Advancing transdisciplinary architecture and engineering education: Defining the needs of a new multidisciplinary built environment design professional



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There is wide recognition in policy, practice and higher education that complex climate change challenges cannot be fully addressed without highly integrated multidisciplinary knowledge and ability. This is especially critical in the built environment. The purpose of this article is to discuss approaches through which educational and practice needs of a new multidisciplinary built environment professional are being considered. The article builds on a prior study by the authors involving a UK case study drawing on the developmental process involved in creating and running a novel highly integrated MEng course and begins to assess the outcomes of the first cohort that completed the programme. The insights help define the approaches that underpin development of a multidisciplinary course, evaluate the outcomes, and articulate the potential competency criteria needed for a new design professional. These criteria will aid future development of engineering professions and ways professional bodies accredit educational provision.

Keywords: Built environment, Design, Engineering, Higher Education, Multidisciplinary

Introduction

There is established recognition in international policy that multidisciplinary knowledge and competencies are critical in addressing growing complexity of climate change and carbon emissions challenges (Friedlingstein et al., 2022). The need for multidisciplinary approaches is particularly significant in the built environment context, a key contributor to carbon emissions globally (Friedlingstein et al., 2022). This recognition has led to an increasing understanding in education and practice that solutions may lie not only in more effective integration of built environment multidisciplinary teams but also in the educational development of a new kind of built environment professional (Butt & Dimitrijević, 2022; Nguyen & Mougenot, 2022).

In the higher education (HE) context, multidisciplinary approaches are seen as a classification of interdisciplinarity with interdisciplinarity seen as the 'integration of knowledge drawn from diverse disciplines to address problems that cannot be solved by one discipline' (Van den Beemt et al., 2020). Though there are emerging courses in the built environment that promote integration of different disciplinary domains such as architecture and structural engineering, architecture and building services engineering and more recently architecture, structural and building services engineering, there have been few accounts of their developmental approaches (Oliveira et al., 2022), and a paucity of published evaluations of the educational or career outcomes. It is widely recognised that identifying pathways to multidisciplinary education remain challenging. A recent review carried out by Van den Beemt et al. (2020) on approaches to interdisciplinary education in engineering suggests that developing both multi and interdisciplinary skills demand a different type of pedagogy and 'teaming experiences' that facilitate new ways of learning. Their review also argues for a greater understanding of resources needed as well as barriers to wider development of interdisciplinary education including awareness of the institutional challenges involved.

Research in architecture and engineering education has mostly approached the issue by analysing ways to achieving multidisciplinary curricula largely through either incorporating sustainability or enabling design-studio and/or project-based learning delivered by multiple disciplines (Oliveira et al., 2022). The purpose of this paper is to discuss the development and early implementation of educational and practice needs of a new multidisciplinary built environment professional drawing on authors' prior case study of a UK MEng Course (Oliveira et al., 2022). The discussion has benefits to both higher education providers and practitioners in helping articulate the potential competencies and needs of a future built environment professional, and the underpinning processes that may shape its delivery.

Methodological approach and case

This work builds on the empirical case study explained and discussed in the authors' recent paper (Oliveira et al., 2022). The methodological approach of this previous work involved narrative synthesis including reflection and dialogue of a prior empirical case study as well as thematic review of the literature (Lisy & Porritt, 2016). A review of the development processes for the UCL MEng Engineering and Architectural Design course, with the primary focus being on understanding how the multidisciplinary content and delivery mechanisms developed during the initial stages of the course development, was conducted. In addition to extensive documentary analysis, the case study also involved holding interviews with educators and industry advisors on the curriculum design process. The course was developed to provide a fully accredited pathway for chartered engineer status through JBM and CIBSE, with expanded attributes in architectural design. These requirements informed the initial criteria through which discussions developed amongst the curriculum design team. The curriculum design team involved expertise from multiple departments representing diverse disciplines including academics from The Bartlett School of Architecture, the UCL Institute for Environmental Design and Engineering and the Department of Civil, Environmental and Geomatic Engineering as well as leading industry experts.

The course development also included discussions of facility provision and the site for course delivery was a critical aspect of joining up disciplinary thinking and developing the multidisciplinary ethos of the course. The following section describes the empirical setting, the rationale for the course as viewed by its creators and the ways future graduates and their experiences were conceived.

The rationale for the course – a paradigm shift

The UCL team's contention in developing the course was rooted in their view that 'grand challenges facing society, and indeed the planet i.e., sustainability, well-being, changing climate, and intercultural interactions, all implicate the built environment'. The course was described to be aimed at creating a novel interdisciplinary workforce, and network, of creative professionals each with complimentary knowledge and skill in both engineering and architectural design, who are better equipped to exploit the opportunities afforded by new technologies and methods. The need for this programme was described by its creators to be also evidenced in the paradigm shift that is taking place in the way our built environment is designed, procured, constructed, and regulated.

The rationale for launching this new programme also related, according to the team developing it, to UCL's location in London and its unique proximity to many of the world's leading consultants operating in the forefront of the field such as, AKT II, Arup, Foster and Partners, Fielden & Clegg, Buro Happold, Price and Myers, and Laing O'Rourke. The programme is based at new facilities at Here East, Hackney Wick which house a sequence of multi-functional and adaptable large-scale spaces. These extend from 1) public/exhibition/foyer/studios, to 2) a large collaboration hub for demonstrations/assemblies/and gatherings of variable scale, through to 3) a large volume fabrication space for large scale manufacture and assembly, and 4) a large research hub for dedicated projects at an advanced level, including environmental chambers. The ensemble is promoted to provide a state of the art, world-class facility with unrivalled transparency and ease of engagement between the constituent parts of learning, research, and enterprise. Occupants are said to be provided with an entirely novel environment that is part gallery and archive, part auditorium and theatre, part studio and office, part laboratory and factory, and part social generator, all in one envelope.

Student experience and teaching delivery was described to be centred on a combination of the design studio model that underpins ARB/RIBA validated programmes with engineering problem-based learning excellence. This was viewed to be a unique mix, placing creativity and design at the centre of engineering education, to challenge conventional models, allowing students the opportunity to understand and develop advanced design methodologies whilst acquiring expertise on how they are augmented and resolved through engineering knowledge. The course development team also initially described how graduates needed to develop the confidence, knowledge, expertise, and creative propositional abilities to undertake the critical first steps of a project including brief development and design in a context of significant uncertainty, and to advocate their designs and engage in robust critical interdisciplinary discussion as they evolve. The course structure is graphically summarised in **Figure 1** and an outline of the core and elective modules is provided in **Table 1**. Rooted in discussions of developing key knowledge and ability were initial thoughts on key competencies needed.

Approaches to initial thinking on key competencies for multidisciplinary built environment design professionals

The course is intended to provide an environment where completing graduates will:

- Be prepared for a professional life in the integrated design of the built environment
- Have the educational competencies for corporate membership of a relevant professional institution such as the ICE, IStructE or CIBSE
- Practically apply fundamentals to real-world scenario to enable rich and divergent analysis and development
- Critically apply appropriate tools and processes to expeditiously deliver advanced and pertinent propositions
- Have the tools and confidence to bridge and unify previously disparate disciplines
- Develop a study, research and work principle that is both conceptually and practically interdisciplinary Be equipped with the necessary skills and expertise to discover and grow their own design and engineering vision within a diverse culture and fast-changing environment
- Have knowledge and skills to authoritatively challenge status-quo and develop new paradigms
- Lead in meeting the national and international demands for productive and environmentally effective built environments
- Have the acumen and knowledge to undertake further research and scholarly activity
- Be inspired, prepared and fully supported individuals with opportunity to fulfil their personal goals, their intellectual and creative potential

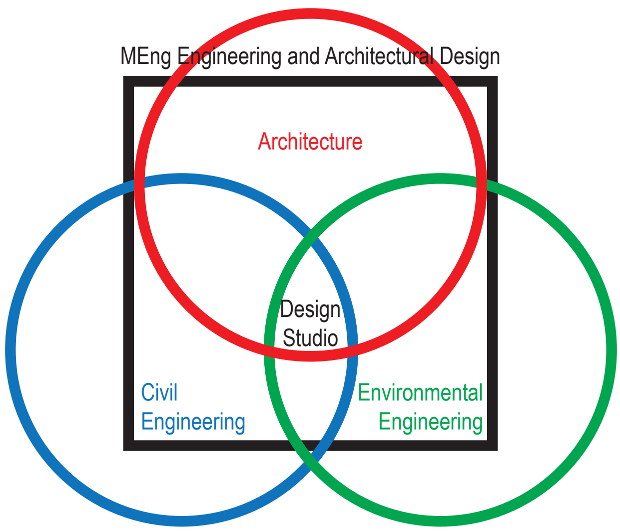

Figure 1. Course structure diagram. (Oliveira et al., 2022)

Integrated master's degrees (often denoted MEng) accredited for the purpose of CEng registration need to demonstrate an emphasis on developing solutions to problems using new or existing technologies, through innovation, creativity, and change. The integrated master's is promoted to go beyond the outcomes of accredited bachelors (honours) degrees to provide a greater range and depth of specialist knowledge, within an authentic environment, as well as a broader and more general academic base. As such the development team drew on the Accreditation of Higher Education Programmes (AHEP4) learning objectives, noting how they provide a sharper focus on inclusive design and innovation, and the coverage of areas such as sustainability and ethics. The coverage of equality, diversity and inclusion is also noted to be further strengthened to reflect the importance of these matters to society as a whole and within the engineering profession.

Courses like this, according to the team developing them, were seen to provide a foundation for leadership and innovative engineering practice. Graduates from an integrated master's degree such as this were intended to achieve interdisciplinary learning outcomes, possessing a broad and coherent body of knowledge including mathematics, natural science and engineering principles, and a proven ability to apply that knowledge to analyse and solve complex problems. Graduates need to be able to select and apply quantitative and computational analysis techniques in the absence of complete data, discussing the limitations of the methods employed. With an appreciation of professional engineering practice and ethics, graduates were also expected to be commercially aware and able to apply their knowledge and skills to design, deliver and evaluate innovative new products or services to meet defined needs using new or existing technologies.

Whilst the above section explained the ambition and initial thinking conveyed by the development team, the following section discusses key findings that emerged from the narrative synthesis of the development process itself, positioning the findings as discussed in Oliveira et al. (2022) within extant literature. Additionally, the section presents the findings from an initial review and analysis of the final classifications and job placement of the first cohort to complete the programme. The student outcomes are presented to begin to evaluate the strengths and weaknesses of the structure described in detail by Oliveira et al. (2022) and to inform the future refinement and development of the course, and of architecture and engineering education more broadly. In this way, evidence will be added to support one of the indicators of engineering education success as described in Graham (2018), that is, the 'value added' to the student. This work also aims to

Table 1. *Summary outline of the course structure.*

Year 1	Year 2	Year 3	Year 4
Core Module 1 History and Theory of Engineering & Architecture	**Core Module 8** Structural and Foundation Analysis and Design	**Core Module 13** Mechanics of Buildings	**Elective Module 1** (Range of options)
Core Module 2 Mathematical Modelling and Analysis I	**Core Module 9** Advanced Mathematical Modelling and Analysis	**Core Module 14** Sense, Sensing and Controls	**Elective Module 2** (Range of options)
Core Module 3 Building Physics and Energy	**Core Module 10** Urban Physics	**Core Module 15** Practice and Project Management	**Core Module 18** MEng Dissertation
Core Module 4 Building Physics and Environment	**Core Module 11** Environmentally Responsible Building Systems	**Core Module 16** Making Buildings	**Core Module 19** Design Practice 3: Vertical Design Units
Core Module 5 Materials Mechanics and Making	**Core Module 12** Design Practice I: Design Studio	**Core Module 17** Design Practice 2: Vertical Design Units	
Core Module 6 Design Make Information			
Core Module 7 Design Make Live			

help fill the gaps defined by Richter and Paretti (2009), notably a lack of measurable outcomes of interdisciplinary engineering education.

Findings

Narrative analysis

A key ingredient to developing multidisciplinary curricula was found to be ensuring that the team has a shared ethos and understanding, flexibility and agility in meeting both professional and personal expectations of the process, and critically obtaining institutional support. These findings are echoed in much of the literature on multidisciplinary education and practice. Power and Handley (2019) discuss three interrelated approaches for better integration of interdisciplinarity in HE including, maintaining clear communication, providing an adequate structure, and facilitating cultural change through shared values.

In the Oliveira et al. (2022) study these shared values were found by the participants to be not only of a professional character but also deeply personal. Some participants observed and discussed the importance of conveying a sense of a 'common desire' to achieve an 'integrated approach' that 'realised the importance of each team'. In addition to shared beliefs, most participants reflected upon a sense of having 'a blank sheet of paper' when developing the course content to ensure that all content created was bespoke and could fit the diverse professional body criteria. This 'ground-up' approach differs from ways many similar interdisciplinary integrated courses develop by fitting around shared modules and content. Professional expectations were also found to reflect many of the participants own professional experiences, working across disciplines with many discussing the importance of that experience to provide the skills to transcend disciplinary boundaries. Whilst many described the future graduate to be a new type of professional, a 'building designer' as well as a 'specialist generalist', many also discussed the potential other possibilities the course could offer to a developing industry need for greater collaboration and integration.

When personal expectations were discussed, these tended to convey the practicalities of developing shared values such as maintaining a positive focus and ensuring starting points and goals were well communicated. Some describe the inherent challenges of communicating across differing disciplinary expectations and the need for maintaining a shared vision and positive outcomes as critical to managing those differences. For many, their life experiences beyond the course shaped their understanding of their particular roles in the course development – seen by some as fulfilling the role of negotiators, others as visionaries. Whilst much of the detail was uncertain at the start of the discussions, there was a wider acceptance that the process was largely unknown and flexibility and agility to adapt to the process was observed by all as key. The need for flexibility and agility supports and extends work by Clevenger et al. (2017) on the importance of a shared programmatic and course level vision as well as providing opportunities for iteration and risk taking in facilitating multidisciplinary curricula.

Whilst being mindful of both professional and personal expectations was found by all to matter, the critical, and possibly most significant challenge, was obtaining institutional support. The institutional support and resource to ensure all content created and developed was bespoke to the needs of the course was found to be a critical component of the discussions' successful outcome. Insights also suggest that willingness to take risks by both the institution and the course developers is critical to the success of the course development process. Participants discussed the process of developing the course as being challenging as well as open and a venture into the unknown. Many participants stressed the importance of the course being a new type of discipline- neither engineering nor architecture. Institutional support as well as having the possibility of the course being delivered in a purpose-built facility driven by a design studio style teaching delivery were important factors in maintaining vision as well as overcoming cross departmental challenges. Many participants discussed the importance of 'maintaining ambitious vision' as an important aspect of the course development conversations. The need for institutional support is also reflected in other studies as a key condition to enabling multidisciplinary curricula to evolve (Richter & Paretti, 2009).

Review of the outcomes of the first cohort

According to UCL's Bartlett School of Architecture (BSA), there are 300 permanent members of staff at BSA and 1,600 undergraduate and postgraduate students, or an academic staff to student ratio of approximately 1:5. In comparison the academic staff to student ratio for UCL as an institution is approximately 1:10. The MEng Engineering and Architectural Design has about 30 primary teaching staff and 44 tutors for a maximum 'steady-state' student enrolment of 240 (60 per year for 4 years), or a staff to student ratio of just over 1:3, making this a staff-resource intensive programme.

Thirty students made up the first cohort, and as of May 2021 twenty-three had completed their dissertation. The average final dissertation mark was 71, the highest mark was 88 and the lowest mark was a 44; where marks above 70 are equivalent to an 'A', 60-69 a 'B', 50-59 a 'C', and marks below a 50 are fails. Results from eighteen students of this first cohort were reviewed, sixteen with a Master of Engineering and two with a Bachelor of Engineering. Of those who completed the MEng eight earned first class honours with final marks above 70; seven received second class honours (upper division) with marks above 60; and one earned a second class honours (lower division) with a mark above 50. In modules that are shared across programmes, the students enrolled in the MEng EAD programme were some of the highest performers. Reasons for this could, in part, be due to the type of students that were attracted to the nascent programme. Information gathered from initial interviews with staff suggest that the first cohort were largely self-motivated high achievers. It is unknown if the distribution of final classifications will remain skewed to as many distinctions as the programme matures.

Early reports from graduates and employers indicate high rates of employment with some students receiving offers of employment as early as the first term of their final year. Comments from employers suggest that the broad set of skills learned by graduates is very desirable. However, both students and employers expressed concerns about how, or where, they fit into a traditional practice. Approximately one quarter of the first two graduating quarter are working towards RIBA Part 1, another 25% report employment as 'graduate structural engineer', an additional quarter list their job as 'architectural engineer' or as part of a sustainability team, the remaining graduates report a wide variety of job types including, digital media, robotics, or further education (e.g., RIBA Part 2).

Further evaluation of the programme through extensive interviews with graduates, current employers, and staff is on-going.

Conclusion

It is well established that developing multi-, inter-, and transdisciplinary curricula is a complex endeavour and that it requires coordinated efforts by academics and industry from different university departments and different disciplines. However, it is less well known that coordination and communication of such efforts can also be shaped by professional and personal expectations as well as institutional contexts as discussed above. In addition, many of the academics involved in the course development discussed above had prior experiences of working or learning in multidisciplinary environments and this prior experience and knowledge enabled an open mindset and positive focus on shared outcomes.

Whilst the implications of this study are primarily in advancing engineering and architecture curricula, there are helpful insights that might benefit other curricula in other engineering disciplines. For instance, the importance placed on personal experiences and expectations. Most participants engaged in developing this course had some prior experience of multidisciplinary curricula, either as students or educators in past institutions. There may be further helpful benefit in developing STEM professional courses or seminars that could offer insight and experience of learning in a multidisciplinary environment, leading to a positively led curricular approach that merges and draws on different disciplines. Whilst the participants did not reflect on the role of the environment both on terms of equipment or space needs, it may have been helpful to further explore how the physical design of a very novel and bespoke space facilitated or enabled certain curricular understandings or discussions. Future studies could further explore how this novel environment may inform or enable particular types of activities and learning environment that otherwise may not have been possible. It is also recognised that this study is based on one course. Future studies could compare course development processes with regards to multidisciplinary content of two or more courses, perhaps across different sectors or between different countries. Future studies are also needed to analyse further the role different people and their activities, vision and expectations play in developing multidisciplinary content.

Transcending multiple disciplinary boundaries is becoming increasingly important for devising solutions to the world's most pressing issues, such as climate change and decarbonisation. Multidisciplinary education offers opportunities to help develop new competencies and attributes of future built environment professionals. There is emerging evidence, from the review of the interdisciplinary MEng programme in Engineering and Architectural Design at UCL, that both students and industry find the educational approach to be of great value. The insights from this paper offer helpful pathways to how curricula that ensure development of new competencies could be considered. ■

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