

Four measures to activate students in Engineering Mechanics

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Abstract

Courses in Engineering Mechanics at TUD Dresden University of Technology traditionally rely on lectures and exercises, a format that poses challenges for student engagement, self-assessment, knowledge transfer, and collaborative learning. To address these issues, four activation measures were introduced: lecture questions, online quizzes, introductory videos for exercises, and learning group tasks. This paper describes the implementation and evaluation of these measures for one cohort of students across three semesters of Engineering Mechanics, from October 2024 to February 2026. Quantitative and qualitative analyses reveal increased participation, improved exam outcomes (with scores up to 11% higher for quiz participants), and enhanced group collaboration. The measures require a relatively small amount of additional effort while they are flexible and transferable to other curricula, offering a robust framework for activating students in engineering education.

Lehrveranstaltungen im Fach Technische Mechanik an der Technischen Universität Dresden (TUD) stützen sich traditionell auf Vorlesungen und Übungen – ein Format, das Herausforderungen hinsichtlich der Einbindung der Studierenden, der Selbsteinschätzung, des Wissenstransfers und des kollaborativen Lernens mit sich bringt. Um diesen Problemen zu begegnen, wurden vier Maßnahmen zur Aktivierung eingeführt: Vorlesungsfragen, Online-Quizze, Einführungsvideos für Übungen und Lerngruppenaufgaben. Dieser Beitrag beschreibt die Umsetzung und Auswertung dieser Maßnahmen für einen Jahrgang von Studierenden über drei Semester des Fachs Technische Mechanik hinweg, von Oktober 2024 bis Februar 2026. Quantitative und qualitative Analysen zeigen eine gesteigerte Beteiligung, verbesserte Prüfungsergebnisse (mit bis zu 11 % höheren Punktzahlen bei den Quizteilnehmern) und eine verstärkte Zusammenarbeit in den Gruppen. Die Maßnahmen erfordern einen relativ geringen zusätzlichen Aufwand, sind dabei flexibel und auf andere Lehrpläne übertragbar und bieten einen robusten Rahmen für die Aktivierung von Studierenden in der Ingenieurausbildung.

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1. Introduction

Engineering Mechanics at TUD Dresden University of Technology (TUD) has traditionally been taught in a classical format given by lectures and exercises. Each week consists of a 90-minute lecture presenting theoretical concepts and example applications, followed by a 90-minute exercise session in which students are expected to independently solve problems. While this structure is well established, several challenges have been identified in practice:

- Maintaining deep, uninterrupted focus on one topic for the entire 90-minute lecture is inherently difficult.
- Students often struggle to assess whether they have adequately understood the presented concepts.
- Transferring theoretical knowledge from lectures to problem-solving in exercises is demanding and occurs at different paces among students.
- Collaborative learning has been shown to be beneficial, yet not all students are able to establish effective study groups on their own.

In response to these challenges, several measures have been implemented in recent years. General concepts of these measures have already been presented in Sähn et al. [1]. The present contribution focuses on the evaluation of four specific measures aimed at increasing student activity within the traditional lecture–exercise framework. For each measure, a representative example is presented,

and student participation is analyzed across multiple semesters. Furthermore, both qualitative and quantitative evaluation results are discussed in order to assess the effectiveness of the implemented measures.

To that end the paper starts with an overview of the investigated courses in chapter 2, followed by chapters 3 to 6 - one for each implemented measure. Finally, conclusions are drawn in chapter 7.

2. Structure of the Courses in Mechanical Engineering

The analysis presented in this study is based on the subsequent courses Statics (S), Strength of Materials 1 (SoM 1), and Strength of Materials 2 (SoM 2), for one cohort of students between October 2024 and February 2026. As listed in Table 1, these courses are part of several engineering degree programs, including Mechanical Engineering, Materials Science, Process Engineering and Natural Materials Technology, and the Master's program in Textile Machinery and High-Performance Material Technology.

In Statics and SoM 1, the weekly schedule consists of one lecture and one exercise, each lasting 90 minutes. In SoM 2, the lecture is also held weekly, while exercises take place every second week. The number of participating students amounts to 251 in Statics, 245 in SoM 1, and 185 in SoM 2¹.

Differences in examination schedules arise from the structure of the degree programs.

Tab. 1: Structure of the three classes referred to in this contribution

	Statics	Strength of Materials 1	Strength of Materials 2
Lectures / Exercises per week	1 / 1	1 / 1	1 / 0.5
Course of study	Mechanical Engineering Materials Science Process Engineering and Natural Materials Technology Master's Degree Textile Machinery and High Performance Material Technology		Mechanical Engineering
Number of students	251	245	185

¹ The number of students refers to the number of exams that have been taken in that respective course.

Students of Mechanical Engineering take examinations after the first and third semesters, whereas students from other programs take examinations after the first and second semesters or after the second semester only. As a result, the number of exam participants in the evaluation in the following chapters varies between courses.

3. Lecture Question

To address the limited span of attention during lectures, interactive lecture questions were introduced. After approximately 45 minutes, students are presented with a multiple-choice question related either to the material just covered or to upcoming content. They are given three to five minutes to discuss the question with their peers before submitting their answers anonymously via a QR code using the platform Particify [2].

An example is taken from the first lecture of the Statics course, in which the concept of the rigid body is introduced. Students are asked to identify which of the following three examples can be modeled as rigid bodies²:

- a) the deformation of a bridge under loading,
- b) the crack propagation in an airplane or
- c) a tipped over crane.

After the voting phase, the results are discussed, and the lecture continues.

The evaluation of participation in Figure 1 shows that more than half of the students in Statics consistently take part in these questions throughout the whole semester³. Participation in SoM 1 starts similarly high but decreases in the second half of the semester. This decrease is caused by the students of Mechanical Engineering, who do not take an exam after that semester and tend to focus on the upcoming exams at hand. In SoM 2, participation is generally lower.

The lecture questions require students to actively reflect on the content and thus contribute to increased engagement during the lecture. Also, encouraging students to discuss the lecture question with their peers before voting

helps them to reflect on the content and provides a real break in the 90 minute lecture. In evaluations of courses, which are performed in every semester, students consistently rate this measure very positive.

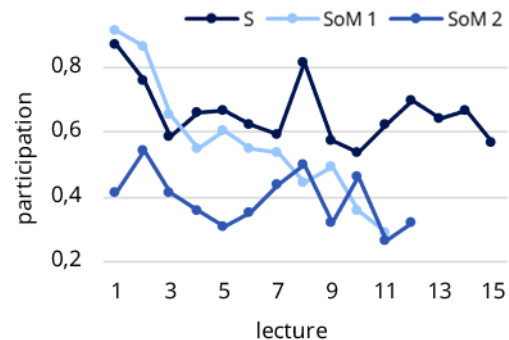


Fig. 1: Lecture Question: participation of the students throughout all three semesters.

4. Quiz

In order to provide students with opportunities to assess their understanding of theoretical concepts, online quizzes were implemented. Four quizzes are offered per semester, each consisting of ten multiple-choice questions and conducted via the learning platform OPAL [3]. Each quiz is available for one week and there is only one attempt to take part. The students are usually able to answer all ten questions within 10 to 15 minutes.

Students who correctly answer at least half of the questions receive a small bonus for the final examination. After the completion of each quiz, all questions are discussed in the subsequent lecture, including detailed explanations of the correct answers.

An example for a question in the quiz is shown in Figure 2 (a). A hinged beam with several loads is given and the students have to decide which distribution of the shear force in the given solutions belongs to the depicted beam. Other types of questions might include small calculations or may aim at a more detailed understanding of concepts and equations.

The student participation in those quizzes exceeds 50% across all courses, with the highest engagement observed in Statics, as can be

² The correct answer is c).

³ The participation is calculated by taking the number of votes for each lecture question divided by the number of students in the course (see Table 1).

seen in Figure 2 (b). The fact that successful participation in those quizzes is rewarded with bonus points for the exam, enables the quantitative evaluation of this measure. To that aim, the examination results are linked to the (successful) participation in the quizzes in Figure 2 (c). The plot shows the percentage of total points reached for all three evaluated courses. The bonus points from the successful participation in the quizzes are not taken into account at this point. Students who participate in

the quizzes achieve higher average scores compared to the overall cohort, depicted in black. This effect is even more pronounced for students who successfully complete all quizzes. The largest difference is observed in SoM 2, where these students achieve on average 11% higher scores than the overall group. Since bonus points are not included in this comparison, the improvement can be attributed to increased understanding rather than advantages at grading.

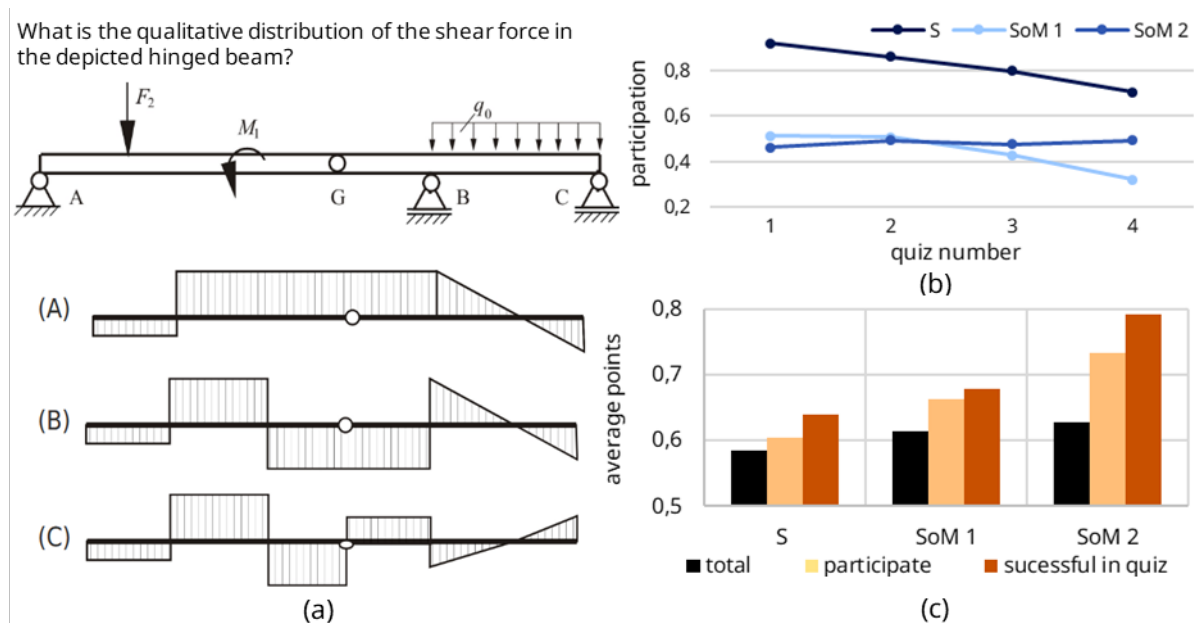


Fig. 2: Quiz: (a) example quiz question⁴, (b) participation of the students throughout all three semesters, (c) average points reached in the exam.

5. Introductory Video

Each exercise consists of three to four tasks to be solved by the students. The students are asked to prepare for the exercises by trying to solve the tasks by themselves in advance and ask the tutors for help during the exercise whenever they get stuck.

Traditionally, exercises begin with a 20- to 40-minute introduction by the tutor, including a summary of theoretical concepts and additional problem examples as well as hints for the tasks to be solved. This approach has some major drawbacks: First of all, students who prepared the tasks in advance - as they had been asked to do - have to wait until the end of the introduction by the tutor to get a chance

to ask a question. If those students already understood the concepts the tutor is introducing in that time, they lose valuable time. Students who tried to prepare but made little progress might need the information given by the tutor during the introduction to solve the tasks. Not having all the information from the beginning and knowing to get them only at the start of each exercise might demotivate them and some might not prepare at all for the next exercise. Some students need more detailed and individual support than an introduction on the blackboard can give them. In summary it can be said, that it is very hard to tailor an introduction at the beginning of an exercise to meet the needs of all students and still encourage them to prepare for each exercise.

⁴ The correct answer is (A).

To address those problems, an introduction to the exercises, as would be given during the exercise, was recorded and can be accessed prior to each exercise. An example for the final frame of such an introductory video is given in Figure 3 (a).

The students are encouraged to prepare the tasks with the help of the recordings and no additional introduction is given during the exercise. This enables the students to prepare in their own pace and at their own time and watch the videos in time-lapse or slow motion and more than once if they need to. In addition to a more individualized preparation of the exercises, the full 90 minutes can now be completely dedicated to discussion and problem-solving.

Data of the usage indicates that students make extensive use of these introductory videos. Figure 3 (c) shows the number of interactions⁵ with the videos throughout all three semesters, which is consistently above one and even close to two for Statics. This leads to the conclusion, that every student accesses each video at least once. To further evaluate the preparation of the students, Figure 3 (d) shows the participation by only taking into account the interactions with the videos until the day before the first appointment of the corresponding exercise⁶. For the Statics course this participation is close to one throughout most of the semester. Those numbers decrease for SoM 1 and SoM 2. The drop at the end of SoM 1 is expected, as already discussed in chapter 3. The lower participation in SoM 2 can possibly be related to the biweekly exercise schedule, neglecting the preparatory interactions of the students who prepare for the exercise in the second week. Another point worth mentioning is, that in Statics and SoM 1 the videos are online for a limited time only, aiming to enforce learning throughout the semester. In SoM 2 the videos were available from before the exercise until after the exam at the end of the semester.

⁵ Interaction with the videos can be the watching of the full video or just accessing parts of it. It was not possible to get more detailed information from the OPAL-statistics.

⁶ Exercises are distributed throughout the week to accommodate the students' different schedules. If the same exercise is held on Tuesday and Thursday, the plot will take

A more detailed view of the interactions over time with the videos for exercise one and nine in SoM 1 is shown in Figure 3 (g). The shaded blue box marks the period of time when the video for exercise one is online. The vertical medium blue lines mark the days on which exercises being held. The dark blue line documents the interactions on each day. There are three distinctive peaks in this curve. The first peak is located on the day before the first exercise – clearly indicating the students' preparation for the upcoming exercise. The second peak rises one week later when the next exercise is relevant, probably indicating some follow-up studying of the first week. Another week later, there is a third peak when students try to access the video that is already offline. Interestingly, the same general shape of the curve can be observed for exercise nine. While participation in general decreased, there is still a majority of interactions before the exercise. Since one goal of providing the videos was to encourage the students' preparation of each exercise, this data indicates a clear success of that measure.

In addition to the presented quantitative participation data, a qualitative evaluation of those introductory videos was conducted during the SoM 1 course using limesurvey [4], where 94 students took part in that survey.

Figure 3 (e) shows the students' opinion about the length of the videos, which is perceived as just right. Figure 3 (f) shows, that most students feel that enough details are presented in the videos, followed by a smaller portion of students wishing for more details.

When discussing the more detailed opinions shown in Figure 3 (b) from bottom to top, it can be stated, that more than 70 % of the students state to watch the video before each exercise. This is consistent with the quantitative results from Figure 3 (d). About half the students claim to have a look to review the actual tasks for each exercise in advance, while 40 % feel that

into account the participation up until Monday. Therefore, some interactions for preparation might be neglected if the students of a Thursday exercise prepare on Tuesday or Wednesday.

the videos help them to solve those tasks by themselves. Around 30 % of the students would rather have an introduction during the exercise instead of the introductory video.

The introductory videos are introduced, to foster self-paced preparation of exercises and, by

freeing up time, enable longer and more detailed discussions during the exercise. The numbers of participation as well as qualitative feedback and the subjective experience of the tutors testify to the effectiveness of this method.

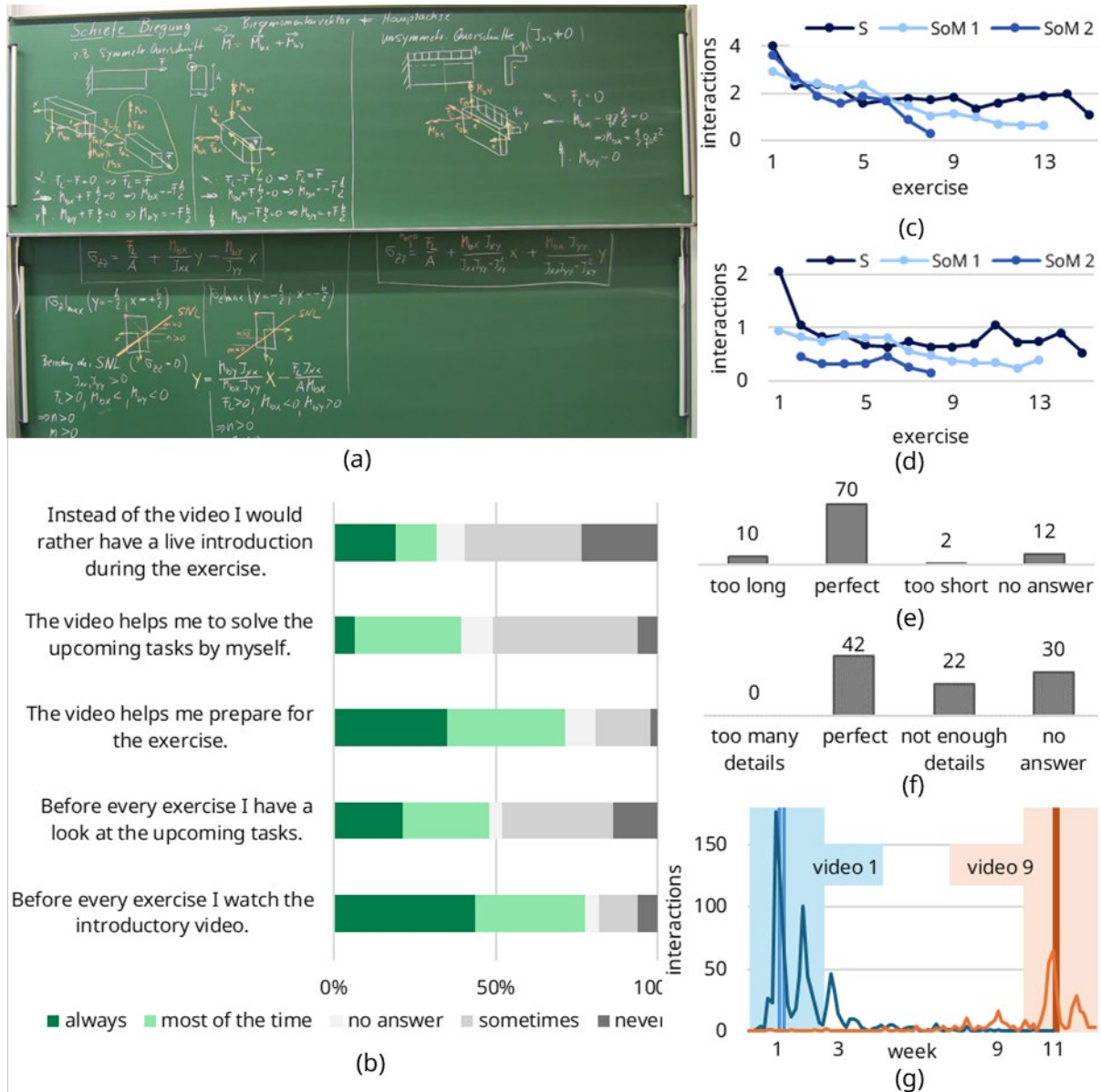


Fig. 3: Introductory Video: (a) picture of the blackboard at the end of an introductory session, (b) qualitative evaluation of the videos, (c) interactions of the students throughout all three semesters, (d) interactions of the students until before each corresponding exercise throughout all three semesters, (e) student's opinion on the length of the videos, (f) student's opinion on the amount of details in the videos, (g) detailed interaction with video 1 and 9 for the course Strength of Materials 1.

6. Learning Group Task

To promote collaborative learning among students, learning group tasks⁷ were introduced. For that purpose students enroll in groups of six. Those groups are fixed throughout each semester. Within the group, they have to solve several tasks (1 in Statics, 5 in SoM 1, 6 in SoM 2) and hand in their solutions. The tutors check the results and give feedback. If students complete almost all tasks correctly in a given semester and have attempted all of them, they receive one bonus point for the exam.

The content of the task is often a very practical problem, as shown for example in Figure 4 (a) and (b). The students are presented with a picture of a traffic sign near the campus in (a) and a model of the traffic sign in (b). They are then asked to calculate the inner forces within this traffic sign.

The necessary knowledge to solve the respective problem has been discussed during the lecture but was not yet covered in the exercise. Therefore, the students have to transfer the presented knowledge into application all by themselves. This requires considerable effort

for the students as well as reviewing the results and providing feedback requires a lot of effort for the tutors.

Even so, the participation rates are high across all courses, reaching approximately 80 % in Statics, over 70 % in SoM 1, and above 50 % in most of the tasks in SoM 2.

Since bonus points are awarded for correctly solving the tasks, the (successful) participation in the learning group tasks can again be linked to the results of the exam, as presented in Figure 4 (d). On average, students who do take part in the learning group tasks achieve higher scores in the exam than those who did not⁸. Even higher scores of up to 7 % are reached by those students who successfully took part and earned all available bonus points. The increase in performance is less prominent than for the quizzes presented in chapter 4. This might be attributed to the nature of group work in general, since it does not ensure that every team member actively participates.

More importantly, it could be observed that the formed learning groups not only worked together to solve the given tasks in Engineering Mechanics but also continued to collaborate in

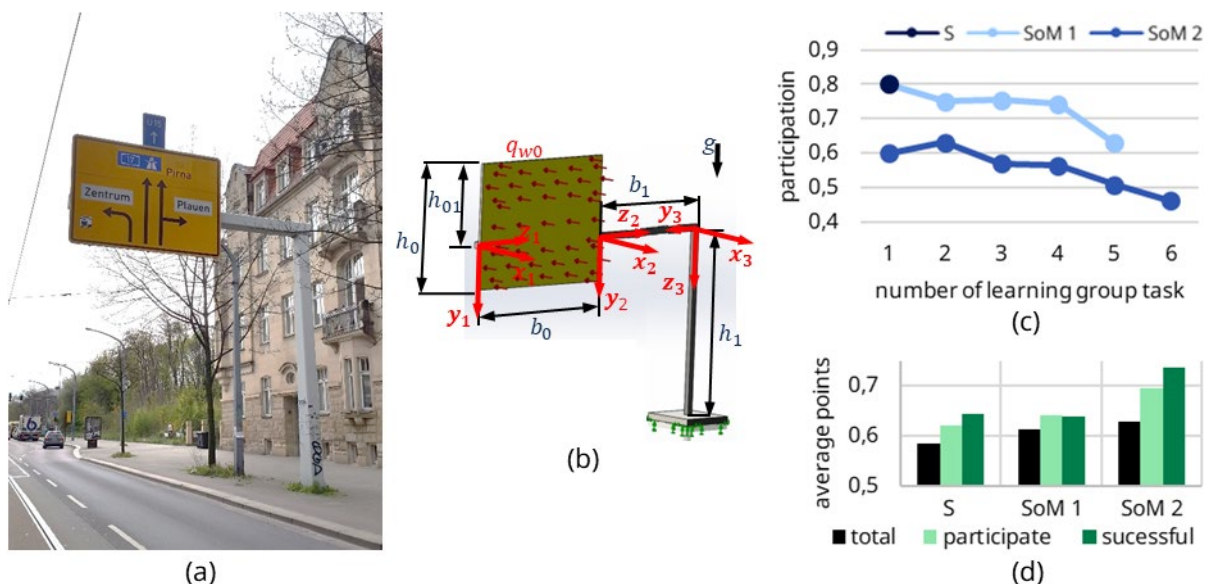


Fig. 4: Learning Group Tasks. Exemplary task: Calculate the inner forces of the traffic sign near the campus (a) according to the model in (b); (c) participation of the students throughout all three semesters, (d) average points reached in the exams.

⁷ First implemented by Prof. Stefan Odenbach (private communication, 2017)

⁸ For better comparison, bonus points are not included in this evaluation.

other courses, fostering a valuable network of collaboration from the very beginning of their studies. Additionally, the tutors recognized that those learning groups who solved the tasks were much better prepared for the exercises to come. By transferring the presented knowledge into practical application on their own, they seemed to learn the concepts of mechanics much more effectively.

7. Summary and Conclusion

This study has demonstrated the successful implementation and evaluation of four activation measures within the classical curriculum of Engineering Mechanics at TUD consisting of lectures and exercises. The introduction of lecture questions effectively breaks up lectures and is highly valued by students. Regular online quizzes provide essential feedback on theoretical understanding and are strongly correlated with improved exam performance. Pre-recorded introductory videos enable self-paced preparation, freeing exercise time for deeper engagement and discussion. Learning group tasks promote knowledge transfer and foster lasting collaborative relationships, further enhancing exam outcomes. Each measure is relatively simple to implement and can be adapted to a wide range of curricula. Moreover, measures such as the lecture question and introductory video also enrich the teaching experience. Overall, these measures offer easy-to-implement methods for activating students and improving learning outcomes in engineering education.

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used you.com, ChatGPT, DeepL as well as Claude (Anthropic) to aid in text refinement and grammar checking. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Credit Authorship Contribution Statement

U. Gebhardt: Conceptualization, Data Curation, Formal analysis, Methodology, Visualization, Writing – original draft. **M. Kästner:** Conceptualization, Methodology, Project Administration, Resources, Supervision, Writing – review & editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Literature

- [1] Sähn, M., Gebhardt, U., & Kästner, M. (2023). "Mechanik macht Spaß": Lehrveranstaltung Technische Mechanik - Statik/Festigkeitslehre – nach 2 Jahren Corona. *Lessons Learned. Spin Offs Digitaler Lehrerfortbildungen*, 3(2). <https://doi.org/10.25369/ll.v3i2.78>
- [2] Particify [cited 8th of April 2026] <https://www.particify.de/de/>
- [3] OPAL - Online-Plattform für Akademisches Lehren und Lernen [cited 8th of April 2026] <https://bildungsportal.sachsen.de/opal/>
- [4] limesurvey Umfragetool [cited 17th of April 2026] <https://www.limesurvey.org/de>