28TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
2 – 4 SEPTEMBER 2026, UNIVERSITY OF BRISTOL, UNITED KINGDOM

TEACHING ENGINEERING DESIGN RESEARCH SKILLS; AN AUTHENTIC APPROACH

Jeff BARRIE and Chris McMAHON
University of Bristol, United Kingdom

ABSTRACT
This paper discusses the introduction of a new module and innovative pedagogical approach in teaching Engineering Design-related research topics to final year undergraduate students. Students were taught through research seminars where there was a focus on engagement and debate. The cohort were given independence to hone their research topics and read literature. The students were asked to submit abstracts and anonymous paper submissions for peer review by scientific committee before they had to submit a final paper and assessed through conference presentations. While student feedback was positive, the paper acknowledges the variety of undergraduate perspectives on University-based research, expectations on individual interests, themes and topics as well as the appetite to pursue a post-graduate research career. The paper also provides some unique insights into cohort diversity and how the unit might be tailored or improved to sustain such diversity in the Engineering Design research field for the future.

Keywords: Research, innovation, authentic, conference, writing

1 INTRODUCTION
The field of Engineering Design research can be very broad and diverse, sitting at the "crossing point of two spectra from science to production and from art to politics" [1]. When considering Pahl et al's [2] simplified view of research communities, it does show how closely interlinked Design Research is with Engineering Science, Technology and Industrial Design. As of 2009, the scope of topics, specialist interest groups and methodology also proves to be varied, from Design Processes (experimental methods and modelling) to Human Behaviour in Design (observation and surveying). Fast forward 15 years, to a research era that now includes artificial intelligence (AI), data-driven design and sustainable design.
At University, undergraduate engineering and design students are surrounded by researchers and centres of excellence. The lecturer teaching 2nd year thermodynamics could be a world-leading professor in gas turbine research but is diligently trying to explain how to apply heat transfer principles to an engineering problem; akin to having a world rally car champion as a driving instructor. Equally, academics and practitioners in design bring authenticity and industrial experience respectively to problem-based learning (PBL) and studio-based project work.
Beyond tutorials and project supervision, the research-focussed aspect of an academic is part of a lecturer's role that students rarely see, but nonetheless "being taught by academics who are active researchers is seen as stimulating and associated with teaching being seen as authoritative and the curriculum up to date" (as long as the research does not take them away from teaching). [3]. In circumstances where undergraduates partake in a research project, they may get a better glimpse into their supervisors' disciplinary expertise. Students, particularly those in final year of an integrated masters, are treated almost like pseudo-PhD students. Their supervisors scrutinise their literature, methodology and analytical approach, and their final dissertations are assessed with a high degree of academic rigour. At this level of study, there is an expectation that students can scope projects and critically review academic literature. There are a range of approaches for facilitating this, from specialist modules to integrating resources and support in a final year design or engineering project (approaches include *active learning, PBL and cooperative learning*). This can prove to be challenging as '*research methods education is not an established field of research like, for example, math education, nursing education, science education, or statistics education'* and anecdotally students fail to see the relevance of research to their course, are anxious or nervous about the difficulty of the course, or simply uninterested or unmotivated. This prompts further research in learning outcomes and assessment, to help

students understand the *process* of doing research [4]
A typical learning outcome would be to 'search, appraise and synthesise literature'. For example, a literature review is a critical component of an engineering dissertation, as well as any conference or journal paper. A 2014 study by Maura Borrego et al [5] indicated that the number of systematic reviews from Scopus (between 1995-2012) for developing interdisciplinary subjects (in this case, engineering education) was relatively low. On a subject basis, engineering had approximately half the number of reviews compared to education, and a quarter compared to psychology. The study argued that not only would engineering students gain valuable experimental results but also draw from other disciplines when it comes to appraising the efficacy of design. Well established methods such as the PICO framework are discussed, as well as adaptation of PRISMA. Another well-cited study in 2018 [6] also provides a range of methodologies to conduct systematic literature reviews in a highly structured manner within the field of engineering research, but what strikes as typical of engineering design research is the broad range of quantitative and qualitative information in the field, as well as interdisciplinary within other associated fields, such as psychology. This often makes engineering design research more complex and somewhat distinct from traditional experiment-focussed literature.
Regarding structure, the life of a typical postgraduate research (PGR) or PhD student is not as neatly timetabled as a final year undergraduate. PGR students often work in research teams with others and have a strong relationship with their supervisor. Some PGR students may be expected to attend research seminars, or publish papers, present posters or attend workshops at conferences. Despite technically still being part of a post-graduate student community (or graduate school in the US), there is a balance of learning academic research skills, professional development and the discipline of scholarly thinking.
As such this paper explores the creation of a dedicated research-focussed module, which was offered as an elective to final year students on a design course, to provide a means of experimentation with different learning approaches and defined learning outcomes over a 2-year cycle. This unit was adapted from and compared with another research module which was mandatory for Mechanical Engineering students. The outcomes of the paper may prove useful in improving the following objectives to successfully integrate research methods teaching into final year engineering and design projects:

- Help students **understand the process** of academic research in an **authentic** manner
- Ensure **appropriate learning outcomes and assessments**
- Provide **relevance** to student's course and discipline
- Support anxious and nervous students who find **active learning difficult**
- Maintain **interest and motivation**

2 THE WORLD OF RESEARCH; PUBLISH OR PERISH

It is important to note that students undertaking this optional unit would have done so in an elective manner and would already have some invested interest compared to students who would have to a undertake a mandatory research project. The module also doubled down on Engineering Design research and associated specialist topics in this field to ensure disciplinary and course relevance. From the outset, students were asked to discuss their prior understanding of academic research and research specialisation within their own School of Engineering, which includes advanced research in aerospace composites as well as geotechnics, civil engineering structures, earthquake engineering and infrastructure (to the cohort's surprise there is no dedicated research group for engineering design within the University. Part of the introduction was to impart a broad understanding, as well as introduce advanced research tools (including reference management, and institutional access to research literature). Students were also introduced to the differences between conference and journal papers, as well as their proceedings.
Following this, students were introduced to Engineering Design research, helping them understand the diversity of topics, as well as appropriate research methodology. This is where the diversity of engineering design research was acknowledged, and as students explored areas of interest, they gained a good understanding of appropriate methodology. They also gained an insight into engineering education research, research specialisation within the school as well as research which is conducted in collaboration with industry (for example, Autodesk) as part of the unit delivery. A PhD showcase was also conducted where current PGR students can discuss their research, as well as build some rapport with the cohort on why they chose a research career.
The scope of research, even in a single field, can be somewhat overwhelming for an undergraduate student on a time constrained module. To help ensure a manageable approach to literature reviews and methodology, a research 'theme' was introduced (much in the same way in conference proceedings). In

the first year of delivering of the module, students were asked to explore the impact of Artificial Intelligence in the Engineering Design field. For the cohort in the following year, the theme was a little more nuanced towards AI use in human-centred product-service design. By introducing a theme and disciplinary area, this ultimately provided a more systematic and manageable approach to relevant research topics and appropriate methodologies. For example, students interested in Design Organisation and Management were referred to literature studies, as indicated by the number of relevant papers in that specialist interest area.

With a relatively small cohort, students were treated like they were part of a research group and given a lot of freedom and autonomy. The module schedule and contact hours were skewed to allow as much time for self-study and writing as possible, with only a 2hr class scheduled in the week followed by a 1hr drop in (which students could use for 1:1 supervisory meetings or group discussions)

The chaos of academia dictates a 'publish or perish' attitude, and undergraduate students were not spared from joining the madness. To 'publish' a conference paper, students were asked to submit abstracts, followed by a full anonymised paper which undergoes a rigorous academic peer review. After edits, tweaks and re-writes, the students submitted a final paper which was followed by a conference presentation (which included a keynote speaker, poster sessions and sandwiches of a questionable quality). The comments provided in each submission provided ample formative feedback for students to develop and hone their research paper before undertaking the final revision (be it minor or major). Students also had to follow an established template and format and ensure paper numbers were assigned.

3 AUTHENTIC LEARNING OUTCOMES & ASSESSMENTS

With a dedicated research module, the learning outcomes and assessments could be directly tied to understanding the process of research and prepping undergraduate students for a potential career in academic or industrial research. Key learning outcomes included investigating state-of-the-art research developments, appraising resources and using appropriate tools for conducting research as well as discussing research findings in a peer-reviewed conference paper, written to a professional, academic standard, which made up the bulk of the module marks. A critical learning outcome associated with the conference presentation was to present findings and research impact in a clear, accessible and coherent manner, with the ability to answer questions and take comments. As such, the Q&A aspect of the presentation was weighted significantly higher than any assessment criteria related to presentation quality or delivery. As academic conferences include presentations, posters and workshops, students were given the option to either present an oral presentation or poster as part of their summative assessment. This approach provided an alternative to students who, for various reasons, may find oral presentations difficult, and was aligned to the University's Assessment and Feedback Strategy that strived to assess students learning in different ways, and offer alternatives for assessments that some students may find difficult. Instead of speaking in front of an audience, poster presentations were conducted in a more open, in-formal manner. The trick was to run the presentation assessments like a pseudo conference, such that it did not feel like an academic assessment at all. Students were encouraged to invite friends for moral support and feel more like an inclusive community of networking academics rather than students being marked (this was deemed significantly less triggering than a mock PhD viva/defence). The pseudo conference format offered ample breaks, the allure of a free (albeit disappointing and fashionably late) lunch and 'fun' workshop and networking activities. At the close of the 'conference' academics and the student cohort voted on who should receive the accolade of 'best paper', 'best presentation' and 'best poster'.

To ensure authenticity, students were asked to submit their conference paper in a rigid format (such that proceedings were consistent) and were scored using criteria directly mapped from those used by a scientific review board, which included thematic relevance, significance of theory and practice as well as innovation and originality. The student cohort were surprised to learn that a significant proportion of the marks (almost 50%) was attributed to the 'overall recommendation of the academic reviewer' and remarked that the fate of their paper being accepted for publication or rejected was determined by two (or three) independent academic viewpoints that they have no influence or control over.

4 SEMINARS VS LECTURES VS LECTORIALS

Another important consideration about life in academia is that PhD students do not go to lectures but may be expected to attend research seminars. A seminar is distinct from a lecture in that it is designed for a smaller audience (typically lectures could be 200 students, but seminars work well with smaller

cohorts of 30-40 students). As such, when compared directly, seminars are deemed better designed to stimulate interest, prepare entry level students in their learning and offer somewhat higher value to lectures; especially when it comes to professional knowledge or practice [7]. For specialised engineering topics, a seminar provides a degree of efficiency as it adequately supports pre-learning and consistency of engagement (students need to come to the seminar prepared) [8]. Moreover, a seminar provides a more intimate intellectual experience with academic staff and exposure to engineering thought, especially when an academic can use the session to talk about what they like [9].

The delivery approach for the research module was also inspired by lectorial formats used at NTU and other institutions, which provide a high level of intellectual engagement as seminars but can be adaptable to larger cohorts (100+) [10]. Students were asked to do some prior research and read a relevant paper or two prior to attending the session. As such, they were asked to be a participant in their learning rather than an observer and actively encouraged to ask questions during the session, especially if they did not understand something or needed clarification. Speakers were also given freedom to include questions or any forms of discussion during the session without being strictly timed, which allowed academics to expand on their points if required. As such, the 1hr lecture slot (in reality-45min once latecomers arrive and the room is used for another class) was deemed to constraining and seminars lasted up to 2hrs. Rarely, was this timeslot was used to full capacity but it did offer an opportunity for slower pace of delivery, 1:1 interactions, breaks and off-topic conversations, which would be otherwise difficult to achieve in a single lecture.

5 LEARNING TO READ PAPERS; & WRITE PAPERS (& DO ARITHMETIC)

University library services provide an abundance of services to undergraduate engineering students that they rarely seem to take advantage of. This includes direct access to research literature as well as standards, workshops for reference management software, patent searches, LaTeX and more. Many University libraries have pivoted to providing e-books for teaching, as opposed to having multiple print copies, for the large-scale demand of engineering students. Students on the design course are given a literature review exercise to conduct as part of their design methods model (critiquing papers in design thinking, rapid prototyping and inclusive design). This exercise proves to be a continual challenge for students, not only due to the loose essay-based format (which is widely different from technical and lab reporting students are used to), but also the amount of reading, resource management and synthesis of information it requires.

Many conference and journal papers are available in pdf format, which is ideal for downloading or printing in proceedings, but are not particularly engaging to read on a laptop or PC, let alone a smartphone (although some students do try). In the modules goal to give students more time to research, read and critique academic literature, a case-control study was conducted which allowed students to borrow a tablet device, on the basis that they would use the device primarily for reading literature and making notes. It was made clear to students that the use of a tablet did not provide an advantage to achieving learning outcomes (as all literature was available in multiple formats-and some students had their own personal devices). The study was to observe how students used the devices and gain some valuable insight into how they interact with unit content in this format. From a qualitative perspective, students remarked that the tablets allowed them to read papers on public transport, and away from their desk (they also acknowledged that they often read books for pleasure but have rarely handled a physical book or publication used for their studies). Comparative or quantitative studies on tablet use for reading in a higher education setting are somewhat limited, but literature around the use of these devices for improved reading and comprehension in school environments is extensive, since the introduction of these devices in 2010 [10]. Studies have indicated that access to tablet devices can assist struggling readers, such as those with Attention Deficit Hyperactivity Disorder (ADHD) [11]. Tablet technologies have been acknowledged as an effective means for improving reading rates, as well as providing accessibility to low-vision readers [12]. The current University Library Services provision is limited to short-term laptops and reading aids for students with disabilities, but other institutions, such as Imperial, can provide tablet devices on long term loan for any student on request. Further research is required in this area, given the studies were limited, but it opens a pedagogical research question that asks if students disinterest and poor engagement with academic literature could be linked to reading issues experienced in primary and secondary education, or English being a second language (after all, Engineering courses only ask for qualifications in Mathematics and Science as entry requirements). An engineering or design student with reading difficulties (visual impairment, or ADHD for example) would be able to navigate

course content, online resources and use appropriate, assistive tools in writing a research paper using a word processer and other software; but to read and synthesise information from a document, report or paper, may prove more difficult. This also demonstrates a viable threat from Artificial Intelligence, with tools becoming more advanced in the critique, summarisation and translation of text, bypassing the synthesisation and critical thinking process. Tablet technology may help provide an inclusive and accessible means for students to access literature within a research-based module (and beyond), and coupled with adequate time and freedom to read, may help counter some of the difficulties diverse ranges of engineering students face in engaging with a research module (through no fault of their own). A significant amount of further research is required in this area (a separate study along with appropriate methodology) but seems like a relatively simple intervention to promote equity when accessing academic literature in a Higher Education context.

6 DISCUSSION/CONCLUSION

Over two academic cycles, the experimental research module has been withdrawn, and reflections and learning can potentially be integrated into other modules, programmes and academic practice. Comparing the outcomes of the design students research module, at time of writing, with that of Mechanical Engineering students, it can be noted that students that had chosen a research pathway tended to be more motivated and engaged. Mechanical Engineering students on their research unit were given a broad range of advanced topics (ranging from Biomechanics to Automotive Engineering) and were randomly allocated a topic for their assessment. While learning outcomes were closely matched, the assessments were different. The design module opted for an authentic conference paper submission followed by a presentation element, whereas the Mechanical Engineering module asked for a single piece of coursework in a technical report format. While the design module leaned on Engineering Design research and guided students in terms of topic and appropriate methodology, the Mechanical Engineering module offered dedicated topics with in-depth analytical approaches. The Mechanical Engineering students had a busy timetable, whereas the design students had significantly more self-study time, and less in-contact hours. While it is hard to quantitively compare both modules and their approaches, the difference in scale is significant (with over 200+ students in the Mechanical Engineering module, and between 3-6 in the design module). In both programmes, these modules were coupled with a capstone group project activity.

In terms of meeting objectives, the following insights are as follows:

- Helping students **understand the process** of academic research in an **authentic** manner

Consider treating the undergraduates like PhD students, acting as supervisors and facilitators to their research topic. This should be a 1:1 relationship, or a small group. Their goal is to create publishable, meaningful research in their disciplinary field.

- Ensure **appropriate learning outcomes and assessments**

Focus on the skills required for appraisal of resources, synthesis of information, writing in an academic format for publication and providing sufficient means for formative feedback (abstract and peer review of paper), a presentation style assessment or viva is also recommended.

- Provide **relevance** to student's course and discipline

Play to the institutions research areas and centres of excellence, as well as individual academics and their research specialisation. Invite students into research areas or labs they are not normally permitted to enter and interact with PGR students to spark interest in a potential research career.

- Support anxious and nervous students who find **active learning difficult**

1:1 support and feedback are important for guidance, create an inclusive learning environment and give students the appropriate tools and time to succeed. Provide alternative means of assessment for students who find presentations or oral speaking difficult.

- Maintain **interest and motivation**

For small cohorts, consider a seminar format (allow academics freedom to talk about what they want) and for larger cohorts, a lectorial format may suffice. Allow freedom and time to ask questions and debate; avoid lectures.

Furthermore, it is important to ensure that students have the right tools for success, from access to library resources and reference management software, as well as IT equipment. The merits of using tablet devices to facilitate accessibility to reading will be further explored.

Further work will be conducted in how these insights could be integrated into final year research projects or other research-focussed modules. There is also a wide range of publications around the appetite,

retention and diversity of the post-graduate research community within engineering and design, which warrants further investigation. This includes studies around gender equality, ethnicity and mental health, which may offer valuable insights and comparisons between

REFERENCES

[1] McMahon C. A. Reflections on diversity in design research. *Journal of Engineering Design*, 23:8, 563-576, DOI: 10.1080/09544828 (2012).

[2] Pahl G. and Bietz W. et al. Engineering Design - A Systematic Approach. 3rd Edition 2007 (Springer).

[3] Dandridge N. The relationship between teaching and research in UK universities - what is it and does it matter? *HEPI Report* 162 (2002).

[4] Earley M. A. A synthesis of the literature on research methods education. *Teaching in Higher Education,* 19:3, 242-253, DOI: 10.1080/13562517.2013.860105 (2014).

[5] Borrego M. et al. Systematic Literature Reviews in Engineering Education and Other Developing Interdisciplinary Fields. *Journal of Engineering Education*. Volume 103, Issue 1 pp. 45–76 ASEE (2014).

[6] Torres-Carrion P. et al. Methodology for Systematic Literature Review applied to Engineering and Education. 10.1109/EDUCON.2018.8363388. IEEE (2018).

[7] Vigeant M. A. S. et al. Evaluating the Seminar Model for First-Year Engineering Education. *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition*. Copyright © 2007, American Society for Engineering Education.

[8] Overholser K. A. Engineering Freshman Seminars. *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*. Copyright © 2001, American Society for Engineering Education.

[9] Thalluri J. and Penman J. Innovative Teaching and Learning Project: "We just don't sit there—we participate, interact and learn, and we rarely get bored": That is a lectorial. *Focus on Health Professional Education: a multi-professional journal*. Vol. 19, no. 2, (2018).

[10] Simpson A. The digital reading path: researching modes and multidirectionality with iPads. *Literacy (UKLA)*. Volume 47 Number 3 November (2013) 123.

[11] McClanahan B. et al. A Breakthrough for Josh: How Use of an iPad Facilitated Reading Improvement. *TechTrends.* May/June 2012 Volume 56, Number 3.

[12] Morris E. et al. Assessment of the Apple iPad as a low-vision reading aid Eye. 31 865-871 (2017).