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Shifting the focus of assessment in engineering dynamics to improve understanding

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ABSTRACT

CONTEXT

The use of computer software and simulation tools to assist in learning of rigid-body dynamics courses has been explored in a variety of ways. The use of these tools has often been associated with improvements in students' understanding of concepts. But while technology is being used for teaching, many assessments still use traditional methods. The use of automated assessment tools that are also used for teaching can have the benefits of motivating students and focusing their attention on the concept and less on the math.

PURPOSE OR GOAL

The objective of this project is to analyse the implementation of MATLAB Grader with instructor customized feedback as automated assessment tool in a rigid-body dynamics subject. The purpose was to evaluate the effectiveness of this type of assessment in assisting students' understanding. Additionally, the project aims to understand how the feedback provided is used and how it influences their learning.

APPROACH OR METHODOLOGY/METHODS

Assessments were re-designed to use the new assessment tool. The deployment strategy was informed by the literature and used a combination of limited and unlimited tests. Additionally, guiding information about the assessment tool and the types of feedback provided were created for students. An outcome survey to evaluate students' perceptions of the implementation and feedback was conducted.

ACTUAL OR ANTICIPATED OUTCOMES

The survey shows that student experience with the assessment tool MATLAB Grader is mostly positive. Students' perception of learning with the tool is very positive. However, feedback is indicated as one point that needs improvement. A lack of correlation between perceived learning and perceived usefulness of feedback indicates some contradiction of answers and requires further exploration.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The use of the automated assessment tool MATLAB Grader in a rigid-body dynamics subject has been successfully implemented. The flexibility of the tool allows different degrees of detail and assessment levels. The flexibility of feedback customization is very useful, however, feedback strategy must be further explored.

KEYWORDS

Automated assessment, feedback, MATLAB Grader.

Introduction

The use of computer software and simulation tools to assist in learning of the multibody dynamics courses presented in the literature varies from demonstration of the movement of a mechanical system using software simulations (Gu & Tan, 2009) to full computer program and animation development by students (Lipinski et al., 2012). These technological advances in teaching are highly appreciated by students, as mentioned by many authors reporting innovations in teaching dynamics with technology (see for example (Gu & Tan, 2009; Kumar & Plummer, 1997; Narayanan et al., 2019)). These authors report on improvements in students' understanding of concepts, better visualisation of the problems and better understanding of the solutions. Many of these studies used mainly students' self-reported evaluation, but other studies also show improvement in the average grade of students in traditional exam assignments (not technology-assisted) (Gu & Tan, 2009) as evidence of the efficiency of the methods used.

While technology is being used to assist learning, many assessments still apply traditional methods, as it is the case, for example, in (Gu & Tan, 2009). Felder et al. (2000) compiled a list of recommendations to improve engineering education. While these recommendations do not target the use of technology specifically, they do include the fairness of assessments. Felder et al. (2000) notes that different types of learners might have different ways to solve the problems, some might take longer than others, and assessments must take this into account. The use of technology for teaching and practice questions, but not for all assessments, seems to contradict the idea of an assessment that is fair to all and accounts for the different types of learners. One student might take longer to write all the calculations needed than others, but this does not necessarily mean they know less. Moreover, Hattie & Timperley (2007) showed that feedback is one of the most influential factors in learning, and that different types of feedback have different effect sizes. In large cohorts, providing timely feedback is particularly challenging.

Automated assessment tools have the advantage of providing feedback that is timely and consistent. By offloading calculations to computers, these tools have the potential to level the playing field for individuals who require more time for computations, allowing them to focus on core concepts. The objective of this project is to analyse the implementation of MATLAB Grader with instructor customized feedback as an automated assessment tool within the context of a rigid-body dynamics subject. The purpose was to evaluate the effectiveness of this type of assessment in assisting students' understanding. Furthermore, the project sought to analyse how the provided feedback was utilized by students, shedding light on its impact on their learning process.

Background

Dynamics is a master-level subject with around 150 students, which focuses on 3D rigid-body dynamics. This subject is considered extremely challenging by many students. Although many technology tools have been used for teaching, some assessment tasks, both formative and summative, still relied on handwritten calculations. This is critical for this subject, which involves many lengthy vector-matrix operations. From experience, students tend to focus their effort on getting the correct mathematical expression, but they do not always achieve a deeper understanding of the meaning of what they are calculating. Lee et al. (2020) analysed the primary difficulties faced by students in a dynamics course and observed that many struggle to comprehend the proposed exercises and explain the obtained results. Moreover, the threshold concepts in this subject area were studied in Hesterman et al. (2011). It was observed that the possible threshold concepts are related to the system identification, temporal-spatial frames of reference and the interpretation of the vectors, not the mathematical calculations. However, the same study Hesterman et al. (2011) also points out that there is "a link missing between the inert mathematics and the physical behaviour for some students". Indeed, the mathematical concepts and lengthy calculations can cloud the main intended learning outcome in dynamics, that is, to study and analyse the motion of rigid bodies.

Design and implementation

MATLAB Grader is a web-based tool for assessing MATLAB coding assignments. Previous work, showed that the tool allows a broad range of applications, such as providing an avenue for programming practice to develop proficiency in programming skills, or providing automated assessment and feedback on their application in engineering problem-solving (Yee Chan et al., 2022). In this project, we implemented MATLAB Grader as a tool for teaching and assessments. The objective of this change was to use an engineering tool that reduces the focus on mathematical calculations. By combining MATLAB Grader with more engaging and relevant problems, we aimed to shift students' attention toward the core concepts of engineering dynamics, thereby enabling a deeper understanding of these fundamental principles. The rationale was to reduce the cognitive load associated with complex calculations, allowing students to focus their efforts on grasping the underlying concepts that govern the motion of rigid bodies.

The deployment strategy of MATLAB Grader was informed by the literature (Smith, 2019; Yee Chan et al., 2022) and used a combination of limited and unlimited tests. This strategy was chosen to avoid the random attempts and lack of accountability previously reported by Smith (2019), which would not be consistent with the goal of focusing students' attention on the core concepts.

Each assignment comprised three MATLAB Grader problems, with the number of tests varying across problems. The first problem in each set included more tests, corresponding to a greater number of steps required for solving. Subsequent problems offered fewer tests, or steps, but addressed similar concepts. Table 1 provides details on the number of tests for problems in the first assignment. A portion of the tests allowed unlimited attempts, while the remaining tests were limited to three attempts. Before the first assessment, two tutorials followed a similar structure to ensure students could gain experience with the system. This approach allowed learners to familiarise themselves with the MATLAB Grader environment and its functionalities before encountering it in an evaluation setting.

Table 1 Distribution of the number of tests for the first assignment.

	Total number of tests	Number of unlimited tests
Problem set 1	15	7
Problem set 2	9	4
Problem set 3	5	2

Additionally, guiding information about the assessment tool and the types of feedback were provided to students for each assessment. The information provided targeted mainly three aspects: test types, system functionality and feedback. First, the types of tests and the number of attempts were detailed. Second, the system was briefly explained, and good practice guidance was provided. Last, the types of feedback provided by the system were explained. As the system provides a machine-generated feedback and an instructor-tailored feedback for each test, an explanation of the two types was considered necessary. This is also due to feedback being a source of discontent in past studies (Yee Chan et al., 2022) and was observed to be a source of frustration in our preliminary observations.

Outcomes and Discussion

A subject-wide outcome survey to evaluate students' perceptions of the implementation and feedback was conducted in semester 1 2023 and 2024. Human research ethics approval was granted by the University of Melbourne. There were 32 respondents to the survey. Survey questions were designed around six categories:

1. Prior experience with online assessment and MATLAB
2. Difficulty of MATLAB Grader assessments.
3. User experience with MATLAB Grader.
4. Quality and presentation of assessment questions.
5. Perception of learning with MATLAB Grader assessments.
6. Quality of feedback provided.

All areas had Likert-scale questions with students asked to rate their experience with a 4-point Likert scale (none, minimal, good, advanced) or rate statements with a 4-point Likert scale (strongly disagree, disagree, agree, strongly agree). Categories 2-7 had open-ended questions to enter comments.

In the first category, students were asked to rate their experience with online programming assessments, MATLAB Grader and MATLAB symbolic toolbox, which is a toolbox used in the assignments. While most students declared having good or advanced experience with MATLAB Grader (88%) and MATLAB Symbolic (72%), only around half of the respondents (53%) had experience with programming assessments. Given that MATLAB is used in many undergraduate subjects at our institution, it is not surprising that they have experience with the tool. This observation aligns with the outcomes of the third category, where most respondents disagreed or strongly disagreed (85%) with the statement "Compared to other learning tasks in the subject, I find programming in MATLAB a difficult task."

The lack of experience with programming assessment is not critical as they are given training in tutorials, prior to the assessments. This is confirmed by the outcomes of the questions about the user experience with the assessment tool presented in Figure 1. The figure shows that most students found the assessment tool easy to access and had no technical issues.

The lack of experience with programming assessments could create some frustration with the programming errors and could explain some comments found in later questions. When asked to comment on the feedback received, one student wrote

> *While the feedback indicated how to go about solving the problem, the issues that lead to the code being incorrect were largely syntax related which was not helped by the feedback.*

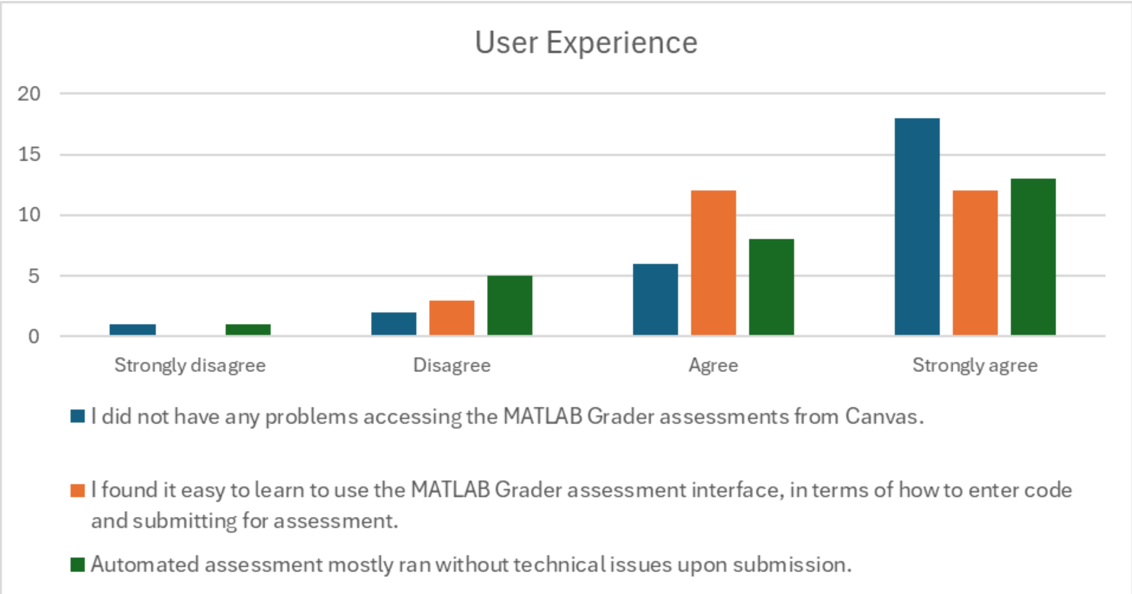

Figure 1 Graph representing student experience with the assessment tool.

The outcomes about the assessment questions are presented in Figure 2. Most students have a positive view of the assessment, with most responses ranging from “agree” to “strongly agree” for all statements. One of the primary objectives achieved with this project was to incorporate more complex, yet realistic problems that would not only enhance student motivation but also deepen their understanding of the systems under study. The third statement rated in Figure 2 indicates that students found the assessment questions interesting from an engineering perspective. This aspect could contribute to improving their motivation while simultaneously fostering a better comprehension of the system being analysed.

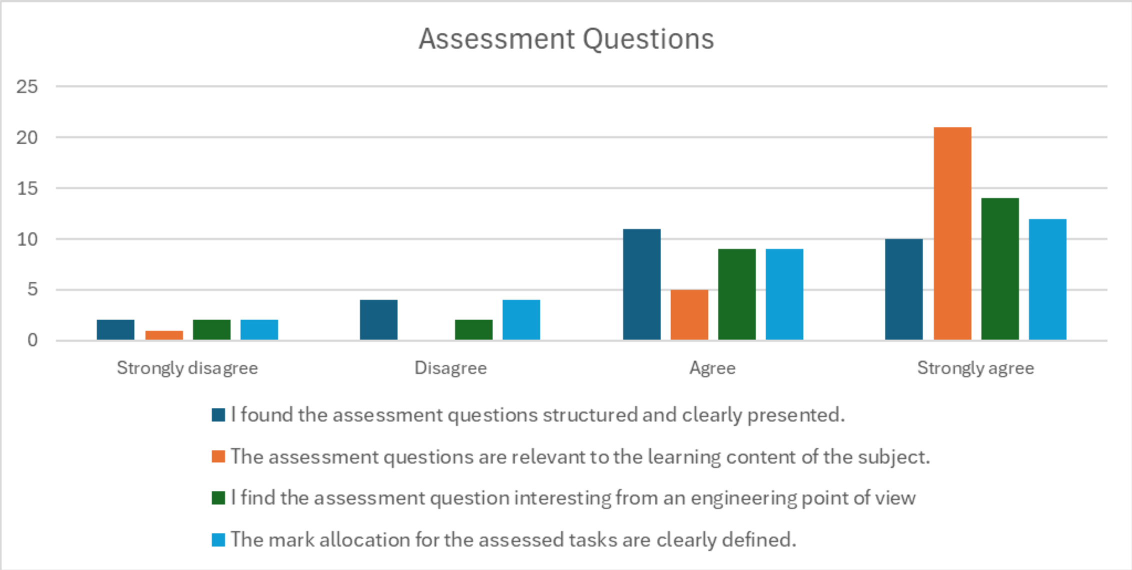

Figure 2 Graph representing students’ perception of assessment questions.

The outcomes regarding the perception of learning, are presented in Figure 3. A 5-point Likert scale was used for this question, with a neutral option being added. Most students are confident that they have learned in the subject. When asked if completing the assessments in MATLAB Grader contributed to their understanding, most students agree or strongly agree with the statement. However, neutral answers for the first statement were noticeably higher than the other three statements. This observation could suggest that some students may perceive the assessments as a method of measuring their learning progress rather than as a direct contributor to their understanding.

On the evaluation of learning, one should note that the use of this assessment tool allowed the use of more complex questions in the assessments, as mentioned earlier. In my experience teaching this subject for the past four years, the discussion and questions from students went much deeper than before the introduction of this assessment tool. In the past, students would get to the final equations, but they did not seem to understand their meaning. Questions that required some interpretation of the equations were left mostly unanswered in the final examination.

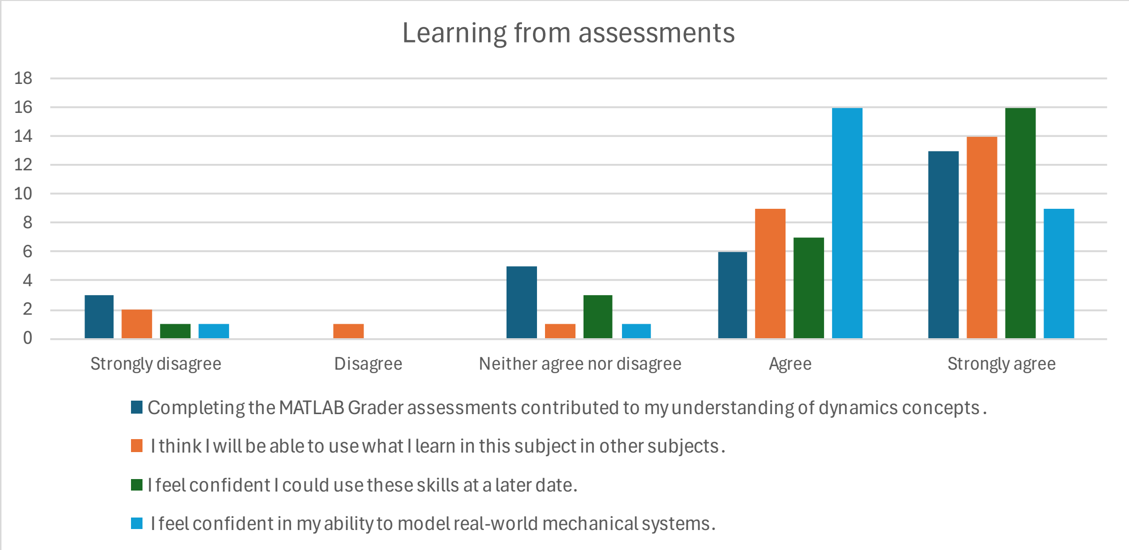

Figure 3 Graph representing students' perception of learning with assessment.

To demonstrate this trend, the evaluation of past exam questions is presented in Figure 4.The end-of-semester exam, while not using the assessment tool directly, allowed students to use MATLAB for their calculations, to ensure fairness of the assessment. The use of MATLAB was also allowed during the COVID period (2020-2021), before the assessment tool was implemented. Past exam questions have been analysed for higher-order understanding and the percentage of students who obtained non-zero marks in these questions was recorded. In 2020 fewer higher-order questions were used, and only around 25% of students attempted or had partially correct answers. In 2021, none of the exam questions were considered clearly high order and results were not included for 2021. MATLAB grader started being partially used in 2022 in a small part of the assessments, while in 2023-2024, most assessments used the tool. It is observed that the percentage of students with valid answers to those complex questions has increased significantly since the beginning of the implementation of this assessment tool. Although many factors influence students' learning, the analysis of past exam questions, when combined with students' perceptions of learning from the survey (Figure 3), provides compelling evidence that the use of MATLAB Grader as an assessment tool is effectively supporting students' learning process.

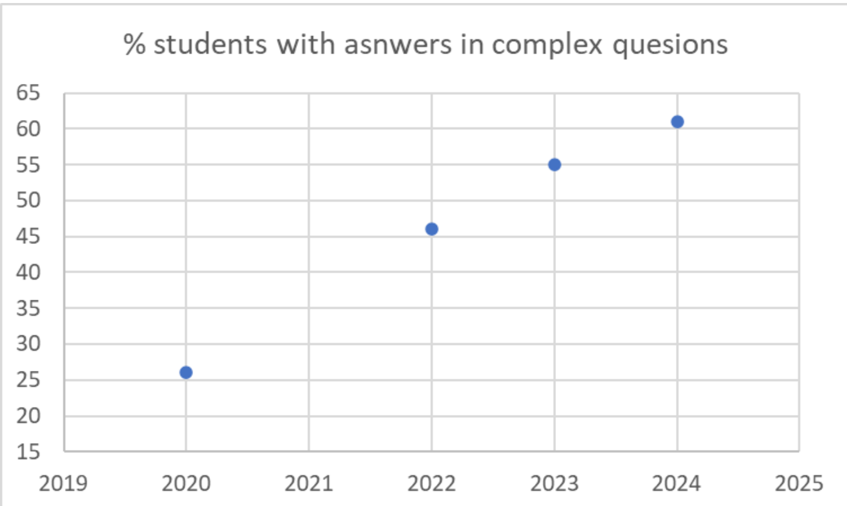

Figure 4 Percentage of students who obtained non-zero marks for complex questions in the final exam.

The outcomes related to feedback are presented in Figure 5. The statements in the survey attempted to make the difference between the machine feedback, related to programming errors, and the instructor-tailored feedback. These differences were also explained to students before the assignments. However, the results do not show a clear trend, and all statements exhibit a similar distribution. The lack of differentiation in the responses across different statements indicates the need for further improvement in this domain. One could expect a stronger correlation between the second and fourth statements, since both refer to instructor feedback after a whole submission. However, such a correlation is not observed. Moreover, looking at individual answers, we see many students give opposite answers to these two statements.

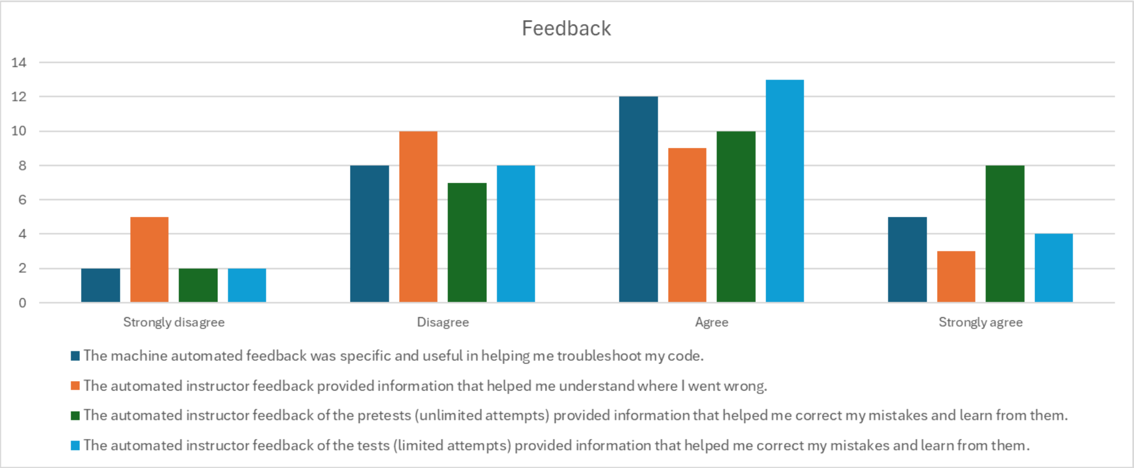

Figure 5 Graph representing students' perception about feedback.

Students' perception of feedback also contradicts students' perception of learning with assessments (Figure 3), where a more positive trend is observed. The feedback has been constantly reviewed over the years. Past students became teaching assistants and collaborated on the improvements of the feedback. Moreover, additional information to clarify to students the different types of feedback received has been provided. Despite these efforts, the perception about feedback is still less positive than the other survey outcomes. There were not many qualitative answers to the survey in general and from the comments received about feedback, it was not possible to identify any recurring theme. To understand this issue, the plan is to expand this work to understand how feedback is perceived and understood by students in this subject, which in turn will enable improvements in feedback delivery.

Conclusion and Recommendations

The use of the automated assessment tool MATLAB Grader in a rigid-body dynamics master-level subject has been successfully implemented. The tool allows different degrees of detail and assessment levels, while still allowing a certain level of flexibility in the way students solve the questions. By offloading calculations to the computer, this approach enables students to concentrate their efforts on understanding the core concepts of the subject matter. The analysis of past assessments corroborates this, as more students are demonstrating their ability to answer complex questions successfully. At the same time, this approach enabled the use of more interesting systems in the assignments, potentially contributing to students' motivation. This is supported by the survey results, which indicate that students find assessments interesting and have confidence in their learning within the subject. The survey results, combined with the analysis of past assessments, strongly suggest that the implementation of this automated assessment tool has effectively shifted the focus towards conceptual understanding of rigid-body dynamics.

While the flexibility of feedback customization in this assessment tool is very useful, feedback strategies must be further explored and implemented. Additionally, students could benefit from support in developing feedback literacy skills, empowering them to effectively utilize the provided feedback to enhance their learning experience.

References

Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). The future of engineering education: Part 2. Teaching methods that work. *Chemical Engineering Education*, *34*(1), 26–39.

Gu, Y. T., & Tan, A. (2009). *Using Visualization Tool to Help Engineering Students Learning Dynamics Methodology / Strategies*. 237–242.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Hesterman, D. C., Male, S. A., & Baillie, C. A. (2011). Some potential underlying threshold concepts in engineering dynamics. *Proceedings of the 2011 AAEE Conference, Fremantle, Western Australia, October*, 619–625.

Kumar, R., & Plummer, M. (1997). Using contemporary tools to teach dynamics in engineering technology. *International Journal of Engineering Education*, *13*(6), 407–411.

Lee, C. K., Hasan, Z., Sidhu, M. S., Lim, S. C. L., Lim, S. P., & Saw, S. H. (2020). A Preliminary Study on Student Learning Difficulties in Engineering Mechanics Dynamics. *8th International Conference on Information Technology and Multimedia (ICIMU)*, 120–125.

Lipinski, K., Docquier, N., Samin, J. C., & Fisette, P. (2012). Mechanical engineering education via projects in multibody dynamics. *Computer Applications in Engineering Education*, *20*(3), 529–539. https://doi.org/10.1002/cae.20421

Narayanan, R., Gudimetla, P., Roy, S., & Jayasuriya, A. (2019). Enhancing student learning experience with a simulation tool in engineering dynamics. *Australasian Association for Engineering Education Conference*, 201.

Smith, J. (2019). Determining Optimal Deployment Strategies of MATLAB Autograder to Maximize Student Learning and Engagement. *2019 ASEE Annual Conference & Exposition*. https://doi.org/10.18260/1-2--32627

Yee Chan, H., Lam, L., & De Souza, R. (2022). MATLAB Grader for Flexible Automated Assessment and Feedback in Large-Scale Engineering Subjects. *Proceedings of the 2022 AAEE Conference*.

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