The Exigence in Engineering Education

The New Model Institute for Technology and Engineering (NMITE)
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Primary Authors: Hitt, S.J. and Rogers, H.L.
Contributing Authors: Allan, D.; E., P. Ling; Guerrero, M.; Metcalfe, P.; Rogers, N.

$$Exigence(action) \equiv \sum_{i=1}^{\infty} need_i + action_i$$

$$\therefore NMITE$$

1.0 INTRODUCTION

"Any *exigence* is an imperfection marked by urgency; it is a defect, an obstacle, something waiting to be done, a thing which is other than it should be."
–Lloyd F. Bitzer, "The Rhetorical Situation"[1]

It may seem unusual to begin a preface to an engineering institution with a quote from the journal of *Philosophy and Rhetoric*. But NMITE is an unusual institution, born out of several exigencies, and nurtured by a community including scholars and activists from all disciplinary backgrounds.

The people involved in the creation of NMITE were moved to action by the belief that engineering education, both in the UK and globally, can and should increase its potential. From all over the world, in every kind of educational institution and industry, they had independently come to the same realization: that the current prevailing methods of educating engineers are not as effective as they could be, and that by working together to introduce a new model of engineering education, they could open up the profession to new and different kinds of thinkers and practitioners with the potential to achieve great things.

This is not simply change for change's sake: 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"[2] from climate change to clean water to resource scarcity, something is waiting to be done about engineering education, and NMITE is one answer to the problem.

NMITE's team is united by an educational philosophy of increasing the potential of human beings—experimenting, failing and responding, learning how to learn, working with people from a variety of backgrounds, reflecting on work done and yet to do—these behaviours, rather than memorizing equations and sitting exams, can inculcate the habits of mind that result in engineers who consider communication, collaboration, and context as essential rather than tangential parts of engineering practice.

The most effective engineers, the ones who will become leaders and drive positive change in society, will be the ones who exemplify much more than technical competency: they will be able to communicate with multiple audiences, be

[1] Bitzer, L., 1968, "The Rhetorical Situation." *Philosophy and Rhetoric* 1, p1-14.

[2] Xu, M. et al., 2010, "Gigaton Problems Need Gigaton Solutions." *Environ. Sci. Technol.*, *44*, (11), p4037-4041.

passionate about making positive change, responsive to legal and business needs, and creative in a world of limited resources. They will embody social responsibility and the joy of discovery. They will be NMITE graduates.

2.0 MASTER'S DEGREE IN INTEGRATED ENGINEERING

"We start with a blank: a world of possibility."
–Peter Turchi, *Maps of the Imagination*[3]

Revamping engineering education "requires commanding the whole problem, not just iterative efforts that barely strike a moving target."[4] 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. Therefore, a team of academic, industry, and community innovators worked for several years researching best practices in engineering education worldwide and developing a unique Master's in Integrated Engineering programme from the ground up, which will be implemented with a Pioneer Cohort of students in 2021. This paper describes a first version of the MEng curriculum as it has been designed, iterated on, and tested with a Design Cohort and Trial Learners over the course of many months. As part of a process of continuous improvement, NMITE will engage in ongoing refinement of this innovative proposal to transform engineering education.

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 as necessary to 21st century engineering work. These include incorporating creativity into engineering; broadening the diversity of students; strong emphasis on project work; industry engagement in design and delivery; experience of the workplace for students; and greater interdisciplinarity within and beyond engineering. 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 are deeply embedded within the programme philosophy and design. While 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, through multiple Community-Based Challenges, to the completion of independent Master's projects.

2.1 Learning Approach

"We are not students of some subject matter, but students of problems. And problems may cut right across the boundaries of any discipline."
–Karl Popper, *Conjectures and Refutations*[5]

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. This is why NMITE's MEng integrates conventionally separate strands of engineering and goes still further—integrating engineering with other disciplines such as arts, humanities and business. 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.

NMITE explicitly defines places within the curriculum where distinct professional behaviours and competencies are developed, and deliberately embeds increasingly complex learning types across the Framework for Higher Education

[3] Turchi, P, 2004, *Maps of the Imagination: The Writer as Cartographer.* San Antonio, TX: Trinity Univ. Press, p28.
[4] Xu, M. et al., 2010, "Gigaton Problems Need Gigaton Solutions." *Environ. Sci. Technol., 44,* (11), p4037.
[5] Popper, K.R., 1963, *Conjectures and Refutations: The Growth of Scientific Knowledge*. New York: Routledge.

Qualifications (FHEQ) levels. Ultimately, this educational model provides the basis for industry-ready engineering capability as well as the foundation for lifelong learning.

Thus, NMITE has maintained a strong focus on the engineering discipline, while further enhancing it by including the broad-ranging intellectual and personal discovery inherent in a traditional university experience.

2.2 Learning Community

"The heart of liberal education's enterprise is to link practice and theory, the workplace and campus, social theory and lived community, science and humanities, writing and doing. The link must be made by students, but without a venue in which such links are invited—and tested—they will frankly not be made by many."
–Bernice Braid, "Liberal Education and the Challenge of Integrative Learning"[6]

NMITE's learning approach depends upon a community of students and educators where these and other links can be made in the service of educating a new kind of engineer. In doing so, NMITE is raising the intellectual stakes: if society demands better and different engineering graduates, engineering students require better and different engineering educators. In turn, these graduates and educators create a cycle that increases diversity of intake, contributes to recruitment and retention of future engineers, and enables varied career paths.

The learning community is a team on a shared journey: Educators act as guides and mentors; learners are equipped with the tools they need to succeed but are given the independence to use them on their own. They provide each other constructive input and feedback. They learn together. They overcome obstacles. They share their achievements.

2.2.1 Students of the Learning Community

Learners embarking on NMITE's MEng will come from a variety of backgrounds and experiences, united more by their attitudes than their aptitudes. They have a drive to innovate and to solve problems. They possess the resilience and perseverance to flourish in a challenge-based environment. They are curious and socially aware. They may not have initially thought that engineering was a career for them, but they want to put their ingenuity, instinct for entrepreneurship, and excitement for discovery into practice.

With the MEng and its programme design predicated on broadening pathways into studying engineering, NMITE's admission processes will identify these students who combine academic ability with resiliency, curiosity and passion, the capacity to develop life-long learning skills, and who value work-life experience. NMITE is keen to inspire women to study engineering and seeks to establish a gender-balanced environment among both educators and learners.

Prospective learners following traditional academic routes will be required to have passed English, Mathematics and Science GCSEs as well as a minimum of three A-Levels, or equivalent assessment (such as an International Baccalaureate). A-Levels in Mathematics and Physics will not be a prerequisite, since these elements will be available (where appropriate and as required) to students as part of NMITE's interdisciplinary engineering curriculum. Using Accreditation of Prior Learning and Accreditation of Prior Experiential Learning approaches, applications will also be welcomed from a diverse range of students from non-traditional academic pathways who have already begun careers, including those who have engaged in apprenticeships or military service.

2.2.2 Educators of the Learning Community

Our core educators represent both diversity and interdisciplinarity, blurring the boundaries between different kinds of academic and industry expertise. While educators do have subject-area expertise, they are not defined or limited by it as they might be in most departments and

[6] Braid, B., 2000, "Liberal Education and the Challenge of Integrative Learning." *Journal of the National Collegiate Honors Council*, *57*.

universities, and instead are valued as members of a single multi-disciplinary team.

The kind of educators who work at NMITE are those who want to keep learning themselves, who are comfortable saying to the student, "I don't know the answer but let's discover together," and who respond and adapt to individual learning styles and needs.

2.2.3 Spaces of the Learning Community

This transformative educational experience is facilitated by carefully designed learning spaces. The studio environment allows learners to occupy one consistent space, where they can establish a pattern of work with their team. Educators can easily and naturally engage with each individual and team, migrating from group to group to provide assistance and advice where needed. A studio is therefore an environment where learners are encouraged to try and to fail as an enjoyable and expected part of the learning process. Studios enable the coaching function of educators, because a higher level of interpersonal engagement occurs when everyone is in the same room for extended periods of time. With increasing accessibility of mentorship comes a quicker development of a trust relationship between educators and learners.

2.3 Learning Style

"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."
–Xunzi, trans. H. Dubs, *The Merit of the Confucian*[7]

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, from the kind that you talk about in the pub--"why hasn't someone figured out how"--to the kind identified by the National Academy of Engineering as "Grand Challenges" facing humanity, to the UN Sustainable Development Goals. Therefore, educators and partners work collaboratively to develop challenges that respond to specific problems and alongside specific stakeholders.

From their very first encounter with these engineering challenges, NMITE students will be learning in real-world contexts. Thus, learners 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.

2.4 Learning Delivery

"Learning is not attained by chance. It must be sought for with ardour and attended to with diligence."
–Abigail Adams, Letter to John Quincy Adams[8]

Everyone remembers certain occasions when learning happens—when an insight becomes clear, when the mosaic of disparate facts coalesces into one coherent whole—those "ah-ha!" moments that mark new awareness and understanding. Learning is an accumulation of repeated tasks, reflection, and dialogue with others that is not limited to the classroom. Learning happens during the joy of play, the frustration of home repair, or in a casual conversation with a mentor.

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 wrestling with the tradeoffs of what they should include and what they can discard from a poster that describes all the work they've done as a team. They are gaining experience in product testing, team management, and risk analysis. All this is achieved within a compressed

[7] *The Works of Hsüntze: Book 8: The Merit of the Confucian*, 1977 Reprint, Translated from the Chinese by Homer H. Dubs., New York: AMS Press, p113.

[8] Adams, A., *Letter to John Quincy Adams*, 8 May 1780, National Archives of the United States "Founders Online."

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.

2.4.1 Accelerated and Focused

NMITE presents its MEng degree over three calendar years, during which students learn 8 hours a day. This schedule contrasts with conventional MEng delivery, which takes place over four academic years, each comprising thirty weeks of 40 hours of study. Either approach enables the completion of the 480 credits required by the UK Course Credit Accumulation and Transfer scheme (CATS), where a credit is taken to be the learning derived from 10 hours of study. NMITE is thus able to achieve these 4,800 hours of study effectively as well as efficiently. This accelerated approach brings a number of advantages. First, for the student, it means that they will enter employment after graduation one year early, and accommodation costs may therefore be reduced.

Secondly, educational momentum is maintained without extensive breaks, and the schedule mimics a professional workplace 9-5 timetable. Finally, this programme integrates students more consistently into their surrounding community and helps remove the often 'town vs gown' feel of city-based Universities.

2.4.2 Integrated Delivery

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 learners 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 learning delivery makes integrative learning more feasible, which facilitates knowledge transfer between disciplines.

At NMITE, the MEng learning outcomes are typically focused on one of the following areas:

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

2.5 Learning Assessment

“Were all instructors to realize that the quality of mental process, not the production of correct answers, is the measure of educative growth something hardly less than a revolution in teaching would be worked.”
–John Dewey, *Democracy and Education*[9]

NMITE’s curriculum has been intentionally designed as a process that builds logically, and is focussed on learning outcomes. Not only are assessment types repeated with added complexity throughout the learning journey, but they also mimic the deliverables that engineers must produce in their careers. Including specifications, posters, and prototypes, learners will produce over a dozen types of assessments during the

[9] Dewey, J., 1916, *Democracy and Education: An introduction to the philosophy of education*. New York: MacMillan.

MEng ranging from media outputs to industrial reports, from presentations to project plans. Crucially, each assessment type is repeated at least once during the programme, so that learners can iteratively improve on their work.

NMITE educators know that assessment is only as good as it is useful to students: it must be timely, accessible, understandable, and actionable. Therefore, formative and summative feedback for each student is provided for every module and is collated in order to provide individualized guidance and monitor student progress. Students have the opportunity to discuss assessment with educators and Personal Tutors so that feedback can be used effectively and productively, and acts as an input towards further development of the MEng.

3.0 CONCLUSION

"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."
–Nathan Dougherty, *Student, Teacher, and Engineer*[10]

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 Engineering. With a new and different approach to engineering education, 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 results of educational experiments elsewhere and extensive consultation with academics, engineers, industry representatives, and the community, this bold new approach 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 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.

NMITE graduates will soon leave their distinctive fingerprints on the work that they do in the world. NMITE alumni will be identified in industry and society as responsive and responsible individuals with a distinctive mindset: curious about everything, imaginative about possibilities, and determined to make a positive contribution.

[10] Dougherty, N.W., 1972, *Student, Teacher, and Engineer: Selected Speeches and Articles of Nathan W. Dougherty*, University of Tennessee Press, p33.

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