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Exploring Strategies to Promote Engagement and Active Learning through Digital Course Design in Engineering Mathematics

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ABSTRACT

This research explores the strategies and techniques used to foster and promote the engagement and active learning of engineering students within a digital course. This digital course has been developed to address the varying levels of understanding of fundamental mathematics among first-year engineering students, who often have disparate levels of prior knowledge at their high school completion. We observe an increasing need to bridge the widening gap between high school and university mathematics in order to prevent engineering students from being hindered in their academic successes due to a lack of prior mathematical understanding. With a team of engineers and mathematicians, both researchers and educators, we are developing a mathematics *Bridging Course* including the use of digital tools, such as videos, online interactions and technology-based assessments. These sources were created, investigated and/or modified to develop an engaging learning environment in which students are made aware of and guided through misconceptions and mistakes in their understanding of fundamental mathematics. In the development of this *Bridging Course*, we consider the importance of interactive learning and timely feedback for student learning. We investigate the impact of digital course design on students' performance and learning outcomes using a qualitative approach. Students feedback within the first stage of the implementation of the course offered a positive assessment of the course, accentuating its inherent advantages and attributes. The students' feedback proved to be an invaluable source of insights, specifically concerning the enhancement of question distractors, thus prompting revisions and augmentations in the assessment items employed.

1 INTRODUCTION

1.1 Literature Review

The phenomena of the mathematics knowledge gap between high school and university manifest itself regardless of time and country (e.g. [1,2,3,4]). Bridging this gap from high school to university level is crucial for first-year engineering students as it lays a strong foundation for the complex mathematical concepts as well as problem-solving skills required in their studies and professional career. However, whether first-year engineering students are coming from high school, a post-secondary program or another route of study, the linking of high school mathematics to university mathematics is a common challenge. First-year students struggle with teachers' unawareness of their background level [5], experience high failure rates in mathematics courses [6, 7], and as a result, even drop out of the program [8].

Developing understanding and confidence in first-year students is key for their development as autonomous learners [9]. Enabling students to bridge the gap in their mathematics knowledge between high school and university will boost their understanding and confidence. Hence, it is crucial to activate first-year students in their learning process to develop the necessary knowledge and skills to succeed in consecutive, more advanced mathematics courses throughout their academic curriculum. Active learning, with its focus on learner-centred approaches, engagement, and immediate feedback, is a highly effective method for supporting students in developing their mathematical knowledge and preparing them for success in their chosen professions [10].

1.2 This Study

In the Civil Engineering (CE) Bachelor's program at the University of Twente (UT), we are also facing the mathematics knowledge gap among our first-year students. First-year CE students increasingly struggle to pass their first courses in (fundamental) mathematics at the University, affecting their academic development and progress throughout the study program. In our case specifically, a change from a Dutch-taught study program to a fully English-taught program (in 2018) stimulated the admission of international students into our Bachelor's program, further increasing the diversity in students' prior mathematics knowledge.

To shed light on this knowledge gap, we asked CE students to take part in an online prior knowledge test that was developed to assess their active understanding of mathematical topics such as solving equations, algebra, trigonometry, exponents and logarithms, and differentiation and integration. In the academic year of 2022-2023, 87 first-year CE students participated in this mathematics prior-knowledge test. Figure 1 represents the results of this test and indicates that the majority of the students had less than 75% competency in most of the mathematics topics that are assumed to be prior-knowledge.

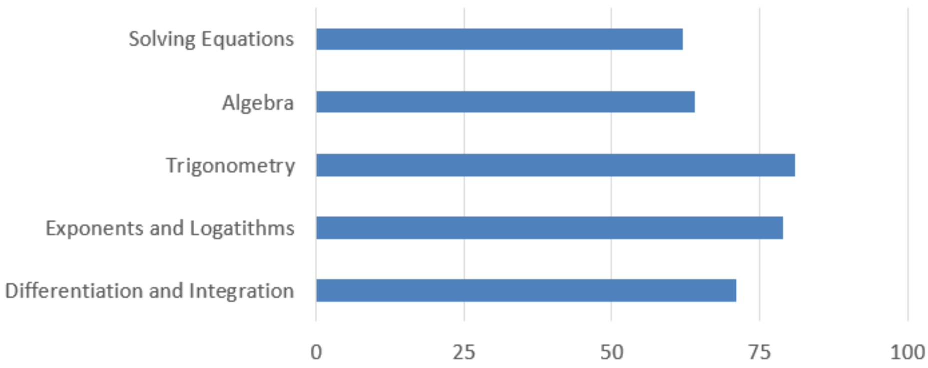

Fig. 1. Results of the prior knowledge test under 87 first-year Civil Engineering students. Results are indicated by correct answer percentages per topic.

To support our CE students with their prior mathematics knowledge, we are now developing an online platform providing a *Bridging Course* to concurrently test and support students in their pre-university mathematics. This *Bridging Course* provides the students with feedback and resources to evaluate and eventually improve their initial mathematics skills. Simultaneously, this online platform will equip teachers with the currently lacking quantitative information on students' pre-knowledge in mathematics. We will assess the efficacy of this *Bridging Course* on the mathematical attainment of students. In this study we aim to investigate the impact of the digital course design of the *Bridging Course* on students' performance and learning outcomes using a qualitative approach.

2 METHODOLOGY

2.1 Developing the Bridging Course

We are developing the *Bridging Course* in CANVAS, which is the standard online learning platform at UT. The *Bridging Course* will cover foundation mathematics for engineering students according to four main topics: arithmetic, algebra, functions, and geometry. Each primary topic is subsequently partitioned into subtopics, each of which introduces its individual learning objectives and skills to be tested. Specifically, the *Bridging Course* covers an extensive array of subjects to ensure that engineering students are equipped with the prerequisite knowledge required to undertake higher-level university courses at UT, such as Calculus I and consecutive courses. The selection of the topics and the subsidiary topics of the *Bridging Course* is based on (i) an analysis of the areas within the Calculus I course where students are typically deficient in foundational knowledge, as well as (ii) an assessment of the topics and skills that high school students frequently encounter difficulties with, and are susceptible to misconceptions and mistakes.

In order to provide additional insight into the approach and methodology behind the *Bridging Course*, the main topic 'arithmetic' and the subtopic 'fractions' will be employed as an illustration of the composition and progression of the course (see Table 1).

Table 1. An illustration of the main topic, its subtopic, and the related learning objectives

Main topic	**Subtopic**	**Skills**	**Learning objectives**
Arithmetic	Fractions	Addition /Subtraction	Students will be able to identify, add and subtract fractions with different denominators and mixed numbers and simplify the results to the lowest terms.
		Multiplication /Division	Students will be able to demonstrate an understanding of fraction multiplication and division, including the ability to identify and apply the appropriate operation, calculate a fraction product or quotient and explain the relationship between multiplication and division of fractions.
		Comparison	Students will be able to compare fractions with different numerators and denominators, as well as recognize which fraction is greater or lesser than another.

The *Bridging Course* digital platform will consist of two phases (see Figure 2): a testing phase and an instructive phase.

The testing phase of the *Bridging Course* consists of a wide range of start-up questions prepared by the researchers. These questions were considered to cover prevalent misconceptions and mistakes. The start-up question aims to ascertain whether the student understands a particular subtopic and possesses the relevant skills required to answer the question. The *Bridging Course* exclusively employs questions of the multiple-choice, true/false, or drag-and-drop type, with no open-ended questions included. The response to the start-up question serves as a determining factor as to whether the student needs to continue with the instructive phase. If the student correctly answers the question, they can move on to the next question, but they can also choose to proceed with the instructive phase for the particular subtopic of the question. Conversely, if the student’s answer is incorrect, they are automatically directed towards the instructive phase.

During the instructive phase, students are directed to video recordings that expound upon the learning objective of the specific subtopic that is addressed by the preceeding start-up question. The selection of videos for the instructive phase is based on both publicly available open-source material online as well as instructive videos that are generated by the team. When no suitable open-source material is available, new instructive videos will be recorded by the team to ensure that all topics are comprehensively addressed in a single source, and to ascertain that all explanations are aligned with the prerequisite knowledge required to support students in meeting the expected attainment outcomes for the Calculus I course at UT. Of particular importance in the selection and development of these videos is the prioritization of conceptual understanding of topics over students' mere execution of procedures.

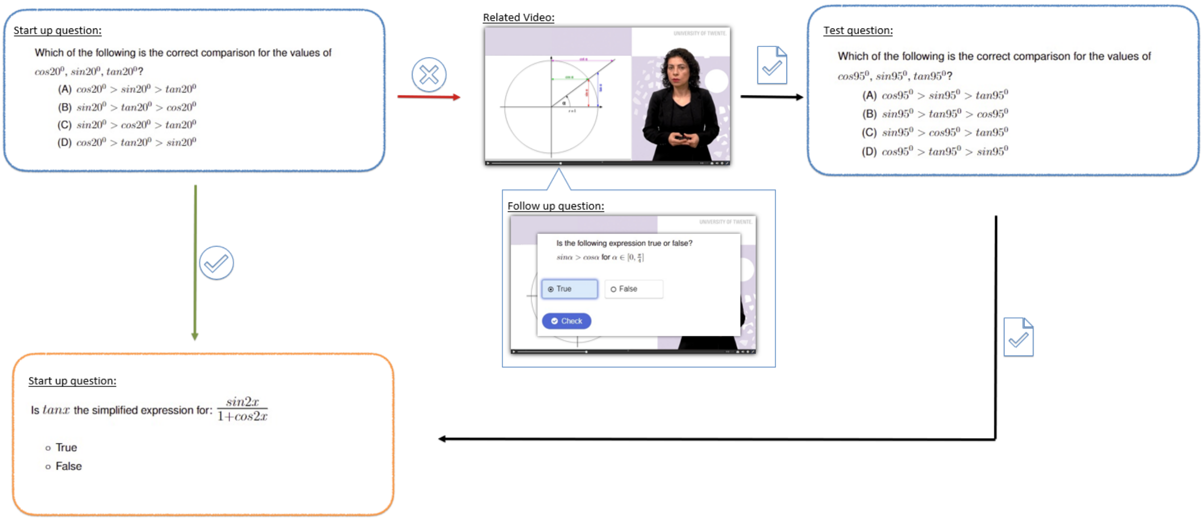

Fig. 2. Setup of the Bridging Course with the testing phase (left-hand side) and the instructive phase (right-hand side).

The instructive videos contain embedded follow-up questions, which serve to ascertain whether the students are actively engaging with the content to facilitate their learning. Upon completion of each video, a concluding question identical to the start-up question is presented, to assess the level of students' newly obtained comprehension of the subtopic. This marks the final point to understanding students' comprehension of the relevant subtopic and the next step is to present the start-up question of the following learning objective.

Upon final completion of the *Bridging Course*, students receive feedback on their comprehension of all topics and subtopics, expressed as correct-answer percentages. Additionally, students are provided with feedback on their most proficiently grasped subtopics and those which require further study. This feedback will include links to the videos fo the instructive phase. The instructive phase will remain accessible to students for repetition and review throughout the academic year.

2.2 Evaluating the *Bridging Course*

The implementation of the *Bridging Course* will be carried out in two stages. Firstly, the course was presented to a panel consisting of 6 CE students for evaluation. Secondly, the course will be implemented during the first quartile of the academic year 2023-2024 among all first-year CE students at UT. The evaluation of the second stage of the implementation, in September 2023, will be quantitative in nature, whereas the qualitative results of the first stage will be shared in this study.

For the first stage of the implementation of the *Bridging Course*, six CE students completed the *Bridging Course* at their own pace and convenience. The selection criteria for the students encompassed an assessment of their relevant skills and experience, taking into account their varying academic development as both master and bachelor level candidates were included. Upon completion, the students underwent a group interview session where discussions addressed the *Bridging Course* as a whole, as well as each learning objective and the related start-up and follow-up questions, including the provided video materials.

3 RESULTS & DISCUSSION

At the current stage of our study, we focus on the qualitative results of the first stage of the *Bridging Course* implementation. It is noted that the second stage of the implementation, which is not covered in this study, is yet to be conducted.

The feedback provided by the interviewed students regarding the course was predominantly positive, with an appreciation for its academic merits and benefits. Students noted that the *Bridging Course* offered them a comprehensive understanding of both the anticipated level of mathematics and their own proficiency within that level. During the interview also the technical issues, such as malfunctioning buttons or videos, were identified and duly addressed, assuring the students these issues would be solved prior to full implementation of the *Bridging Course*.

It is noteworthy to highlight the feedback by the interviewed students yielded valuable insights, particularly pertaining to the improvement of question distractors. In response to this feedback, revisions were made to incorporate stronger distractors, thereby enhancing the quality of the assessment items. Furthermore, the students' observations regarding the discrepancy between follow-up and start-up questions were useful and incorporated, ensuring equivalence and consistency in the final version of the *Bridging Course*.

Regarding the instructional videos, the majority of students found them to be beneficial for learning. Two videos were identified and discussed by the students. Some students found one of the videos lengthy, approximately spanning 8 minutes. Another video was advised to be considered to be replaced with an alternative video that is more closely aligned with the content of the start-up question. These concerns were examined, leading to necessary modifications to rectify the problems.

The performance of the six students in the *Bridging Course* assessment was of remarkably high level. However, we would like to note that these results will not be reported as part of this study's findings. This decision is based on the fact that the students were explicitly encouraged to freely explore and identify any shortcomings within the system. Consequently, some students deliberately chose incorrect answers as part of their conscious effort to fulfil this objective. As a result, the reported performance may not accurately reflect their actual mastery of the course material.

This preliminary study has certain limitations that should be acknowledged. As the course is delivered in an online learning environment, no open-ended questions can be used. While the questions and potential answers have been designed based on expected misconceptions from literature and teaching experience, students may come up with answers that are not accounted for in the course materials. Based on the results of the second stage of the study, several recommendations for further research will be presented. One of the main recommendations will be to implement this course in various disciplines and at different universities to assess its effectiveness within a range of engineering and university contexts.

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REFERENCES

[1] Luk, H. S. (2005), The gap between secondary school and university mathematics, *International Journal of Mathematical Education in Science and Technology*, Vol. 36, No. 2-3, pp. 161-174.

[2] Higgins, P. J., Shaun , R. B. (2009), Bridging the gap: teaching university mathematics to high school students, *Journal of Science Teacher Education,* Vol.51, pp. C640-C653.

[3] Luft, J. A., Patterson, N. C. (2002), Bridging the gap: Supporting beginning science teachers, *Journal of Science Teacher Eduation*, Vol. 13, No.4, pp. 267-282.

[4] Rach, S., Ufer, S. (2020), Which Prior Mathematical Knowledge Is Necessary for Study Success in the University Study Entrance Phase? Results on a New Model of Knowledge Levels Based on a Reanalysis of Data from Existing Studies. *International Journal of Research in Undergraduate Mathematics Education,* Vol. 6, pp. 375–403.

[5] Metje, N., Frank, H., Croft, P. (2007), Can't do maths: understanding students' maths anxiety. *Teaching Mathematics and Its Applications,* Vol. 26, pp. 79-88.

[6] Mastoi, S., et al., (2021) A Statistical analysis for mathematics & statistics in engineering technologies (Random Sampling). *International Journal of Management*, Vol. 12, No. 3, pp. 416-421.

[7] Nortvedt, G. A., Siqveland, A. (2018), Are beginning calculus and engineering students adequately prepared for higher education? An assessment of students' basic mathematical knowledge, *International Journal of Mathematical Education in Science and Technology*, Vol. 50, No. 3, pp. 325–343.

[8] Meyer, M., Marx, S. (2014), Engineering Dropouts: A Qualitative Examination of Why Undergraduates Leave Engineering, *Journal of Engineering Education,* Vol. 103, No. 4, pp. 525-548.

[9] Macaskill, A., Denovan, A. (2013), Developing autonomous learning in first year university students using perspectives from positive psychology, *Studies in Higher Education*, 38, 1, pp. 124-142.

[10] Gavalcová, T. (2008), On strategies contributing to active learning, *Teaching Mathematics and its Applications: An International Journal of the IMA*, Vol. 27, No. 3, pp.116–122.