

THE ROLE OF LEARNING SPACE IN ENHANCING ACTIVE LEARNING: INTRODUCING THE STEM-CENTER AT TAMPERE UNIVERSITY OF APPLIED SCIENCES

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This paper describes the transformation of engineering physics education through activating teaching methods for better learning outcomes and the redesign of learning spaces to support these pedagogical approaches. The transformation of a traditional physics laboratory into a versatile group work and multipurpose space known as the "STEM-Center," at Tampere University of Applied Sciences is presented. The transformation was inspired by active pedagogical methods such as "Peer Instruction," "PDEODE," and the "SCALE-UP" method and its associated spaces. After the transformation, the space remains suitable for physics laboratory work. Across all courses, it encourages students to be active participants rather than passive listeners, which in turn improves learning outcomes. Most students express high satisfaction with the pedagogical methods and the learning environment as well as a preference for these engaging and activating methods over traditional lecture-based teaching, highlighting an enhanced learning experience and a stronger sense of ownership over their learning.

Keywords: Learning space, groupwork, activating methods.

INTRODUCTION

Engineering physics combines theoretical concepts of physics, the laws of physics, and their practical applications in everyday life, in machines, devices and measurements. This requires teaching methods that go beyond traditional lecture-based approaches. In recent decades, the emphasis has shifted towards more participatory and student-centered approaches and activating teaching methods.

The concept of active learning encompasses a broad range of practices that promote student engagement, critical thinking, and a deeper understanding of course contents. Unlike passive listening to lectures without direct participation, active learning encourages students to participate actively in their education through discussions, problem-solving, group work, and other interactive methods. Different studies have highlighted benefits of active-engagement learning methods. Prince [1] has found support for all forms of active learning examined in his studies. Freeman et al. [2] carried out a meta-analysis of 225 studies that had reported course scores and passing rates in STEM courses, and they compared results of studies between traditional lecturing method and active learning methods. Their analysis indicated that using active learning methods can increase passing rates and course scores. Deslauriers et al. [3] has show improved learning outcomes in a large-enrollment physics class when using pre-class reading assignments, pre-class reading quizzes, in-class clicker questions with student-student discussion, small-group active learning tasks and targeted in-class instructor feedback. Especially, they found that active learning methods have great benefits with small groups, but it is effective for all group sizes. Wieman has found similar positive effects [4]. In addition to active-engagement methods, also self-regulatory skills are also often connected with active learning. Research has shown that when mastering own learning process and feeling the ownership of learning, learning outcomes are typically better [5, 6].

The physical and virtual environments where learning takes place play a crucial role in facilitating or hindering active learning practices. Learning spaces include traditional classrooms, digital platforms, laboratories, libraries, and any other environments where learning occurs. The design and organization of these spaces can significantly affect students' ability to engage actively with the material, their peers, and their instructors. In physics learning and teaching, the space should accommodate various teaching methods and learning activities, including group discussions, individual study, and hands-on experiments. Therefore, the layout and furniture should be easily reconfigured for different activities. Modern learning spaces incorporate ICT technology to facilitate access to information, collaboration, and interaction both onsite and online. Designated spaces for group work and collaboration encourage students to work together, share ideas, and learn from one another, which is a key aspect of active learning. Research has shown that well-designed learning spaces can have a positive impact on student engagement, motivation, and learning outcomes. A study by Cotner et al. [7] found that students in classrooms designed for active learning reported higher levels of engagement and better understanding of course material compared to those in traditional lecture-based classrooms.

While the benefits of learning spaces designed for active learning are clear, there are challenges to their implementation. These include the cost of redesigning physical spaces, the need for faculty training on how to effectively use these environments, and the ongoing maintenance of technology and furniture. Additionally, the transition to more active learning spaces requires a cultural shift within educational institutions, moving away from traditional lecture-based teaching methods toward more student-centered approaches. Beichner and Saul demonstrated the impact of the SCALE-UP (Student-Centered Active Learning Environment for Undergraduate Programs) classroom design on student performance and engagement in physics education, highlighting the importance of physical space in promoting active learning strategies [8].

The next chapter describes the transformation of a traditional physics laboratory at Tampere University of Applied Sciences (TAMK) into a versatile group working and multipurpose space known as the "STEM-Center". The transformation was inspired by active pedagogical methods such as the above mentioned "SCALE-UP" method and its associated spaces and other methods like "Peer Instruction" [9] and "PDEODE" [10]. These methods are explained in more detail later. The focus is on how the learning space and its facilities can enhance the use of active learning techniques, and how students receive activating methods.

FROM PHYSICS LABORATORY TO STEM-CENTER

A few years ago, one of the physics laboratory spaces was transformed into an engaging group work and multipurpose space. This STEM-Center is used to deliver engineering degree education, vocational teacher education, international degree education, continuous learning, and pedagogical training courses. After the transformation, the space still remains suitable also for physics laboratory work. Across all courses, it encourages students to be active participants rather than passive listeners, which in turn improves learning outcomes.

Active participation and knowledge processing are the cornerstones of effective learning. The goal was to create a classroom environment where students are constantly interacting with the material, engaging in group work, reflecting on phenomena, sharing their outputs, and applying concepts in different contexts. Group work serves as a platform for collaborative problem-solving and idea exchange. It reflects real-world scenarios where engineers often work in teams to solve complex problems. In this environment, students learn to articulate their

thoughts, listen to alternative perspectives, and develop solutions together. Group projects and laboratory work are typical examples where students can apply theoretical knowledge to practical tasks, enhancing their understanding of physics concepts. Additionally, group work helps develop soft skills such as communication, teamwork, and leadership, which are crucial in professional engineering roles.

Figure 1 shows the room as a traditional physics laboratory before the transformation (A), the initial sketch of the desired outcome (B) and the realized outcome (C). The plan was inspired by SCALE-UP layout with additional option for laboratory working. Before the transformation, the laboratory typically accommodated 16-24 students simultaneously. Now there are group work tables for 36 students and additional 10 seats near the windows. Unfortunately, both budget and structural limitations changed the plan in such a way that it was impossible to remove the wall between the corridor and the former laboratory room (Fig. 1 C). Also, the glass wall between the STEM-Center and the adjacent laboratory room had to be left out. Despite these limitations, the space now has facilities for group working and laboratory working, sharing of outputs both onsite and online, and streaming the teaching and measurements online.

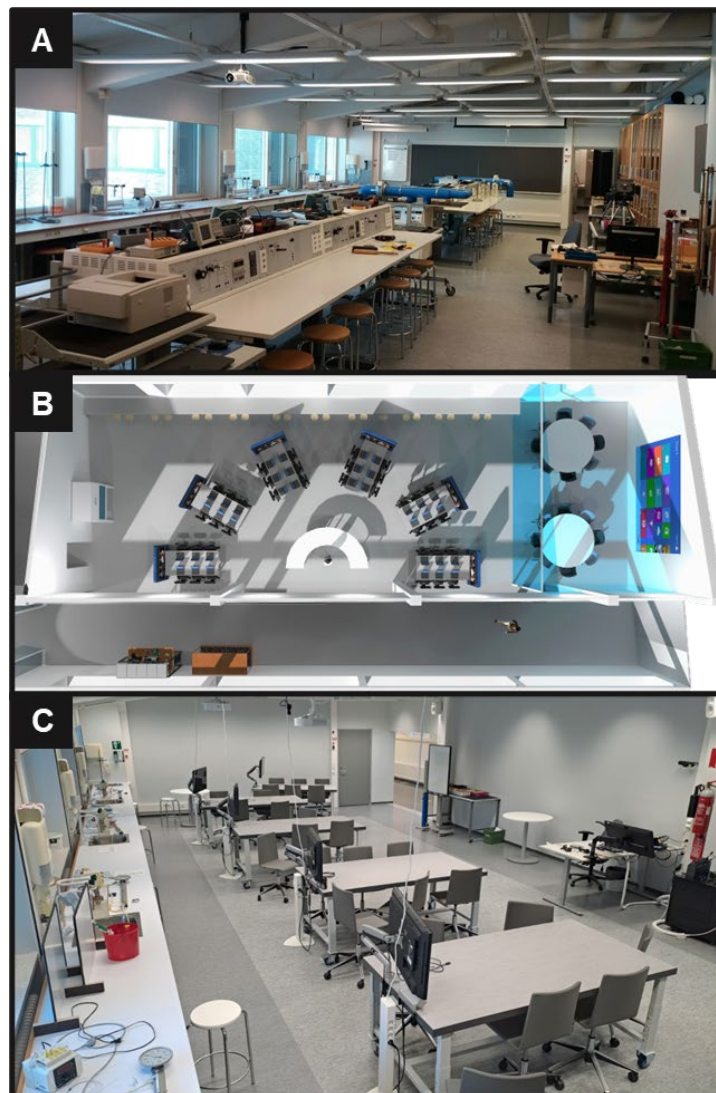


Fig. 1. The space initially as a physics laboratory (A), the sketch for modifications (B), and the actual output, the space as STEM-Center after the renovation (C).

PEDAGOGICAL METHODS

Unlike traditional classroom teaching, STEM-Center fosters student-centered and active learning where theory and practice are both present. One pedagogical method used in engineering physics at TAMK is peer instruction, developed by Harvard professor Eric Mazur in the 1990s (Mazur, 1999). It emphasizes collaborative learning through peer interaction. In this approach, students engage in discussions with their peers to grapple with challenging concepts and solve problems collectively. By explaining concepts to their peers or engaging in peer-led discussions, students not only reinforce their understanding but also develop communication and critical thinking skills. This collaborative environment fosters a sense of shared responsibility for learning, promoting a deeper understanding of engineering physics principles.

In a typical peer instruction situation, the teacher poses a conceptually challenging question, students initially ponder the question individually, and then they discuss their thoughts with their peers. This method not only promotes deeper understanding through discussion but also allows students to teach and learn from each other, promoting a collaborative learning environment. Mazur's approach has proven to be particularly effective in elucidating complex physics concepts, enabling students to explore and correct misunderstandings through peer discussions. Another method, PDEODE (Predict, Discuss, Explain, Observe, Discuss, Explain), expands Peer Instruction with the observation phase. After pondering the phenomenon individually and in small group, the students actually observe a measurement or a demonstration of the topic. Then they (re)form their understanding of the topic again. One version of this PDEODE method is simple measurement assignments for enhancing active participation and building of conceptual understanding of the topic [11]. These measurement assignments also serve as one method of continuous formative assessment.

In all above-mentioned pedagogical methods, the key issue is to first make own understanding visible (by sketching, explaining etc.). Then, the understanding needs to be presented and shared with peers. With the help of the learning environment's technology, the outputs, ideas, and thoughts produced by student groups can be easily shared digitally for further discussion. The teacher can easily facilitate the independent work of student groups. The monitors at the group workstations help small groups work together, processing the same data or working on presentations (Figure 2).



Fig. 2. Students working in small groups and sharing the output within the group.

Simultaneous sharing of learners' outputs is possible with three projectors. One projector image can be divided into four equally sized areas, each of which can be shared from one computer screen using a wireless transmitter (Figure 3 insert). With these transmitters and projectors, it is possible to simultaneously display the outputs of eight groups with two projectors and compare or discuss them (Figure 3). For laboratory working, all necessary equipment and devices are stored in the room or in its immediate vicinity (Figure 4).

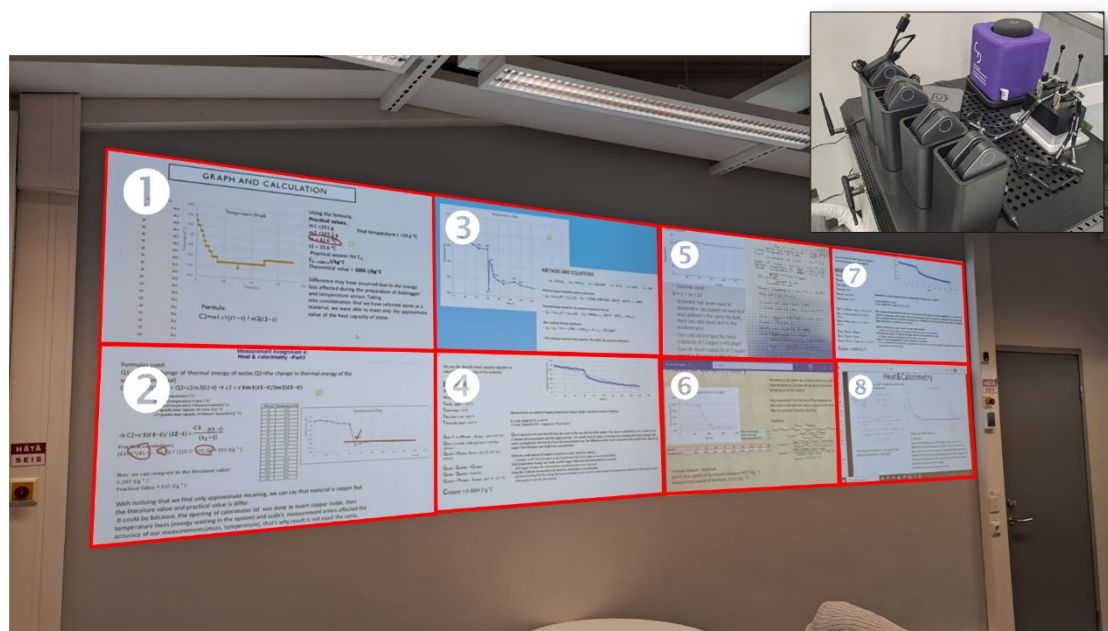


Fig. 3. Using the wireless transmitters (insert) it is possible to simultaneously display the outputs of eight groups with two projectors and compare or discuss the results.



Fig. 4. For laboratory working, all necessary equipment and devices are stored in the room or in its immediate vicinity.

STUDENT FEEDBACK AND TEACHER EXPERIENCES

Teaching held in the STEM-center space mainly consists of laboratory work and smaller measurement tasks supporting theoretical courses. Teachers' experience of the space is that it works well in both roles. Monitors for group workstations allow small groups of people to work together, processing the same data or making a presentation. Simultaneous sharing of learners' outputs is possible. The space is spacious enough so that group work can also be done while taking measurements.

Feedback was collected from one student group. There were 24 answers from 36 students. It consisted of open-ended questions and statements on 5-point Likert scale. The statements and the answers to them are shown in the figure 5. By first analyzing the open-ended feedback, the following aspects can be highlighted:

- 80 % of the responses mentioned the effectiveness and appreciation for practical, hands-on learning, measurement tasks, and the application of physical principles in real-world scenarios.
- 63 % of the responses highlighted the positive aspects of the course's structure and learning approach, including the practical method of teaching, interesting classes, and the versatile grading method consisting of measurement tasks and exams.
- 13 % of the respondents recommended refining assessment methods to better gauge individual learning outcomes instead of having a heavy weight on group working results.

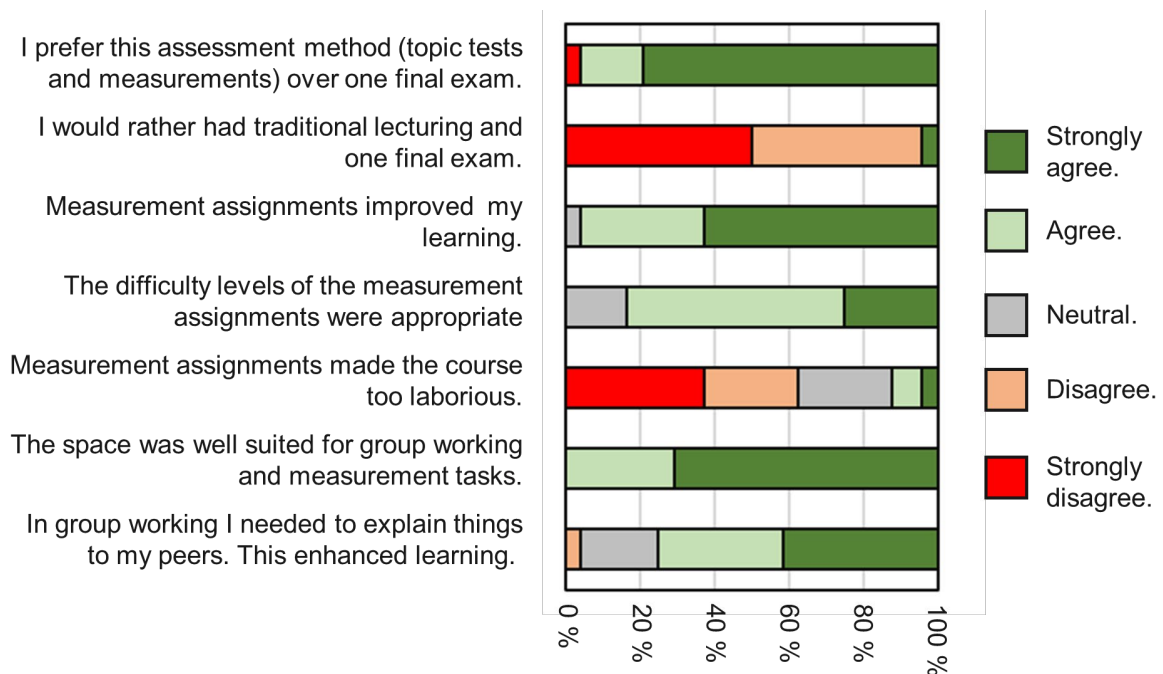


Fig. 5. The statements and the answer distributions to them.

The results indicate high satisfaction with the pedagogical methods and the learning environment. Vast majority of students express a preference for these engaging and activating methods over traditional lecture-based teaching, highlighting an enhanced learning experience and a stronger sense of ownership over their learning. Based on the responses, students are quite

satisfied with pedagogical methods and measurement tasks. They felt that both experimental measurement and visualization and group work improved their own learning. Only very few would like to return to traditional lecture-style teaching and a single final exam. Instead, almost all respondents supported engaging methods.

SUMMARY

In conclusion, activating methods and peer discussion-enhanced active learning play a crucial role in enhancing learning outcomes in Bachelor's level engineering physics education. By fostering active engagement, deepening understanding, promoting skill development, facilitating retention and enhancing motivation and engagement, these methods empower students to become active participants in their learning journey. A student response to open-ended feedback question summarizes it well:

“After taking this course, I felt that I never had a real physics course before. I enjoyed it a lot. Also, it made me feel that I will become an engineer one day, hopefully.”

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