



International Journal of Mathematical Education in Science and Technology

ISSN: 0020-739X (Print) 1464-5211 (Online) Journal homepage: www.tandfonline.com/journals/tmes20

Contextual questions and their implications for engineering undergraduates' attitudes towards mathematics

Lydia J. Buckingham

To cite this article: Lydia J. Buckingham (09 Nov 2025): Contextual questions and their implications for engineering undergraduates' attitudes towards mathematics, International Journal of Mathematical Education in Science and Technology, DOI: [10.1080/0020739X.2025.2574949](https://doi.org/10.1080/0020739X.2025.2574949)

To link to this article: <https://doi.org/10.1080/0020739X.2025.2574949>



© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



[View supplementary material](#)



Published online: 09 Nov 2025.



[Submit your article to this journal](#)



[View related articles](#)



[View Crossmark data](#)

Contextual questions and their implications for engineering undergraduates' attitudes towards mathematics

Lydia J. Buckingham 

Department of Mathematics Education, Loughborough University, Loughborough, UK

ABSTRACT

When teaching mathematics to undergraduate engineers, questions may be written in an abstract, mathematical way or in an engineering context. Existing mathematics modules for engineers vary widely in this regard, with contextualisation integral to some modules but entirely absent from others. Contextual questions are generally considered to be beneficial for students' motivation to study mathematics, which is often problematically low, as they emphasise the relevance of mathematics for engineering. However, contextual questions are also difficult and time-consuming for service-teaching mathematicians to create in large quantities, without the questions becoming contrived or irrelevant. In this study, I consider a compromise in which small numbers of contextual questions are incorporated into mathematics modules for undergraduate engineers. I investigate the implications of this for students' interest in and motivation to study mathematics. I find that even a small number of such questions can improve students' attitudes towards mathematics and that students also overwhelmingly favour the inclusion of at least some contextual questions in their mathematics modules. I therefore suggest that it is not enough for students to see applications of mathematics in engineering-specific modules later in their course, but that they should ideally also be exposed to contextual problems when learning mathematical skills.

ARTICLE HISTORY

Received 25 June 2024

KEYWORDS

Higher education; engineering education; service mathematics; interdisciplinary; contextual questions; student perceptions; motivation; attitudes

1. Introduction

Mathematics is a key component of all undergraduate engineering courses (Alpers et al., 2013; Pepin et al., 2021; The Quality Assurance Agency for Higher Education, 2023) but how this mathematics is taught varies considerably both within and between institutions (Czocher, 2017; Harris et al., 2015; Pepin et al., 2021). In particular, mathematics modules for engineers are often delivered by mathematicians with little or no experience in the field of engineering (Bingolbali & Ozmantar, 2009; Harris et al., 2015; Pepin et al., 2021). These service-teaching mathematicians may tailor their modules to the fact that they are teaching engineering students to varying extents (Bingolbali & Ozmantar, 2009; Bolstad et al., 2022;

CONTACT Lydia J. Buckingham  lydia.j.buckingham@gmail.com  Department of Mathematics Education, Loughborough University, Loughborough, UK

 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/0020739X.2025.2574949>

© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

Czocher, 2017; Harris et al., 2015; Klymchuk & Spooner, 2020; Scanlan, 1985) or they may teach in an entirely non-contextual, mathematical way and leave all engineering applications to be covered separately in modules taught by engineers (Harris et al., 2015; Loch & Lamborn, 2016; Sijmkens et al., 2024). One of the most common ways in which lecturers seek to customise their modules for engineering students is by including contextual questions and examples (Bolstad et al., 2022; Czocher, 2017; Harris et al., 2015; Klymchuk & Spooner, 2020; Sijmkens et al., 2024; Wolf, 2017). These may be presented in exactly the same way as purely mathematical questions but with each variable given a physical interpretation, or the contextualisation may be more detailed and include units, physically realistic numerical values, descriptions of experiments or real-world engineering scenarios and require the use of engineering principles as well as mathematical skills (Wolf & Biehler, 2016). Contextual questions may be used sparingly, appearing as one question at the end of a problem sheet or one example at the start of a topic (Czocher, 2017; Sijmkens et al., 2024), or they may be integral to a module and be included at every stage: in learning new mathematics content, practising it and in assessments (Czocher, 2017; Mathias et al., 2024).

Contextual questions have been shown to be beneficial for engineering students' interest, motivation, engagement and attainment in mathematics (Bolstad et al., 2022; Gijsbers & Pepin, 2017; Harris et al., 2015; Lishchynska et al., 2023; Mathias et al., 2024; Tossavainen et al., 2021). However, it can be very challenging for lecturers to include large quantities of contextual questions in their modules without the questions becoming repetitive or irrelevant (Harris et al., 2015; Mathias et al., 2024; Schmidt & Winslow, 2021; Willcox & Bounova, 2004; Yeatts & Hundhausen, 1992). One way to mitigate against this is by including a smaller number of contextual questions or examples. This could be done, for instance, by starting each topic with one or two contextual examples or by finishing each topic with a 30-minute discussion based on a short exercise of contextual practice questions.

In this study, I aim to explore the following questions:

- (1) Can short interventions (of up to 30 min) focussed on contextual questions improve engineering students' interest in and motivation to study mathematics?
- (2) What are engineering students' preferences in terms of the extent to which contextual questions should be included in their mathematics modules?

I will first describe an intervention where half of the students on a purely non-contextual mathematics module for first-year undergraduate electrical engineers spent a seminar exploring contextual questions, whereas the other half saw only non-contextual questions. I will then describe an extension to the study comparing two larger cohorts of first-year engineering students taking different mathematics modules who had either seen no contextual examples or only a small number. I will then compare the levels of interest which these different groups of students have in studying mathematics and explore their preferences for contextual versus non-contextual problems.

2. Literature review

2.1. Types of contextual task

There are many different ways of incorporating engineering contexts into mathematics problems. Vos (2020) describes three different classifications of such problems: dressed up tasks (where the question is presented in context but the need for answering it is not

justified); tasks with realistic contexts (where the question and its answer have some use within the context); and tasks with authentic contexts (where the context is presented using realistic information and sources). An additional classification described by Forman and Steen (2002) is tasks embedded in real contexts (where the question is more open-ended and there is no single approach to answering the question). Throughout this paper, I will use the term ‘contextual questions’ to refer to all of these types of problems, although I will mainly focus on dressed up tasks.

2.2. Students’ attitudes towards mathematics

Engineering undergraduates vary widely in their attitudes towards mathematics, which depend considerably on their reasons for studying it. Eccles (1983) categorise students’ motivation to study mathematics in terms of intrinsic value (studying mathematics because it is interesting in its own right), attainment value (studying mathematics because it is important to be considered good at it) and utility value (studying mathematics because it will be useful for the future). These different motivations, as well as the student’s perceived cost of studying mathematics (for example, the time and effort required) combine to influence their overall attitudes and performance, with undergraduate engineering students shown previously to have higher performance if their perceptions of the utility and intrinsic values of mathematics are high (Tossavainen et al., 2021).

2.3. Impacts of contextual questions

Unfortunately, many engineering undergraduates consider mathematics to have low intrinsic and utility value and cannot see its relevance to their degrees and future careers (Goold, 2015; Harris et al., 2015). Contextual questions have been proposed as a way to make the connections between mathematics and engineering more explicit and so increase students’ appreciation for the utility value of mathematics (Bolstad et al., 2022; Gijssbers & Pepin, 2017; Harris et al., 2015; Lepellere, 2022; Mathias et al., 2024; Wolf, 2017). This may, in turn, have a positive effect on the intrinsic value of mathematics as these students have chosen to study engineering and so generally find engineering applications interesting and enjoyable to study. By increasing the intrinsic and utility value of mathematics, contextual questions may consequently improve students’ motivation to study mathematics (Lishchynska et al., 2023). For example, Mathias et al. (2024) investigated the impact of employing a subject-specialist to create problem sheet tasks embedded in real contexts and deliver applications-based seminars to undergraduate earth sciences students, alongside lectures taught by a mathematician, and found that this approach led to significantly higher student satisfaction than when the module was taught by a mathematician alone. Moreover, Wolf (2017) found that providing engineering undergraduates with weekly discipline-specific tasks with authentic contexts increased their motivation to study mathematics. However, Klymchuk and Spooner (2020) found that there are still engineering students who describe purely abstract questions as more relevant and useful than dressed up contextual tasks. In particular, contextual questions may fail to inspire interest in mathematics if the specific contexts being used are not interesting to the individual students, who may all have very different opinions of what contextual scenarios are engaging and useful (Beswick, 2011; Wolf, 2017).

In general, however, contextual questions have been found to improve students' motivation to study mathematics, which can in turn have strong, positive effects on their enjoyment, engagement and attainment (Lishchynska et al., 2023; Mathias et al., 2024; Tossavainen et al., 2021). For instance, Mathias et al. (2024) found that student attainment improved by 10% in their mathematics module's final assessment when taught by both a subject specialist and a mathematician, compared to previous years when it had been taught by a mathematician alone. Similarly, Tossavainen et al. (2021) categorised engineering students based on the utility value they placed on mathematics and found that students who saw mathematics as useful for describing the real world scored 68% higher on a set of mathematics exercises than those who did not (the groups had average scores of 7.09 and 4.21 marks respectively).

Contextual questions can also be helpful for teaching students how to apply their mathematical knowledge and infer which skills are needed to solve problems. These are crucial skills for engineers (Cardella, 2008; Healey, 2005) but students often find them very difficult unless they have specifically been taught how to approach contextual tasks (Rezaei & Asghary, 2024; Sijmkens et al., 2024). These skills can be improved by demonstrating to students the relevance of mathematics through more contextualised teaching (Faulkner et al., 2019). In some cases, however, contextual questions may not provide this benefit, particularly if the questions are posed in such a way that the context is not necessary to answer the question, as many students will then not stop to consider the connections between the mathematics and the context (Greer, 1997; Wolf & Biehler, 2016). Conversely, if the context is more integral to the question, such as in the case of tasks embedded in real contexts, some students may rely too heavily on the context and neglect the intended mathematical steps, which also leads to a disconnect between the mathematical skills and the context and, most likely, an incorrect answer. There is evidence that female and working-class students are more likely to infer too much from the context of contextual questions (Beswick, 2011) and so, if such questions are assessed, this could generate unwanted inequalities.

Learning to solve contextual problems is clearly an important skill for engineers, but it is one which they often find very challenging. Many students, particularly those who struggle with mathematical skills, find contextual questions significantly more difficult than non-contextual questions (Harris et al., 2015; Klymchuk & Spooner, 2020; Sijmkens et al., 2024). Many engineering students find mathematics the most challenging part of their course, with some students dropping out of their degrees because of their struggles with mathematics (Van Dyken et al., 2015). The inclusion of contextual questions could compound this problem, with the greater level of difficulty reducing confidence, causing anxiety and leading to more polarised outcomes. Indeed, there is evidence that many students would prefer their mathematics modules to be entirely non-contextual for this reason, despite finding contextual questions more interesting and useful than non-contextual ones (Klymchuk & Spooner, 2020). Contextual mathematics questions are also generally less familiar to students than non-contextual ones, as school-level mathematics in the UK does not generally focus on applications of mathematics (Harris et al., 2015).

Contextual questions can also help students to develop intuition about mathematical concepts. This is demonstrated by Sijmkens et al. (2024), who found that students had a better conceptual understanding of differential equations as representing rates of change when they were taught using dressed up tasks, as opposed to non-contextual questions. Similarly,

Czocher (2017) found that continually emphasising real-world applications when teaching differential equations can deepen students' understanding of the relationship between the equations and their solutions. This may be because contextualisation provides more concrete examples of how the mathematical theory applies in situations which are already familiar to the students; students can then build their conceptual understanding upon this more familiar, concrete foundation (De Bock et al., 2011).

In many cases where contextual questions are omitted from mathematics modules, this is done with the view that they are not necessary because students will see the applications of their mathematics skills later on in modules taught by expert engineers (Bolstad et al., 2022; Faulkner et al., 2020). However, in these cases, students often fail to notice the connections between their mathematics learning and its engineering applications and still believe the mathematics they have learnt to be irrelevant, even after they have been exposed to its engineering applications (Coupland et al., 2008; Harris et al., 2015; Pepin et al., 2021). This may be due to significant periods of time passing between the teaching of the mathematics skills and their applications (Faulkner et al., 2020; Flegg et al., 2012; Tsui & Khan, 2023) or it may be because the notations and conventions used by mathematicians and engineers are quite different and so the same topic may appear differently to students when taught in different modules (Flegg et al., 2012; Pepin et al., 2021; Tsui & Khan, 2023). This has consequences for students' ability to transfer their mathematical knowledge to engineering problems, as students who are less appreciative of the usefulness of mathematics are less likely to be able to identify real-world scenarios where mathematics might be useful (Faulkner et al., 2020; Goold, 2015; Harris et al., 2015; Klymchuk & Spooner, 2020). As this is one of the key objectives in teaching mathematics to engineering students in the first place (Faulkner et al., 2019; Flegg et al., 2012; Goold & Devitt, 2012), it is clearly problematic when students lack this skill. Indicating the future uses of mathematical content through contextual questions at the time when the mathematics is taught may help to reduce this problem.

2.4. Difficulties of including contextual questions

Unfortunately, including contextual questions is often challenging for the module lecturer, particularly if they are a service-teaching mathematician with very little knowledge or experience of engineering. In this case, contextual questions may be very time-consuming to write, the contexts chosen may be inappropriate or irrelevant for the students being taught or the lecturer may use the engineering context incorrectly. There is evidence that service-teaching lecturers find writing contextual questions very challenging (Harris et al., 2015; Mathias et al., 2024; Schmidt & Winslow, 2021; Willcox & Bounova, 2004; Yeatts & Hundhausen, 1992) and hence it is very easy for questions to become contrived, repetitive, too mathematically simple or too mathematically demanding. However, there is also evidence that mathematicians can produce effective contextual questions (Harris et al., 2015; Schmitz & Ostsieker, 2020), particularly when they have good communication with the engineering departments concerned. It should be noted that using textbooks to source contextual questions does not always provide an effective solution as many resources utilise a wide range of engineering contexts, many of which may be too advanced or too specific to one particular engineering discipline to be of any interest or relevance to the students on

a given module, and mathematicians are likely to struggle to identify these issues without wider knowledge of their students' course of study (Schmitz & Ostsieker, 2020).

2.5. Suggestions for using contextual tasks

In light of these advantages and potential problems, a number of sources have made suggestions about how service-teaching mathematicians should approach the use of contextual questions. Wolf and Biehler (2016) suggest six key principles for designing good contextual tasks for mechanical engineering students: include appropriate mathematical skills which appear in a conspicuous way; make the relevance to engineering clear and include units and realistic physical values; ensure that both the mathematics and the context are necessary to complete the question; avoid excessively long questions and unnecessary amounts of text; provide any engineering knowledge which the students will require unless it is very familiar to them already; and consider how the question will develop students' abilities to complete similar tasks in the future.

Some studies suggest using contextual questions only after students are comfortable with the necessary mathematical content to reduce their level of difficulty (Harris et al., 2015) but others advocate for using contextual questions from the beginning of the learning process to increase motivation from the outset (Beswick, 2011; Bolstad et al., 2022; Lishchynska et al., 2023). For instance, Bolstad et al. (2022) introduced a mathematics module for engineers in which applications were emphasised early in the learning process. They found that this increased the percentage of students who claimed to understand the importance of mathematics for engineering from 77% to 99%, compared to a year when applications were not integral to the module.

Another suggestion which appears in the literature advocates for the use of contextual questions which are specific to the engineering discipline of the students being taught, as students are likely to be more interested in and motivated by contexts which they see as directly relevant to their own future studies and potential careers (Bolstad et al., 2022; Schmitz & Ostsieker, 2020; Wolf, 2017). Indeed, Wolf (2017) introduced contextual homework tasks related to mechanical engineering when teaching a mixed cohort of mechanical and industrial engineering students and found that, although the mechanical engineering students reported an increase in motivation, no increase was observed for the industrial engineering students. Similarly, Schmitz and Ostsieker (2020) used a contextual question based on content from an energy and infrastructure engineering course with a mixed cohort of engineers and found that it was viewed as most interesting, motivational and authentic by the students studying this specific engineering course.

Another recommendation given in the literature is to incorporate contextual questions into assessments to emphasise their value (Flegg et al., 2012; Schmidt & Winslow, 2021; Wolf, 2017). In particular, Wolf (2017) found that students showed increased motivation to study mathematics after working on tasks with authentic contexts, but that this motivation fell again once students were told that such tasks would not be included in their assessments. Various studies have also suggested that service-teaching mathematicians should collaborate with engineers to ensure that contexts are appropriate for their students (Faulkner et al., 2020; Mathias et al., 2024; Schmitz & Ostsieker, 2020). This suggestion may be implemented in different ways, as demonstrated by Mathias et al. (2024), who describe a situation in which subject-specialist lecturers were responsible for writing

mathematics exercise sheets and delivering seminars, and Schmitz and Ostsieker (2020), who taught first-year engineers using contextual questions written by engineering students in later years of study. Both of these approaches received positive responses from students.

Contextual examples and questions are not the only way to incorporate engineering applications into mathematics modules. Some university courses include longer modelling-based projects in which students investigate open-ended questions relating to engineering practice (Christensen, 2008; Harterich et al., 2012; Schmidt & Winslow, 2021). This approach provides some additional benefits, such as allowing students to choose a project which is closely tailored to their interests (Schmidt & Winslow, 2021), giving them opportunities to practise choosing between different possible methods (Harterich et al., 2012) and perhaps developing group-work and presentation skills (Harterich et al., 2012; Schmidt & Winslow, 2021). However, creating and supervising high-quality projects requires a huge amount of staff time and effort (Schmidt & Winslow, 2021) and students can find less-structured assignments much more difficult (Harterich et al., 2012). An alternative approach is explored by Goold (2015) and Lepellere (2022), who directly tasked students with exploring how the mathematics they had learnt might be used by professional engineers. This showed promise in increasing students' interest in mathematics (Goold, 2015), although the students also found it time-consuming and difficult (Lepellere, 2022).

2.6. Summary

The literature demonstrates that there are benefits to introducing engineering students to the applications of mathematics through contextual questions and examples, which suggests that the common approach of teaching mathematics with no reference to its applications may not be ideal. However, these studies generally consider the impacts of using contextual questions on a large scale. Clearly, integrating applications extensively into mathematics modules for engineers and scientists poses challenges due to the substantial workload required to ensure that examples, exercises and assessment questions are based on realistic and relevant contexts. Decreasing the quantity of contextual questions would clearly reduce this workload but very little is known about the effects of using contextualisation on a smaller scale. In this study, I will attempt to determine whether small numbers of contextual questions can benefit students' attitudes towards mathematics.

3. Methods

3.1. Background

The study participants were first-year engineering undergraduate students at a UK university, studying three different second-semester mathematics modules, each of which catered for a different engineering discipline. I will refer to these modules as Module E (electrical engineering), Module M (mechanical engineering) and Module A (aeronautical and automotive engineering).

In its current form, Module E contains no contextualisation whatsoever on the first topic covered (integration) and a small amount on subsequent topics. Students attend two 50-minute whole-cohort lectures per week for twelve weeks, in which they are taught the content of the module. Students also attend one 50-minute seminar per week, in which

Table 1. Summary of research participants and the mathematics modules they were taking at the time of the study.

| | Module E Seminar Group 1 | Module E Seminar Group 2 | Module M | Module A |
|--|--|---|--|--|
| Engineering Discipline | Electrical | Electrical | Mechanical | Aeronautical and automotive |
| Prior Mathematical Attainment | Average score of 80.2% on first-semester mathematics examination | Average score of 79.6% on first-semester mathematics examination | Typical entry requirements: A-Level grades AAB (including mathematics) | Typical entry requirements: A-Level grades AAB (including mathematics) |
| Prior Engagement in the Module | 63.8% seminar attendance | 67.8% seminar attendance | | |
| Extent of Contextualisation of the Integration Topic | None | Approximately 30 min of one seminar devoted to practice questions in an electrical engineering context. | None | Includes calculations of centres of mass. Half of one lecture devoted to examples in various engineering contexts. |
| Number of Participants | 22 | 18 | 29 | 63 |

they practise the content they have been taught and consider additional examples, with the support of the lecturer. Half of the students were allocated to seminar group 1 and the other half allocated to seminar group 2. The students are allocated to the seminar groups at random. In particular, the prior mathematical attainment levels of the two groups in the year in question were very consistent, as were the prior levels of attendance of the students who participated in the study from each group (see Table 1). The integration topic in Module E consists of a typical set of introductory components (see Appendix 1). The students had not previously been shown engineering applications of these topics.

The integration topic of Module M also includes no contextualisation whatsoever and covers very similar mathematical content to that taught in Module E, with the addition of solving second-order linear differential equations with constant coefficients.

In Module A, however, the integration topic begins with one 50-minute introductory lecture, which includes providing motivation through some contextual examples (see Appendix 2). Subsequently, the only other time that any contextualisation appears in this topic is when the formula for calculating centres of mass is given. Otherwise, the content covered is very similar to that taught in Module M.

The degree programmes taken by the students studying Module M and Module A have the same entry requirements, including the same grades required in mathematics (see Table 1). As such, the students taking Module M and Module A have similar mathematical backgrounds and have studied the same content on integration through very similar teaching methods, with the exception of Module M's introductory session.

First-year undergraduates were used for the study because they have generally had very little prior exposure to engineering applications of mathematics. The electrical engineering cohort was chosen because of the seminar structure of their mathematics module (Module E), which allowed half of the students to see contextual questions whilst the other half

did not. The mechanical and aeronautical engineering cohorts were chosen because their mathematics modules (Modules M and A) were very similar, apart from the difference in their inclusion of contextual questions.

3.2. Study design

This study was approved by the university's ethics committee.

In order to explore students' interest in and motivation to study mathematics, I chose to focus on one specific area of mathematics for which I could control the extent of the students' exposure to contextualisation and applications. Specifically, I chose the topic of integration and differential equations as this is an area of mathematics which many different engineering cohorts study but of which first-year undergraduates have generally not yet seen engineering applications (Gonzalez-Martin, 2021). Moreover, students on different engineering courses usually study very similar mathematical content on integration and there are many relevant and not overly complicated contexts in a variety of engineering fields where integration can be applied (Horwitz & Ebrahimpour, 2002; Wolf & Biehler, 2016).

To determine the effects of small numbers of contextual questions, I designed an exercise sheet containing eight questions on integration and differential equations, dressed up in electrical engineering contexts. I chose to use dressed up tasks because they are the simplest type of contextual question for lecturers to write, as they require less detailed knowledge of the engineering contexts than other types of contextual questions. Also, my aim was to consider the effects of small interventions using contextual questions, in contrast to some previous studies which looked at the impacts of larger interventions using tasks embedded in real contexts or tasks with authentic contexts (Mathias et al., 2024; Wolf, 2017). Short, dressed up tasks are generally quicker for students to complete than these more detailed types of contextual questions and so were more appropriate for my study.

As well as writing contextual exercises, I also created a corresponding set of non-contextual questions which required the same mathematical working. The questions on these sheets covered a range of content from throughout the integration topic. The questions contained all of the information required to answer them which did not relate specifically to the mathematical skills taught in the module. Although there is evidence that encouraging students to apply both their mathematical skills and engineering knowledge simultaneously improves their modelling skills and provides a more authentic experience of using mathematics (Rezaei & Asghary, 2024), I decided to prioritise practice of the mathematical content of the module. The full set of contextual and non-contextual questions is provided in Appendix 3 and an example is shown in Figure 1.

I then trialled the following intervention. Students taking Module E (electrical engineering) in seminar group 2 worked on the contextual exercise sheet during one seminar immediately after finishing the integration topic of the module. I led this seminar myself, encouraging the students to attempt the questions individually or in pairs before discussing some of the more challenging aspects of the questions with the group. This intervention lasted approximately 30 min. During the same week, the students in seminar group 1 took part in an identical seminar but were given the non-contextual exercise sheet. In order to minimise any unfair advantage which the students in one or other of the seminar groups might have derived from the study, I ensured that both sets of questions were provided

A

The power (measured in Watts) produced by a battery is given by $P(t) = 10 + (t - 3)e^t$ at time t seconds. The work done by the battery (W , measured in Joules) between times t_1 and t_2 satisfies:

$$W = \int_{t_1}^{t_2} P(t) dt$$

Find the work done by this battery between times $t = 0$ and $t = 2$. Give your answer to two decimal places.

B

Evaluate:

$$\int_0^2 (10 + (x - 3)e^x) dx$$

Give your answer to two decimal places.

Figure 1. An example of a contextual question written in an electrical engineering context (A) and the equivalent non-contextual question (B). The full set of questions used in the study can be found in Appendix 3.

to all of the students after the study was completed. The intervention also only lasted for 30 min, all of the students saw questions with identical mathematical content and contextual questions were not assessed in any way during the module and so the difference in provision offered to the two groups was minimal.

At the end of the seminars, the students were asked to complete a voluntary, anonymous, online questionnaire (see Appendix 4). The first section of the questionnaire consisted of ten statements relating to students' interest in the integration topic and their perceptions of its usefulness for engineering, which were scored on a five-point Likert scale (from Strongly Agree to Strongly Disagree). The statements were based on the Colorado Learning Attitudes about Science Survey (Adams et al., 2006; Physics Education Research Group at Colorado, 2004) and its mathematics-specific alternative, the Mathematics Attitudes and Perceptions Survey (Code et al., 2016), but tailored to the integration topic and the fact that I was interested specifically in applications to engineering (see Appendix 5). In line with Adams et al. (2006) and Code et al. (2016), I then awarded each student one point for each statement they answered in favour of mathematics (that is, one mark for each positive statement about mathematics to which they responded 'Agree' or 'Strongly Agree' and one mark for each negative statement about mathematics to which they responded 'Disagree' or 'Strongly Disagree'). This provided each student with a score out of ten, which I will use to measure their interest in and motivation to study mathematics.

The second part of the questionnaire asked the students explicitly for their views on contextual questions. Students were asked to rate the relative difficulty, interestingness and usefulness of contextual questions compared to purely mathematical questions on a five-point Likert scale. They were also asked to state the extent to which they would like contextual questions to be included in their mathematics modules (whether all, most, about half, some or none of the questions should be contextualised, or whether they had no strong opinion). Finally, a comments box was provided for students to offer any further thoughts on the use of contextual questions.

The same questionnaire was also provided to all students studying Module M (mechanical engineering) and Module A (aeronautical and automotive engineering). A description of the respondents to the questionnaire is presented in Table 1.

The survey was compiled in Qualtrics and the data analysis was conducted using SPSS.

4. Results

The scores measuring the levels of interest and motivation of the students taking Module E are shown in the box plots in Figure 2. An independent-samples Mann–Whitney U-test revealed no significant difference in scores between the students who had seen contextual questions and those who had not ($U = 230.5, p = 0.381$). This may, at least in part, be due to ceiling effects, as a number of students in both groups scored the highest possible mark (10 out of 10). However, it does appear that there were fewer low scores in the group who had seen the contextual questions (no scores under four, as opposed to 4 out of 22 students scoring under four in the non-contextual group). This could suggest that the intervention improved the scores of those students who were initially least interested in and motivated to study mathematics.

The scores measuring the levels of interest and motivation of the students taking Module M and Module A are shown in the box plots in Figure 3. An independent-samples Mann–Whitney U-test revealed that there was a significant difference in scores between these two cohorts of students, at the 5% level of significance ($U = 1154.5, p = 0.040$). The aeronautical and automotive engineering students taking Module A had a higher level of interest in mathematics, on average, than the mechanical engineering students taking Module M, which could be an indication that small numbers of contextual examples can make a difference to students' attitudes towards mathematics, as this was a key difference between the delivery of these two modules.

Interestingly, students across the courses were almost unanimous in saying that they wanted at least some contextual questions to be included in their mathematics modules. Only one student (out of 132) across all of the courses said that they did not want any contextual questions included in their mathematics modules. A further five students

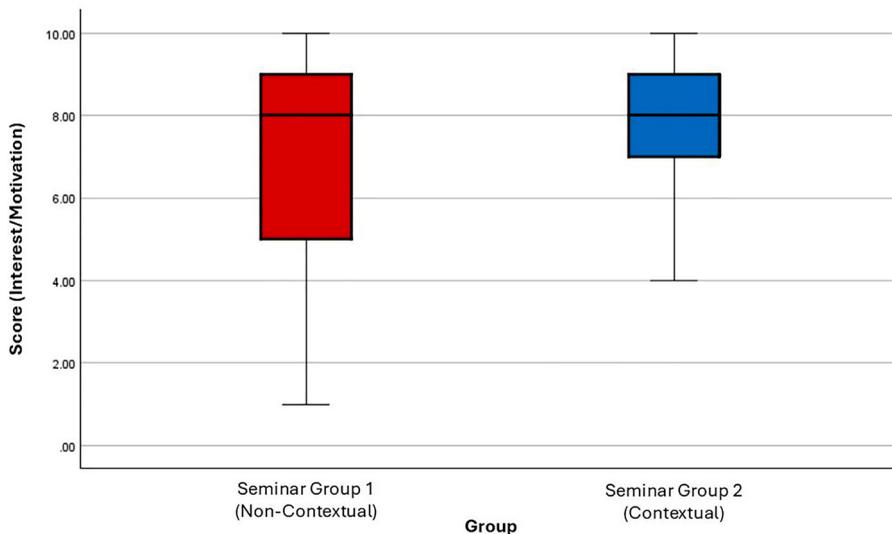


Figure 2. Box plots showing students' levels of interest and motivation towards the integration topic, for students studying Module E. There is no statistically significant difference between the two groups. The statistics shown in these box plots are given in Appendix 6.

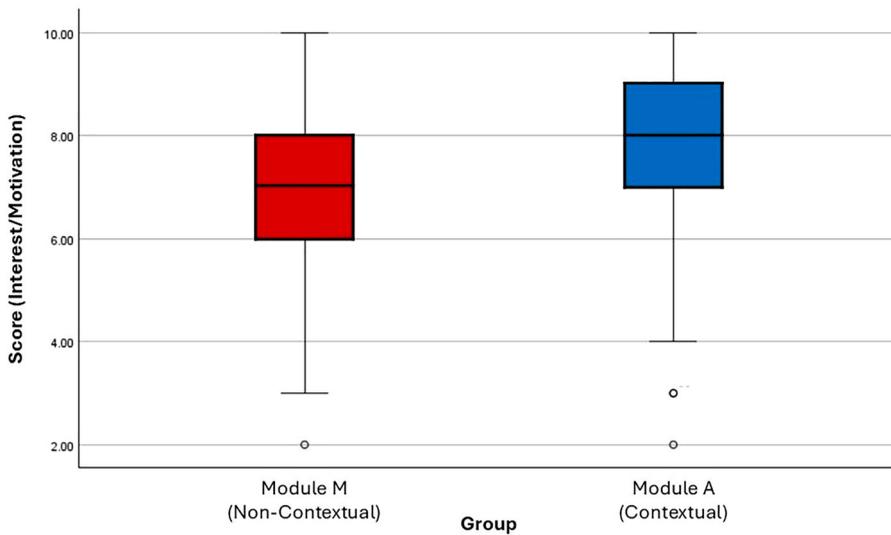


Figure 3. Box plots showing students' levels of interest and motivation towards the integration topic, for students studying Module M and Module A. The difference between the two cohorts is statistically significant. The statistics shown in these box plots are given in Appendix 6.

Table 2. Students' preferences for the inclusion of contextual questions and examples in their mathematics modules, as percentages for each group.

| | Module E Seminar Group 1 | Module E Seminar Group 2 | Module M | Module A |
|-------------------------------------|-----------------------------|-----------------------------|----------|----------|
| All in context | 0% | 5% | 0% | 8% |
| Most in context | 23% | 28% | 28% | 37% |
| Equal numbers in and out of context | 54% | 50% | 69% | 43% |
| Most out of context | 14% | 17% | 3% | 5% |
| All out of context | 0% | 0% | 0% | 2% |
| No opinion | 9% | 0% | 0% | 5% |

expressed no strong opinion, but the remaining 95% of students expressed a preference for the inclusion of contextual questions. Of these, only six students wanted all questions and examples to be written in context, showing that the vast majority of students would ideally like to see a mixture of contextual and non-contextual questions (Figure 4(A)). This is despite the fact that many students thought that contextual questions were more difficult than non-contextual questions (60%; Figure 4(B)). This may have been because students find contextual questions more interesting (72%; Figure 4(C)) and more useful (84%; Figure 4(D)) and these considerations outweigh the issue of increased difficulty for the students taking these particular modules. The level of contextualisation preferred by students was fairly consistent across the different courses (Table 2). In particular, those students who had seen some contextual questions during the integration topic (groups E1 and M) did not have substantially different preferences to the students who had not seen any contextual questions during this topic (groups E2 and A).

A small number of students from across the three degree programmes also provided comments on their views of contextual questions. Three students stated that they would

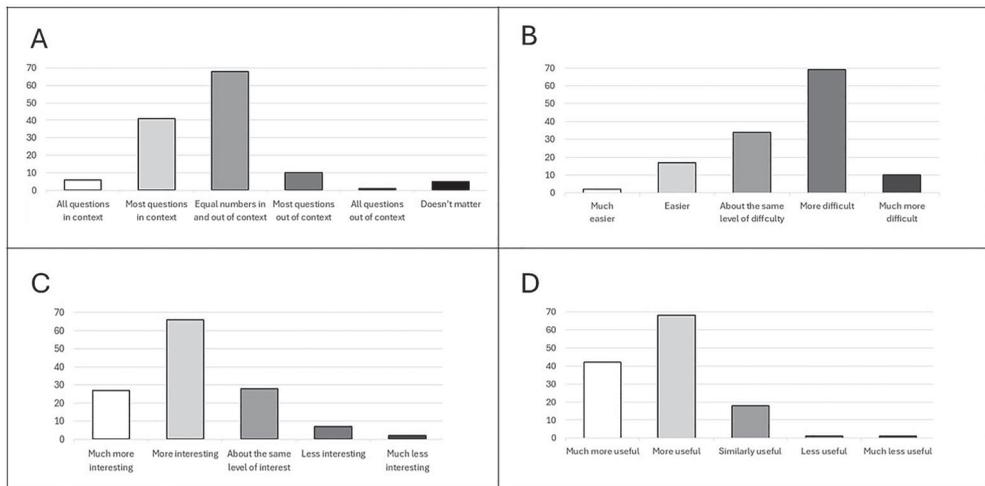


Figure 4. Bar charts showing students' responses to the following statements: (A) 'Please select the statement which best describes your opinions on the use of contextual questions when learning maths skills' and (B-D) 'Compared to purely mathematical questions, I think that contextual questions are ...'. The responses of all students studying Modules E, M and A are combined in these bar charts as the results were similar for all of these cohorts. The data shown in these bar charts are given in Appendix 6.

Box 1. Students' comments relating to the use of contextual questions in mathematics modules.

A

'Contextual questions are important and useful but should only be introduced after one is comfortable with the topic.'

'Purely mathematical examples may be easier to understand when learning the process, but questions with context can be more useful as practice.'

'I think when learning a new topic like integration it is helpful to understand the concepts from a viewpoint which is more mathematical than contextual. However, once you have learned the skills and understand how to apply them, it is important to explore as many different question types and contexts as possible to solidify your knowledge.'

B

'It would be nice to have a summary of where what we are learning can be applied as an intro to a topic. It might encourage me a bit more to try harder (but I am quite lazy to be fair).'

C

'[Contextual questions] can also cause a lot of confusion, with time wasted reading and understanding what the question is asking for which doesn't seem to be what maths is testing at the moment ...'

D

'We could have a few contextual questions which relate to our course but no contextual questions from other courses.'

prefer their lecturers to teach mathematical skills using non-contextual examples and then introduce contextual questions later, after the students were confident with the necessary methods (see Box 1(A)). However, another student suggested that it would be better to see contextual questions from the beginning of each topic in order to increase their motivation to learn the topic from the outset (see Box 1(B)). One student expressed the view that practising contextual questions was a waste of time unless they were going to be assessed (see Box 1(C)). This highlights the fact that students' priorities are often focussed on passing

assessments. In addition to this, one student emphasised the importance of using relevant contexts which specifically relate to their degree programme (see Box 1(D)).

5. Discussion

5.1. Summary of key results

Mathematics modules for undergraduate engineers often have poor engagement, attendance and attainment (Goold, 2015; Lishchynska et al., 2023; Liston & O'Donoghue, 2010; Loch & Lamborn, 2016; Rylands & Coady, 2009), due at least in part to low levels of motivation in the students and a lack of appreciation for the relevance and usefulness of mathematics in their chosen fields of study (Harris et al., 2015; Lishchynska et al., 2023). Contextual questions and examples have been proposed as a way to increase motivation and improve students' perceptions of mathematics (Bolstad et al., 2022; Flegg et al., 2012; Harris et al., 2015; Klymchuk & Spooner, 2020; Mathias et al., 2024; Rezaei & Asghary, 2024) but it is often difficult and time-consuming for service-teaching mathematicians to create large quantities of high-quality examples (Harris et al., 2015; Mathias et al., 2024; Schmidt & Winslow, 2021; Willcox & Bounova, 2004; Yeatts & Hundhausen, 1992). In this study, I have considered balancing these considerations by including small numbers of high-quality contextual questions and examples in mathematics modules for engineers. I have sought to determine whether a small number of contextual questions or examples can have an impact on engineering students' interest in and motivation to study mathematics, and to what extent students would like contextual questions to be included in their mathematics modules.

My findings revealed that small numbers of contextual questions can lead to a significant increase in students' interest in a mathematics topic. It has previously been shown that large-scale changes which incorporate contextualisation as an integral part of mathematics modules can have this effect (Mathias et al., 2024; Wolf, 2017), but such changes are generally impractical to implement. In contrast, Module A in my study included only half a lecture (approximately 25 min) of time spent concentrating on contextual examples, which also produced a positive effect. This suggests that it is beneficial to incorporate some contextual questions into mathematics modules even if this can only be done on a small scale.

The students in my study were overwhelmingly in favour of contextual questions being included in their mathematics modules across all three engineering disciplines surveyed (electrical engineering, mechanical engineering, aeronautical and automotive engineering). This is despite the fact that many students considered contextual questions to be more difficult than non-contextual questions, which is a common belief amongst engineering students (Harris et al., 2015; Klymchuk & Spooner, 2020; Sijmkens et al., 2024). This suggests that the difficulty of contextual questions is outweighed by the fact that both my students and those in other studies find them more interesting and useful than non-contextual questions (Harris et al., 2015; Klymchuk & Spooner, 2020; Mathias et al., 2024; Pepin et al., 2021). These findings agree with a number of studies which also find that students like contextual questions to be included in their mathematics modules (Gijsbers & Pepin, 2017; Harris et al., 2015; Wolf, 2017). However, there are also studies where this is not the case (Klymchuk & Spooner, 2020; Lepellere, 2022). It is important to note that,

in my study, although the students did express a strong preference for some contextual questions to be included in their modules, very few of them supported the idea of fully contextual modules, where all questions and examples are written in context. In fact, the most popular scenario amongst the students was for the module to contain approximately equal numbers of contextual and non-contextual questions. Although students' preferences are not the only consideration when designing teaching materials, the fact that students support modules with a mixture of contextual and non-contextual questions is definitely an advantage for designing modules in this way (Katz & Assor, 2007).

The additional comments that students made during the survey also showed different preferences for how small numbers of contextual questions should be included in mathematics modules. Some students advocated for contextual questions to be included only after they were confident with the underlying mathematical skills. This opinion was also expressed by students in a survey by Harris et al. (2015). This course of action helps to reduce the potential issues of students finding contextual questions too difficult and subsequently losing confidence in their mathematical abilities, as they can demonstrate their skills through non-contextual questions prior to seeing the more challenging contextual questions. Czocher (2017) also finds that this strategy is used when contextual examples are included in engineering mathematics textbooks. Alternatively, it was also suggested that students would prefer contextual examples to be used at the start of learning new topics, to provide additional motivation and to encourage them to work harder as the topic is being taught. This approach has also been recommended in the literature, with several studies describing how an early appreciation for the usefulness of mathematics is highly beneficial for students' learning (Beswick, 2011; Bolstad et al., 2022; Lishchynska et al., 2023). This strategy can also have positive impacts on students' confidence, as they become familiar with contextual questions from the beginning, when the mathematics required in the questions is relatively straightforward, and so do not associate contextual questions with being overly demanding (Sijmkens et al., 2024).

One student also expressed the opinion that contextual questions are not valuable unless they are assessed. This concurs with the findings of Wolf (2017), who found that students' interest in modelling tasks decreased when they realised that these were not going to be included in assessments. A number of other sources have also advocated for the inclusion of contextual questions in assessments (Flegg et al., 2012; Schmidt & Winslow, 2021). For instance, Schmidt and Winslow (2021) describe the importance of high-quality contextual tasks for engineering undergraduates but also emphasise that, if these are to be a serious aspect of the course, then they ought to be incorporated into assessments in some way. In particular, if developing students' abilities to interpret and solve contextual problems is one of the principle aims of using such problems, then it would seem highly beneficial to include them in assessments. If contextual examples are primarily being used to provide additional motivation however, then their inclusion in assessments may not be as important.

One student also noted that they preferred contexts which were specific to their course of study. That is, they were interested in contexts relating to electrical engineering (their degree course) but did not want to see broader contexts from other engineering disciplines or everyday life. The benefits of using contextual questions which are closely tailored to students' specific fields of study have also been explored in the literature, with several studies demonstrating that engineering students benefit most from mathematical activities which relate to their specific engineering discipline (Bolstad et al., 2022; Schmitz & Ostsieker,

2020; Wolf, 2017). Unfortunately, tailoring contextual questions to individual disciplines in this way is not always possible because engineers from different courses are often taught together, sometimes even alongside students from other subject areas (Bailey et al., 2024; Flegg et al., 2012; Tossavainen et al., 2021). However, it may still be possible to include a variety of contexts so that there is something to interest everyone (Harris et al., 2015; Lishchynska et al., 2023) or to group together disciplines with similar interests (Bolstad et al., 2022).

5.2. Study limitations and generalisations

The investigation described in this paper is a small-scale, exploratory action research study and so there are a number of limitations to generalising my results. It is important to recall that the effect of my intervention in Module E for electrical engineers was not large enough to generate a statistically significant result and so I cannot claim that a single seminar spent working on contextual questions was enough to produce a significant increase in motivation. However, this may have been due to the small sample sizes (18 and 22 students for the intervention and control groups respectively) or it may have been the result of ceiling effects, as a number of students in both groups expressed the highest possible level of motivation to study mathematics (10 out of 10) in their questionnaire responses.

A significant difference in motivation was observed, however, between the students studying Module M and Module A, which I hypothesise may have been due, at least in part, to the contextual examples used in the delivery of Module A. However, there are other possible causes of this difference. It may be that the two groups of students were predisposed towards mathematics to different extents before taking these modules, although I did choose to compare two modules with identical entry requirements for mathematics, and so the two groups are likely to have been very similar in terms of their prior mathematical attainment levels, which in turn are often correlated with motivation (Hural & Smolovik, 2023; Lishchynska et al., 2023; Tossavainen et al., 2021). It has been noted by some sources that students of certain engineering disciplines are often more motivated towards mathematics than others but, in these cases, it is generally mechanical engineers who are the most motivated (Coupland et al., 2008; Mustoe & Walker, 1970), which contrasts with my findings where the mechanical engineers who had seen no contextualisation were less motivated than the aeronautical and automotive engineers who had seen contextual examples. Indeed, Flegg et al. (2012) suggests that the heightened level of motivation in mechanical engineering students may be due to the fact that they more often see contextual questions related to their discipline and hence that making more explicit connections to other engineering disciplines may improve motivation for other students. Module M and Module A were also taught by different lecturers and so it is possible that their different lecturing styles may have impacted upon how interesting and useful their students perceived integration to be.

The study also only included first-year undergraduates at a single university in the UK, all with good levels of mathematical attainment on entry. Students who have higher levels of mathematical attainment are often those who have been most motivated to spend time on mathematics in the past and so these students may have higher initial levels of motivation than students studying engineering at universities where mathematical entry requirements are lower (Hural & Smolovik, 2023; Lishchynska et al., 2023). My questionnaires were also only completed by students who were still attending lectures and seminars half-way

through the semester. This means that my participants were likely to have higher-than-average levels of motivation to study mathematics. Gijsbers and Pepin (2017) found that students who were initially least motivated to study mathematics derived the most benefit from contextual tasks, which is supported by the findings from my intervention study with the Module E students. It may therefore be the case that the contextual questions would have had a greater impact, had they been used from the start of the module when more of the less-motivated students were still attending, or at a different university where students were initially less confident with and less motivated to study mathematics.

My study focussed solely on the topic of integral calculus and differential equations, as this was a topic for which I could control the extent of contextualisation seen by the students. It was not possible to ascertain the impact of contextual questions on students' views of mathematics more generally, as the students had already seen various applications of other mathematical ideas. Any intervention would therefore be overshadowed by the students' prior knowledge of mathematical applications in engineering. It is, however, reasonable to assume that, if the use of contextual questions in teaching integration can improve students' interest in and motivation to study this topic, then this should be generalisable to other areas of mathematics as well.

The questionnaire used in this study was based on the Colorado Learning Attitudes about Science Survey (CLASS survey; Adams et al., 2006), which was designed to measure students' beliefs about science, including their levels of interest. The CLASS survey has undergone extensive validation and reliability studies, involving the responses of thousands of students and the opinions of a variety of experts (Adams et al., 2006). These questions should therefore provide a good measure of students' interest in science. However, it was necessary for our study to adapt the CLASS survey to create questions which were relevant to engineering students studying the integration topic. As the CLASS survey has been adapted successfully to other disciplines in the past (Barbera et al., 2008; Code et al., 2016), it is reasonable to suppose that similar adaptations would provide a valid and reliable measure of our students' levels of interest in mathematics.

In this study, I have only considered engineering undergraduates, but students studying a variety of other subjects are also commonly service-taught mathematics by mathematicians. Similar challenges with students failing to see the relevance of mathematics to their subject areas are encountered in a number of these subject areas, including earth sciences (Mathias et al., 2024), business (Bailey et al., 2024; Lishchynska et al., 2023) and biology (Aikens et al., 2021). Even physics undergraduates, whose subject is probably most closely related to mathematics, often do not see the connections between mathematical skills and the applied problems which require them when the two are taught separately (Hitier & Gonzalez-Martin, 2023). It is therefore likely that including small numbers of contextual questions and examples would be beneficial for teaching mathematics to students of these subjects, although further research could help to determine whether there are any significant differences between the effects contextual questions have on these different groups of students.

5.3. Future research

My study highlights a number of important areas for future research. In particular, I have shown that small numbers of contextual questions can have an impact on students' interest in mathematics and their perceptions of its usefulness for engineering, but I do not

know how this might influence students' attendance or attainment. Elsewhere, introducing contextualisation has been shown to have a positive impact on students' attainment, both in terms of their procedural mathematical skills and their ability to answer contextual questions (Czocher, 2017; Mathias et al., 2024; Sijmkens et al., 2024). However, all of these studies incorporated contextualisation on a large scale. Sijmkens et al. (2024) found that small numbers of contextual questions can improve students' conceptual understanding of differential equations. However, more research on the broader impacts of small numbers of contextual questions would greatly improve our understanding and help to inform our practice.

It would also be advantageous for future research to consider how it is best to incorporate small numbers of contextual questions into existing modules. There is evidence that students respond most positively to contexts which are specifically related to their field of study (Bolstad et al., 2022; Schmitz & Ostsieker, 2020; Wolf, 2017), although students may also find other, unrelated contexts interesting if they are perceived to be authentic and have relevance to students' everyday lives (Van den Heuvel-Panhuizen & Drijvers, 2020). For instance, the contextual examples shown to the Module A students in my study were not specifically related to aeronautical and automotive engineering, although they were clearly relevant to those disciplines, and still had a substantial impact on students' perceptions. There may also be differences in how students respond to different types of contextual questions. It would be beneficial to compare the effects of dressed-up tasks to the impact of tasks with realistic or authentic contexts. This would provide insights into whether the latter, more detailed, tasks are worth the additional effort required to write them.

There are also differences in opinion about whether it is better to include contextual examples before teaching mathematical content, as a means of motivating students to want to learn the topic (Beswick, 2011; Bolstad et al., 2022; Lishchynska et al., 2023; Sijmkens et al., 2024), or whether contextualisation should be used after the students are confident with the necessary mathematics, perhaps as an extension to the topic (Harris et al., 2015). It could be argued that the ideal scenario is to include both, but this may not be practical if resources are limited and lecturers do not have the time or knowledge to source sufficient quantities of high-quality contextual questions. More information on the relative benefits of these different approaches, and other methods of introducing contextual questions, would certainly help lecturers to provide the greatest amount of benefit to their students whilst also minimising the impracticalities.

6. Conclusion

Overall, I have found that small numbers of contextual questions or examples can have a significant impact on students' interest in mathematics and their perceptions of its importance in engineering. I would therefore recommend that at least some contextual questions be included in mathematics modules for undergraduate engineers, even if it is not practical to use them extensively. In particular, it may be better to create small numbers of authentic questions which are specifically tailored to the students' areas of interest than to use larger numbers of more tenuous or less relevant questions. This process may benefit from some collaboration between service-teaching mathematicians and engineering lecturers who are more knowledgeable about their students' likely future uses of mathematics.

Acknowledgements

I would like to thank Ian Jones, Colin Foster, Alison Green and George Kinnear for useful discussions about the project.

Disclosure statement

No potential conflict of interest was reported by the author.

Data availability statement

All data collected and analysed as part of this study are available in the figshare repository at: <https://doi.org/10.6084/m9.figshare.26096368>

ORCID

Lydia J. Buckingham  <http://orcid.org/0000-0002-9691-9788>

References

- Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado learning attitudes about science survey. *Physical Review Special Topics: Physics Education Research*, 2, 1–14. <https://doi.org/10.1103/PhysRevSTPER.2.010101>
- Aikens, M. L., Eaton, C. D., & Highlander, H. C. (2021). The case for biocalculus: Improving student understanding of the utility value of mathematics to biology and affect toward mathematics. *CBE: Life Sciences Education*, 20(5), 1–14. <https://doi.org/10.1187/cbe.20-06-0124>
- Alpers, B., Demlova, M., Fant, C., Gustafsson, T., Lawson, D., Mustoe, L., Olsson-Lehtonen, B., Robinson, C., & Velichova, D. (2013). *A framework for mathematics curricula in engineering education* (ISBN 978-2-87352-007-6). European Society for Engineering Education (SEFI).
- Bailey, J. D., Claridge, J., & Partner, A. (2024). Investigating students' perception of the importance of calculus: A cross-discipline comparison to inform module development. *MSOR Connections*, 22(1), 5–27. <https://doi.org/10.21100/msor.v22i1.1457>
- Barbera, J., Perkins, K. K., Adams, W. K., & Wieman, C. E. (2008). Modifying and validating the Colorado learning attitudes about science survey for use in chemistry. *Journal of Chemical Education*, 85(10), 1435–1439. <https://doi.org/10.1021/ed085p1435>
- Beswick, K. (2011). Putting context in context: An examination of the evidence for the benefits of 'contextualised' tasks. *International Journal of Science and Mathematics Education*, 9(2), 367–390. <https://doi.org/10.1007/s10763-010-9270-z>
- Bingolbali, E., & Ozmantar, M. F. (2009). Factors shaping mathematics lecturers' service teaching in different departments. *International Journal of Mathematical Education in Science and Technology*, 40(5), 597–617. <https://doi.org/10.1080/00207390902912837>
- Bolstad, T., Hoyvik, I., Lundheim, L., Nome, M., & Ronning, F. (2022). Study programme driven engineering education: Interplay between mathematics and engineering subjects. *Teaching Mathematics and its Applications*, 41(4), 329–344. <https://doi.org/10.1093/teamat/hrac010>
- Cardella, M. E. (2008). Which mathematics should we teach engineering students? An empirically grounded case for a broad notion of mathematical thinking. *Teaching Mathematics and its Applications*, 27(3), 150–159. <https://doi.org/10.1093/teamat/hrn008>
- Christensen, O. R. (2008). Closing the gap between formalism and application–PBL and mathematical skills in engineering. *Teaching Mathematics and its Applications*, 27(3), 131–139. <https://doi.org/10.1093/teamat/hrn012>

- Code, W., Merchant, S., Maciejewski, W., Thomas, M., & Lo, J. (2016). The mathematics attitudes and perceptions survey: An instrument to assess expert-like views and dispositions among undergraduate mathematics students. *International Journal of Mathematical Education in Science and Technology*, 47(6), 917–937. <https://doi.org/10.1080/0020739X.2015.1133854>
- Coupland, M., Gardner, A., & Carmody, G. (2008, June 28–July 1). *Mathematics for engineering education: What students say*. Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia, <https://api.semanticscholar.org/CorpusID:107203843>
- Czocher, J. A. (2017). How can emphasizing mathematical modeling principles benefit students in a traditionally taught differential equations course? *The Journal of Mathematical Behavior*, 45, 78–94. <https://doi.org/10.1016/j.jmathb.2016.10.006>
- De Bock, D., Deprez, J., Van Dooren, W., Roelens, M., & Verschaffel, L. (2011). Abstract or concrete examples in learning mathematics? A replication and elaboration of Kaminski, Sloutsky, and Heckler's study. *Journal for Research in Mathematics Education*, 42(2), 109–126. <https://doi.org/10.5951/jresmetheduc.42.2.0109>
- Eccles, J. (1983). Expectancies, values and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motives: Psychological and sociological approaches* (pp. 75–146). Macmillan Publishers. <https://osit.nv.gov/uploadedFiles/ositnv.gov/Content/Meetings/STEM/2016/Expectancies%20Values%20and%20Academic%20Behaviors.pdf>
- Faulkner, B., Early, K., & Herman, G. (2019). Mathematical maturity for engineering students. *International Journal of Research in Undergraduate Mathematics Education*, 5(1), 97–128. <https://doi.org/10.1007/s40753-019-00083-8>
- Faulkner, B., Johnson-Glauch, N., Choi, D. S., & Herman, G. L. (2020). When am I ever going to use this? An investigation of the calculus content of core engineering courses. *Journal of Engineering Education*, 109(3), 402–423. <https://doi.org/10.1002/jee.20344>
- Flegg, J., Mallet, D., & Lupton, M. (2012). Students' perceptions of the relevance of mathematics in engineering. *International Journal of Mathematical Education in Science and Technology*, 43(6), 717–732. <https://doi.org/10.1080/0020739X.2011.644333>
- Forman, S. L., & Steen, L. A. (2002). Making authentic mathematics work for all students. In A. Bessot & J. Ridgway (Eds.), *Education for mathematics in the workplace* (pp. 115–126). Springer Dordrecht. <https://doi.org/10.1007/0-306-47226-0>
- Gijsbers, D., & Pepin, B. (2017, February 1–5). *Context based tasks on differential equations to improve students' beliefs about the relevance of mathematics*. Proceedings of CERME10, <https://hal.science/hal-01950500>
- Gonzalez-Martin, A. S. (2021). The use of integrals in engineering programmes: A praxeological analysis of textbooks and teaching practices in strength of materials and electricity and magnetism courses. *International Journal of Research in Undergraduate Mathematics Education*, 7(2), 211–234. <https://doi.org/10.1007/s40753-021-00135-y>
- Goold, E. (2015). Investigating engineering practice is valuable for mathematics learning. *Teaching Mathematics and its Applications*, 34(1), 3–15. <https://doi.org/10.1093/teamat/hru026>
- Goold, E., & Devitt, F. (2012, September 23–26.). *The role of mathematics in engineering practice and in the formation of engineers*. Proceedings of the European Society for Engineering Education 40th Annual Conference. <https://doi.org/10.21427/5fhx-0k95>
- Greer, B. (1997). Modelling reality in mathematics classrooms: The case of word problems. *Learning and Instruction*, 7(4), 293–307. [https://doi.org/10.1016/S0959-4752\(97\)00006-6](https://doi.org/10.1016/S0959-4752(97)00006-6)
- Harris, D., Black, L., Hernandez-Martinez, P., Pepin, B., & Williams, J. (2015). Mathematics and its value for engineering students: What are the implications for teaching? *International Journal of Mathematical Education in Science and Technology*, 46(3), 321–336. <https://doi.org/10.1080/0020739X.2014.979893>
- Harterich, K., Kiss, C., Rooch, A., Monnigmann, M., Darup, M. S., & Span, R. (2012). Math-epraxis: Connecting first-year mathematics with engineering applications. *European Journal of Engineering Education*, 37(3), 255–266. <https://doi.org/10.1080/03043797.2012.681295>
- Healey, M. (2005). Linking research and teaching: Exploring disciplinary spaces and the role of inquiry-based learning. In R. Barnett (Ed.), *Reshaping the university: New relationships between*

- research, scholarship and teaching (pp. 67–78). Open University Press. <https://api.semanticscholar.org/CorpusID:29260053>
- Hitier, M., & Gonzalez-Martin, A. (2023, July 10–14.). *Like finding the acceleration: A praxeological analysis of a calculus/mechanics task with and without its physics context*. Proceedings of CERME13, <https://hal.science/hal-04406697>
- Horwitz, A., & Ebrahimpour, A. (2002). Engineering applications in differential and integral calculus. *International Journal of Engineering Education*, 18(1), 78–88. <https://api.semanticscholar.org/CorpusID:64272586>
- Hural, I., & Smolovik, L. (2023). Мотиваційні фактори та досягнення у вивченні Математики студентів інженерних спеціальностей [Motivational factors and achievements of engineering students while studying mathematics]. *Освітні Обрії [Educational Horizons]*, 2(57), 35–39. <https://doi.org/10.15330/obrii.57.2.2.35-39>
- Katz, I., & Assor, A. (2007). When choice motivates and when it does not. *Educational Psychology Review*, 19(4), 429–442. <https://doi.org/10.1007/s10648-006-9027-y>
- Klymchuk, S., & Spooner, K. (2020). University students' preferences for application problems and pure mathematics questions. *Teaching Mathematics and its Applications*, 39, 29–37. <https://doi.org/10.1093/teamat/hry014>
- Lepellere, M. A. (2022, February 2–5). *A link between a second course in calculus and engineering applications: What the students think about*. Proceedings of CERME12, <https://hal.science/hal-03754868>
- Lishchynska, M., Palmer, C., Lacey, S., & O'Connor, D. (2023). Is motivation the key? Factors impacting performance in first year service mathematics modules. *European Journal of Science and Mathematics Education*, 11(2), 146–166. <https://doi.org/10.30935/scimath/12529>
- Liston, M., & O'Donoghue, J. (2010). Factors influencing the transition to university service mathematics: Part 2 a qualitative study. *Teaching Mathematics and its Applications*, 29(2), 53–68. <https://doi.org/10.1093/teamat/hrq005>
- Loch, B., & Lamborn, J. (2016). How to make mathematics relevant to first-year engineering students: Perceptions of students on student-produced resources. *International Journal of Mathematical Education in Science and Technology*, 47(1), 29–44. <https://doi.org/10.1080/0020739X.2015.1044043>
- Mathias, J., Saville, C., & Leech, S. (2024). Engaging non-mathematics students in mathematics learning through collaborative teaching. *Teaching Mathematics and its Applications*, 43(1), 67–80. <https://doi.org/10.1093/teamat/hrad003>
- Mustoe, L., & Walker, D. (1970). The teaching of mathematics for engineers. *International Journal of Mathematical Education in Science and Technology*, 1(4), 389–401. <https://doi.org/10.1080/0020739700010407>
- Pepin, B., Biehler, R., & Gueudet, G. (2021). Mathematics in engineering education: A review of the recent literature with a view towards innovative practices. *International Journal of Research in Undergraduate Mathematics Education*, 7(2), 163–188. <https://doi.org/10.1007/s40753-021-00139-8>
- Physics Education Research Group at Colorado, University of Colorado. (2004). *Colorado Learning Attitudes about Science Survey – Biology (CLASS-Bio)*. Retrieved June 19, 2024, from <https://www.colorado.edu/sei/class>
- The Quality Assurance Agency for Higher Education. (2023). *Subject benchmark statement: engineering*. Retrieved June 19, 2024, from <https://www.qaa.ac.uk/the-quality-code/subject-benchmark-statements/subject-benchmark-statement-engineering>
- Rezaei, J., & Asghary, N. (2024). Teaching differential equations through a mathematical modelling approach: The impact on problem-solving and the mathematical performance of engineering undergraduates. *International Journal of Mathematical Education in Science and Technology*, 56, 899–919. <https://doi.org/10.1080/0020739X.2024.2307397>
- Rylands, L. J., & Coady, C. (2009). Performance of students with weak mathematics in first-year mathematics and science. *International Journal of Mathematical Education in Science and Technology*, 40(6), 741–753. <https://doi.org/10.1080/00207390902914130>

- Scanlan, J. O. (1985). The role of mathematics in engineering education: An engineer's view. *International Journal of Mathematical Education in Science and Technology*, 16(3), 445–451. <https://doi.org/10.1080/0020739850160314>
- Schmidt, K., & Winslow, C. (2021). Authentic engineering problems in service mathematics assignments: Principles, processes and products from twenty years of task design. *International Journal of Research in Undergraduate Mathematics Education*, 7(2), 261–283. <https://doi.org/10.1007/s40753-021-00133-0>
- Schmitz, A., & Ostsieker, L. (2020). Konzeption und akzeptanz ingenieurwissenschaftlicher anwendungen in mathematikvorlesungen [Conception and acceptance of engineering applications in mathematics lectures]. In H. S. Siller, W. Weigel, & J. F. Worler (Eds.), *Beiträge zum Mathematikunterricht 2020* [Contributions to mathematics lessons 2020] (pp. 825–828). WTM-Verlag. <https://doi.org/10.37626/GA9783959871402.0>
- Sijmkens, E., Scheerlinck, N., De Cock, M., & Deprez, J. (2024). Benefits of using context while teaching differential equations. *International Journal of Mathematical Education in Science and Technology*, 55(4), 829–849. <https://doi.org/10.1080/0020739X.2022.2039412>
- Tossavainen, T., Rensaa, R. J., & Johansson, M. (2021). Swedish first-year engineering students' views of mathematics, self-efficacy and motivation and their effect on task performance. *International Journal of Mathematical Education in Science and Technology*, 52(1), 23–38. <https://doi.org/10.1080/0020739X.2019.1656827>
- Tsui, T., & Khan, R. N. (2023). Is mathematics a barrier for engineering? *International Journal of Mathematical Education in Science and Technology*, 54(9), 1853–1873. <https://doi.org/10.1080/0020739X.2023.2256319>
- Van den Heuvel-Panhuizen, M., & Drijvers, P. (2020). Realistic mathematics education. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 521–534). Springer. <https://doi.org/10.1007/978-94-007-4978-8>
- Van Dyken, J., Benson, L., & Gerard, P. (2015, June 14–17). *Persistence in engineering: Does initial mathematics course matter?* Proceedings of the American Society for Engineering Education Annual Conference and Exposition 2015, <https://www.researchgate.net/publication/283103202>
- Vos, P. (2020). Task contexts in Dutch mathematics education. In M. Van den Heuvel-Panhuizen (Ed.), *National reflections on the Netherlands didactics of mathematics* (pp. 31–54). Springer Open. https://doi.org/10.1007/978-3-030-33824-4_3
- Willcox, K., & Bounova, G. (2004, June 20–23). *Mathematics in engineering: Identifying, enhancing and linking the implicit mathematics curriculum.* Proceedings of the American Society for Engineering Education Annual Conference and Exposition 2004, <https://doi.org/10.18260/1-2-13246>
- Wolf, P. (2017). *Anwendungsorientierte Aufgaben für Mathematikveranstaltungen der Ingenieurstudiengänge* [Application-oriented tasks for mathematics modules in engineering courses]. Springer Spektrum Wiesbaden. <https://doi.org/10.1007/978-3-658-17772-0>
- Wolf, P., & Biehler, R. (2016). *Anwendungsorientierte aufgaben für die erstsemester-mathematikveranstaltungen im maschinenbaustudium* [Application-oriented tasks for first-semester mathematics students in mechanical engineering studies] (Report No. khdm-04-2016). Kompetenzzentrums Hochschuldidaktik Mathematik. <https://opus.bibliothek.uni-augsburg.de/opus4/109927>
- Yeatts, F. R., & Hundhausen, J. (1992). Calculus and physics: Challenges at the interface. *American Journal of Physics*, 60(8), 716–721. <https://doi.org/10.1119/1.17077>