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ENHANCING THE TEACHING OF RESEARCH METHODS IN ENGINEERING: CHALLENGES AND SOLUTIONS

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ABSTRACT
Engineering education primarily provides students with the ability to apply scientific and mathematic principles to technical problems, whilst research methodology refers to the process of applying systematic procedures and techniques to resolve research questions. A lack of scientific training, in research methodology, and an inexperience with human data can be detrimental for engineering students when addressing real world challenges. Therefore, the motivation of this paper was to explore innovative teaching methods, to enhance the education of engineering students on a newly developed, postgraduate research methods module. Said module had a view to expanding student understanding and knowledge through planning and conducting qualitative and quantitative research. This paper explores the differences seen between two cohorts of research methods students, delivered within the first term of study across three MSc Engineering courses. Qualitative findings associated with student feedback are presented considering the unique teaching and assessment challenges of delivery to a predominantly international cohort of postgraduate students. Innovative pedagogic approaches were considered based upon student satisfaction feedback, assessment results and the occurrence of academic irregularities. This study aims to share the module design, the approaches used in teaching, a summary of lessons learned from the two cohorts and suggestions for further enhancement of the module.

Keywords: Engineering education, research methods, quantitative method, qualitative method, international students

1 INTRODUCTION
The importance of acquiring knowledge and practical experiences in personal growth and development has been widely recognised. With the right knowledge and skills, individuals have the power to unlock their full potential [3]. Engineering education is an excellent example, as it integrates theoretical principles with practical applications, placing a strong emphasis on developing analytical thinking skills [5]. Furthermore, engineering graduates play a vital role in driving economic growth by creating innovative products and processes, thereby contributing to the success and competitiveness of society as a whole [11].

Due to globalisation and profound changes in the world, engineering education has been faced with new challenges in recent decades. Evidence suggests that engineering graduates often encounter challenges in securing employment due to their deficiencies in problem-solving and decision-making [9]. In addition, there is a growing emphasis and requirement for engineering students to improve their research skills [1, 7]. One of the key components of an engineering education is the teaching of research methods, which enables students to develop critical thinking, problem-solving, and data analysis skills. These skills are essential for engineers to be able to tackle the complex challenges facing society, including climate change, energy security, and sustainable development and the continued development of medical advancements.

Research methodologies refer to a logical and systematic approach to resolve a research problem, using various techniques to collect and analyse data [8]. Previous research has highlighted the lack of scientific training and limited explicit discussion on the issue of research methodology for engineering students [7, 2]. Despite its importance, the teaching of research methods in engineering is faced with several challenges that can limit its effectiveness [10]. Many of engineering students have difficulties

understanding and implementing research methodologies in their field as well as being unfamiliar with the process and procedures associated with collecting and analysing human data. Engineering students are often highly motivated and eager to learn, but they may not be interested in research methods, which can be seen as abstract and unconnected to their practical interests. In addition, students may not have a clear understanding of the purpose of research methods and how they can be applied in real-world engineering problems. It is often hard for engineering students to make a judgment on how to conduct an experimental study, what method to use to collect data and how to interpret the findings. Therefore, it would be beneficial to make the process of research methodology more explicit in engineering education as it improves students' analytical and problem-solving skills and boost their career opportunities.

The current paper examines the creation of a new research methods module, aimed at postgraduate engineering students studying Medical Engineering, Sustainability Engineering: Energy, and Transport Systems. These MSc courses were first offered in September 2021, with each course offering two entry points either September which represents a standard 12-month MSc or January representing a 15-month course and both entry points are offered with a placement option to extend the course length to 24 months. The research methods module is delivered in the first term of study to both cohorts, alongside the capstone project it is the only module that is repeated specifically for each entry point. The module is repeated so that each cohort benefits from undertaking the module in their first term providing them with a comprehensive overview of the research process, an important introduction to aspects such as plagiarism [12] and setting out research skills, that are required in later modules such as the capstone individual industrial or research project for which research methods is a pre-requisite. The paper focuses on the innovative teaching methods used to instruct MSc postgraduate students and the changes made to accommodate the different styles of learning among the individual cultures [13] represented, as 95% of students were international, with English as an additional language (Table 1). A number of changes were made to this module, without changing the overall structure, the learning outcomes or the underpinning assessment methodologies. These module changes are examined through the experiences of the teaching staff, the student satisfaction derived from module feedback, the number of academic irregularities and the academic performance of students. The authors of the paper also discuss the challenges faced during the development process and the strategies used to overcome these challenges.

Table 1. Nationality of Students as % of Cohort (2022)

	Algeria	Egypt	India	Iran	Nepal	Nigeria	Pakistan	Sweden	Sri Lanka	United Kingdom
January	---	---	65.9	4.5	2.3	11.4	2.3	---	9.1	4.5
September	1.9	1.9	51.9	7.4	---	13	5.6	1.9	13	3.7

2 METHODOLOGIES

The present study delves into the student satisfaction survey data collected from 58 postgraduate engineering students, across two separate cohorts (January 2022 and September 2022), who offered their feedback on the research methods module. The survey was completely anonymous meaning participants could not be identified and that the teaching team could not influence the responses from the students in question. All data were analysed and were organised into two distinct categories: quantitative findings and qualitative findings. Incidences of academic irregularity were compared as were the grades for each of the assessment elements and the overall pass-fail rate of the module. The structure of the module consisted of ten weeks of teaching (Table 2). The first five weeks consisted of a one-hour lecture, a one-hour seminar and a two-hour practical computer lab, to prepare the students for the practical statistics assessment in week six of the term. The sessions were all designed with active learning components embedded based on evidence that this approach is advantageous to STEM students from diverse backgrounds, facilitating reduced failure rates and increased grade rates [4]. The first assessment was a practical statistics assessment using IBM SPSS statistics package to answer a research question posed in a scenario with an accompanying data set. All students were asked to complete the assessment at the

same time under exam conditions in a computer lab. The assessment was, however, open book, meaning access to notes, internet-based guides and academic texts were allowed but all communication was forbidden. This approach was an attempt to make the assessment a part of the learning experience and not simply a way of identifying what information had been retained by the learner but a more holistic approach that more accurately represents a real-world scenario, whilst ensuring that each students own knowledge and ability is assessed [6].

The following three weeks focused on ethics and qualitative research methodologies using the same lecture, workshop, and practical session format. The second assessment was a presentation with delivery from the students focusing on the use of qualitative research methods to answer a subject specific research question, provided as part of scenario where the students would be pitching the research plan to a board of directors. The final week was a summing up week, ensuring the students understood how the materials covered linked to the rest of their studies and their major project. During the period between delivery of the module to the two cohorts some changes to the module structure were made to try and tackle some of the issues that became apparent. These alterations are discussed in the results section with respect to relevant outcomes.

Table 2. Research Methods module schedule (2023)

Week	Session	Topic
1	Lecture	Introduction
	Seminar	Literature searching, reference management software and plagiarism
2	Lecture	Aims, objectives and hypotheses & defining variables & research methodology
	Seminar	Academic writing
	Lab	Descriptive statistics
3	Lecture	Quantitative data analysis / inferential statistics
	Seminar	Types of data
	Lab	SPSS - T-tests
4	Lecture	ANOVA and non-parametric equivalents
	Seminar	Sampling
	Lab	SPSS - ANOVA
5	Lecture	Correlations
	Seminar	Effect sizes
	Lab	SPSS - Correlations
6	Practical Assessment	SPSS - Stats assessment
7	Lecture	Qualitative research methods and data collection (Interviews)
	Seminar	Reliability, repeatability, reproducibility, and agreement
	Lab	Peer interviews
8	Lecture	Qualitative Research and data analysis (Focus Groups)
	Seminar	Data analysis (Interviews)
	Lab	Focus groups participation [14]
9	Lecture	Ethics
	Seminar	Presentation preparation
10	Presentations	Assessment
11	Lecture	Discussion and conclusion writing
	Seminar	Academic writing

3 RESULTS

3.1 Quantitative findings

The quantitative findings were categorised into four main aspects from the module survey: feedback on module teaching, feedback on assessment and marking, feedback on module organisation/resources and overall satisfaction.

Data for feedback on module teaching for both cohorts showed that 80% of students were satisfied with the teaching quality on the module. Although 73% of students in the first cohort sated that the module was challenging them to achieve their best work, this number increased to nearly 86% for the second

cohort. In addition, 78.6 % of students in the second cohort compared to 76.7% in the first cohort stated that the module was intellectually stimulating.
In terms of feedback on assessment and marking more than 96% of students in both cohorts indicated that the criteria used in marking for this module were clear in advance of the assessment. In the first cohort 73% of the students stated that they have received helpful comments on formative or practice tasks they had undertaken within this module. In the second cohort however, this number increased noticeably to 92.9% even though the number of tasks where feedback was supplied to the students was the same. Several reasons for this could be linked to the language used related to session names and the materials provided via the virtual learning environment. Between the running of the two cohorts, language support to ensure clarity of instructions was obtained from the University Languages department. Firstly, the language used in materials (especially assessment based) were simplified and secondly, some support sessions were renamed as coursework drop-in sessions from workshops/seminars.
In terms of feedback on module organisation and resources, similar results were found for both cohorts. 90% of students in both cohorts mentioned that they were happy with module information, module organisation, and ability to contact teaching staff when needed. In addition, more than 90% of the students in both cohorts, stated that the module (including the online resources had provided them with opportunities to engage with other students. Finally, the overall module satisfaction data demonstrated that 90% of students across both cohorts were satisfied with research methods module.

3.2 Academic performance

The data presented in Table 3 shows the academic performance of each cohort based on the spread of the combined grades for both assessment elements and the number of academic irregularities identified per cohort across both assessments. As previously stated, changes were made to the module (that maintained the structure and requirements of the module specification) to try and improve the academic outcomes without negatively impacting on the experience of the students or reducing the challenges presented. The use of language specialist support has already been discussed but other changes included a random allocation of research questions and associated data sets for the practical assessment, using custom assessment tools within the University's online learning environment and a question pool. This coupled with a more in-depth explanation of the concept of exam conditions in the lab sessions leading up to the assessment appeared to reduce the number of academic irregularities associated with the assessment (Table 3).

Table 3. Academic outcome for each cohort based on grade boundary information and number of academic irregularities, presented as a percentage of the total number of students per cohort

	Cohort A (% of students)			Cohort B (% of students)		
	Practical Assessment	Presentation Assessment	Total module grade	Practical Assessment	Presentation Assessment	Total module grade
Fail	49	42	49	31	13	24
Pass	27	33	36	29	44	41
Commendation	22	22	13	22	35	31
Distinction	2	2	2	18	9	4
Academic Irregularity	7	9	16	0	0	0

The other significant change to the module structure was a change to the presentation assessment. Cohort A were asked to produce a seven minute video presentation, using PowerPoint slides and closed captions, for inclusivity. Although there appeared to be genuine enthusiasm for this project, considering the language challenges for a large proportion of the student cohort, a seven-minute monologue appeared to be a step too far and students seemed to struggle to complete the presentation within the time allotted, even though their understanding was evident from the slides produced, which were typically of high quality. Consequently, cohort B were tasked with generating a three-minute presentation with only three slides (a variation on the 3-minute thesis competition concept). Although a much shorter time period,

the students were tasked with covering the same content and providing enough depth of information to sell their project idea. This shorter (and very strict) time allowance focused the students and allowed them to practice and hone their presentations, improving their experience, and the academic achievement without reducing the level of assessment. It encouraged their ability to present information concisely and accurately in order to fit within the three-minute presentation window. Furthermore, the use of the shorter presentation time and multiple markers (including rotating second markers) meant that the presentations could be delivered live, offering students another engagement opportunity and an enjoyable event for all to attend. As can be seen in Table 1, not only did the pass rate for the module improve from 51% to 76% but the number of students achieving better grades also increased with overall commendations rising from 13% to 31% and distinctions rising from 2% to 4%. These findings suggest that the students' academic performance and understanding notably improved increased in the second cohort due to changes to the module structure.

3.3 Qualitative findings

The qualitative findings were categorised into two main sections; 1. feedback on the teaching aspects that students found valuable 2. feedback on the teaching aspects that can be improved.

In terms of the feedback on valuable teaching aspects, the results showed that while students in both cohorts found the research methods module challenging, they stated that it was very interesting and helpful.

For instance, a student said;

"*Overall, this module has been very useful for me to learn new things that I did not know before. The teachers have been very helpful and cooperative."*

In addition, students in both cohorts stated that the way module was taught was very clear, interactive and that teachers were always supportive. For instance;

"The teaching was always clear, and explanations were always provided which benefited me as it was easy to quickly get to grips with the different things we were learning."

In terms of further improvements for teaching aspects of the module, most students in both cohorts stated that there was a need to present more examples, provide more video demonstrations and home activities for further learning. For instance, a student mentioned;

"For presentations, it would have been helpful to have a sample or example presentation highlighting the best way to create and present a study".

Another student stated;

"In the quantitative lab assessments, it would have been better to have separate/more questions to practice on. It would have been helpful to understand the different application for each method".

The final change made to the module related to the final week of teaching that occurred after the final assessment had been completed. Instead of using the week to sum up the materials covered and seek to link this to the remainder of the students' studies such as the individual industrial or research (capstone) project in a broad sense. A new session was designed to cover the materials that should be considered in a discussion and conclusion section of a study. This session not only acted as a clear and obvious end to the module but provided students with an opportunity to consider the dissemination of results from any work they were to carry out within their studies and beyond.

4 CONCLUSIONS

This study identified benefits associated with a combined focus on the use of assessment methods that are incorporated within the learning experience rather than simply as tests of knowledge retention. Improvements were identified and made alongside careful consideration of language and assessment instruction for international students with targeted sessions to prepare students for these experiences. This not only improved grade rates but maintained student satisfaction and reduced incidences of academic irregularities. Furthermore, the module provides students with skills and tools that can be used within their work in other modules and highlights how these tools can be used beyond their immediate environment to encourage engagement and satisfaction.

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