective learning environments that encouraged individuality as well as fulfilling end-user, professional needs. The Design Cohort demonstrated that the learning community is a team on a shared journey: Educators act as guides and mentors; students are equipped with the tools they need to succeed but are given the independence to use them on their own. They provided each other with constructive input and feedback. They learned together. They overcame obstacles. They shared their achievements. They exemplified the essence of problem-based learning.

With the MEng programme design rooted in the ambition to broaden pathways into studying engineering, NMITE's admission processes also identify those students who combine academic ability with resiliency, curiosity and passion, the capacity to develop life-long learning skills, and those who value work-life experience. At the core of NMITE's curriculum design, culture and ethos is the intent to develop a high quality, safe-to-fail PBL environment which provides students with the understanding, knowledge and experiences that will ensure that they are work-ready upon graduation. Therefore, in addition to the traditional (or alternative) academic thresholds, NMITE includes a novel approach to recruitment that assesses individual and team potential and capabilities and offers the opportunity to demonstrate the same qualities that we need in professional engineers: curiosity, passion, resilience, creativity, and insight.

LEARNING DELIVERY

NMITE's sequential modules mainly fit into two categories: Toolboxes and Engineering Sprints. Toolboxes are 2 or 3 weeks long and introduce students to skills and concepts that they will use throughout the remainder of the programme and long into their professional careers. In contrast, Engineering Sprints are typically 3.5 weeks in duration, during which students encounter 26 real-world PBL challenges that they grapple with as teams in a studio environment. As with any engineering problem, each challenge will however automatically and inherently include several subject areas. So although a module may focus primarily on a single topic, in reality it will contain multiple cross-disciplinary elements in an integrated way emphasising the value of our PBL approach within a real-world context. The following subject areas are included within the NMITE MEng Programme:

Subject areas included in *Engineering Sprints*	**Subject areas included in *Toolboxes***
Engineering Materials and Processes	Rhetoric and Communication for Engineers
Electrical and Electronic Engineering	Engineering Design
Statics and Structures	Metrology
Programming	CAD Exploration and Drawing
Integrated Systems	Observant Engineering
Flow, Heat and Energy	Technical Project Management
Dynamics	Engineering in Art
Electromagnetics in Engineering	Design of Experiments and Statistical Analysis
Structural Materials and their Innovation	Creativity
Control Systems	Teams
Energy Systems	Communicating
Manufacturing Systems Optimisation	Engineering Business Strategies
Solid Mechanics	History of Engineering
Thermal Fluids	

Table 1. Subject areas within NMITE's Master's in Integrated Engineering.

As students progress through the degree, challenges become more demanding, needing an increasingly interdisciplinary approach that requires both engineering and broader expertise. Later challenges are built around the thematic areas of Infrastructure, Health, Security and Energy and the impact that future engineers will have on developing sustainable, appropriate, affordable solutions within these areas. PBL enables assessments that mimic the deliverables that engineers must produce in their careers, align with the challenge subject matter, and provide an appropriate vehicle for students to demonstrate comprehensive understanding (Jones et al., 2013).

Additionally, communication and mathematics knowledge is ubiquitous and embedded in the service of project completion rather than presented as topics taken alongside technical coursework. NMITE views both mathematics and communication as vital tools for engineers but does not believe a high level of mathematical or English knowledge should be a pre-requisite for starting an engineering degree. In line with its overall learning style, NMITE will support and scaffold mathematics and communication learning 'through doing' as part of the various modules that are offered. Learning and applying mathematics and communication in this deeply contextual way is both effective and engaging for most engineers and is analogous to the way these topics are experienced in the workplace (Schettino, 2016).

Thus, through PBL, students are doing more than creating technical solutions by solving equations and applying theoretical principles in the service of a product. They are learning to balance the desire to satisfy customer needs with the pressure to create a technically sound prototype. They are gaining experience in product testing, team management, and risk analysis. All this is achieved within a compressed timescale where they can be solely focused on one challenge, where they combine motivation and self-belief with resilience, and where the feedback they receive develops both competence and independence in learning how to learn.

The sequential and modular delivery of the MEng facilitates the accelerated and focused approach, as well as enables reinforcement and achievement of professional outcomes beyond technical expertise. Sequential learning allows students to build upon prior knowledge in a coherent and structured way, while modular learning enables dedicated, in-depth focus on particular topics and projects. This style of PBL delivery makes integrative learning more feasible, which facilitates knowledge transfer between disciplines.

CONCLUSION

NMITE was established to add value to a profession that is critically important globally, and to enrich the existing menu of options for students who want to study it, with the knowledge that "The ideal engineer is a composite . . . not a scientist, . . . not a mathematician, . . . not a sociologist or writer. But [she or] he has to use the knowledge and techniques of any or all of these disciplines in solving engineering problems."[4]

With a new and different approach to engineering education centred in best practices of PBL, NMITE dispenses with the one-size-fits-all model of learning and challenges the stereotypical and limited idea of what it means to be an engineer. In doing so, we both improve educational practice to the benefit of students and communities, and make a positive impact on companies, industries, and the challenges they exist to solve.

Based on the PBL results of educational experiments elsewhere, engagement with our Design Cohort, and extensive consultation with academics, engineers, industry representatives, and the community, this bold new programme will produce the graduates we need: engineers who are excellent communicators, instinctive collaborators, broadly trans-disciplinary in their approach to problems, and ready to craft creative and innovative solutions for their employers, their communities, and the world. Aptitude for this kind of engineering practice depends as much, if not more, on attitude as on accomplishment. Therefore, through NMITE's distinctive PBL educational model, we are determined to educate engineers who are willing to take the risks needed to be the creative problem-solvers society needs, and who are able to be innovative, entrepreneurial, and resilient in the face of as-yet unknown challenges. In examining and evaluating their own ideas as well as existing thinking, they will not just be able to know if and how they can do something, but also ask if and why they should.

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