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Active Learning in Engineering Education: Case Study in Mechanics for Engineering

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Abstract. A task force on outcome-based approaches (OBE) to develop higher education was focused on by the Ministry of Higher Education, Science, Research and Innovation (MHESI) and Mahidol University (MU). MU had already started emphasizing student outcomes in its quality reviews and considered OBE a logical next step in advancing higher education. Active learning, in the concept of 'teach less, learn more', is a teaching method that involves engaging students in the learning process through activities such as discussion, boardgame, project-based solving, and collaborative activities. It was claimed that academic attainment could be enhanced by active learning. In the field of engineering education, active learning has been shown to be an effective way to enhance student learning and improve outcomes. This paper gives a comprehensive study case of the subject "Mechanics for Engineer" including how the instructor created the active learning activities for each module, the indicators used to assess students' learning outcomes, an analysis of the results of using active learning, and the reflections of stakeholders. The presented activities in this paper consist of 3D equilibrium & Application: Think-Pair-Share, Vector addition - Board game, and Structural analysis - Project-based learning. Additionally, the case study explored reflection to analyze the challenges and issues that arose during the implementation of active learning and discuss strategies for addressing them.

Keywords. Engineering Education; Outcome-based approaches; Active learning; Project-Based Learning

Introduction

Outcome-Based Education (OBE) is an educational approach that focuses on the desired learning outcomes or skills that students are expected to acquire at the end of their educational journey. According to the Ministerial Regulation Standards for Higher Education Curriculum B.E.2565 (2022) by the Ministry of Higher Education, Science, Research, and Innovation (MHESI), OBE has become the main issue for all universities and Higher Education institutions in Thailand. One of the key advantages of OBE is that it helps students become more engaged and active participants in their learning process. By clearly defining learning outcomes and aligning teaching strategies with those

outcomes, OBE creates a more student-centered approach that allows students to take ownership of their learning and develop the skills and knowledge they need to succeed in their chosen fields. [1]

Higher education, especially in the field of Engineering, can be challenging for a variety of reasons including academic issues, student engagement, support, and the provision of resources. To be an effective teacher in engineering, it is important to stay updated in the field and to have a deep understanding of the latest developments and technologies. This can involve staying up to date with research and staying engaged in professional organizations and networks.

There is a strong link between OBE and active learning. OBE is designed to promote active, student-centered learning that emphasizes the practical application of knowledge and the development of critical thinking skills. Active learning, similarly, involves engaging students in the learning process through experiential activities that promote deeper understanding and retention of information [2-4]. Students' cognitive involvement has been connected to deeper learning [5].

In an OBE framework, as shown in Figure 1, active learning strategies can be used to help students achieve the desired learning outcomes. These strategies may include problem-based learning, case studies, group projects, simulations, and other collaborative activities that encourage students to take an active role in their learning. By engaging in active learning experiences, students are able to develop the skills and knowledge needed to achieve the learning outcomes defined by the institution or program.

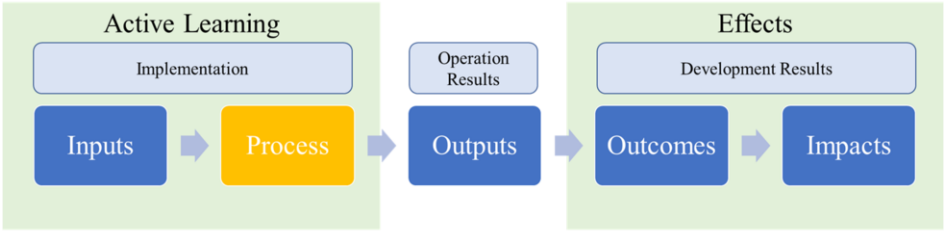


Figure 1. Outcome-based education framework.

Engaging your students in the learning process can be key to your own development as a teacher in engineering [6]. This can involve using innovative teaching methods, such as problem-based learning or project-based learning, to keep students engaged and motivated. Encouraging your students to think critically and solve problems is also an important part of being an excellent teacher in engineering. You can do this by presenting students with challenging problems or tasks and asking them to develop their solutions. Moreover, creating a positive learning environment is key to being an *active learning* teacher in engineering. This can involve being approachable and available to students, fostering a sense of community in your class, and promoting a culture of respect and collaboration.

The objective of the study is to demonstrate the example of developed activities and analyze the SWOT (Strengths, Weaknesses, Opportunities, and Threats) of "The Mechanics for Engineering (EGII201)" class using active learning as a teaching approach. Critically reflective teaching requires community college teachers to identify and investigate the assumptions they hold about teaching and learning by using the lenses at their disposal: students' eyes, colleagues' perceptions, and teachers' autobiographical experiences as learners [7]. It is hoped that this study can help educators to understand

the potential benefits and challenges of using active learning and to make informed decisions about how to implement it in their classrooms.

1. Development of the Active Learning activities

Figure 2 shows the process to develop the active learning class. Developing active learning for EGII201 starts by considering the course's learning objectives and setting them as the main goals. Course content is divided into sessions and sub-topics as defined in the curriculum using the design principle of outcome-based education [8] to select the priority of topic to create the activities and assessments as shown in Figure 3. After that, the objective of each session will be created to fulfill the course objective and to create the session outline.

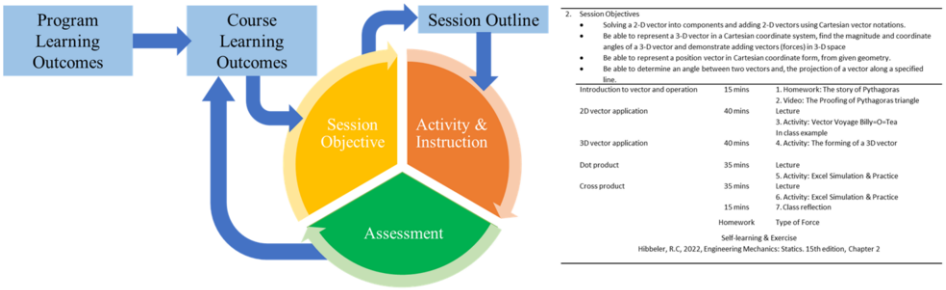


Figure 2. Outcome-based education framework.

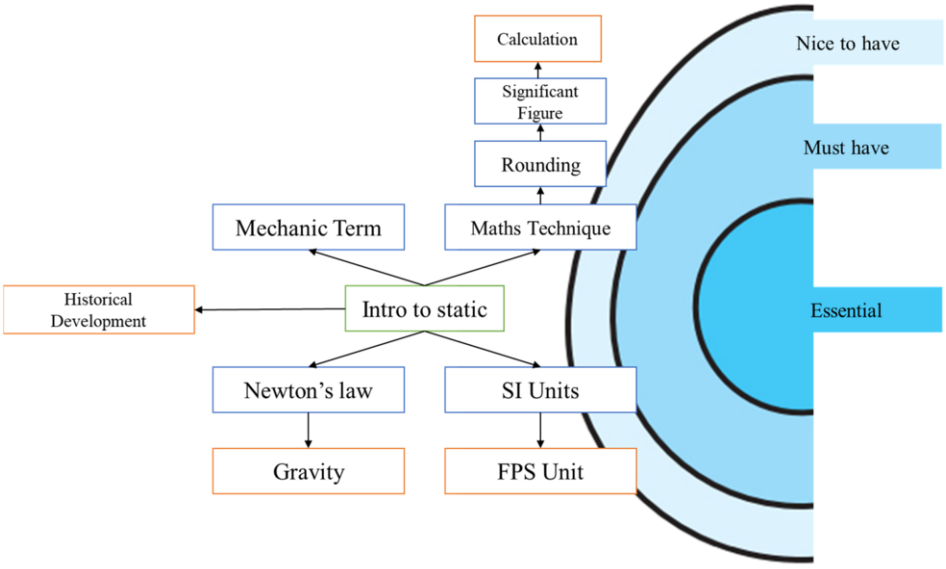


Figure 3. Sub-topic based on the design principle of outcome-based education.

1.1. 3D equilibrium & Application: Think-Pair-Share

The Think-Pair-Share approach [9] is an active learning strategy that encourages students to engage with course material and each other through a three-step process as shown in Figure 4. The Think-Pair-Share approach is a simple but effective way to get students actively engaged in their own learning, while also promoting collaboration and communication. It can be used in a variety of subjects and at different grade levels and can be adapted to different class sizes and time constraints.

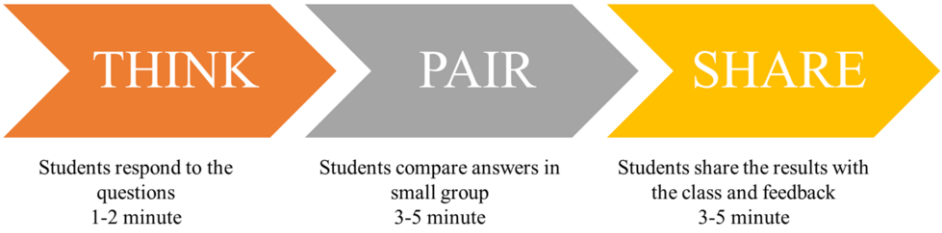


Figure 4. Think-Pair-Share approach.

In this activity, after learning the basics of equilibrium, students will be assigned to finish the construction of 3D floating Lego (Figure 5) to make sure that students can gain the idea of 3D equilibrium in real-life applications. There are some leading questions in the activity worksheet to make them "Think". Next, students were grouped in pairs and groups of 4-5 to "PAIR" the ideas with the levitation table/chair. Finally, the groups of students will present the ideas and calculations as "SHARE".

Figure 5. 3D equilibrium & Application using the Think-Pair-Share approach.

1.2. Vector addition: Board game

Board games can be a useful and enjoyable tool for education. Many different types of board games can be used for education, including strategy games, educational games, and games that teach specific subjects such as math or history [10]. It is important to choose a game that is appropriate for the age and ability level of the students and aligns with the educational goals of the lesson.

This activity is designed to reinforce a lesson on 2D Vector Addition and Subtraction: Graphical Methods. Students are divided into 4 groups of approximately 4-5 students each. The equipment used consists of A2 size maps for groups, A4 size maps for individuals, and color pens. Each group will be randomly selected to originate in

Asian countries with the target of moving to the designed country. In each sailing time, students can choose no more than 5 units for north-south, and east-west directions. The instructor will randomly determine the wind direction for each round. Students are responsible for finding the sum of the results of the sailing that the group has chosen along with the received wind direction as shown in Figure 6 by using the different methods of the vector operation.

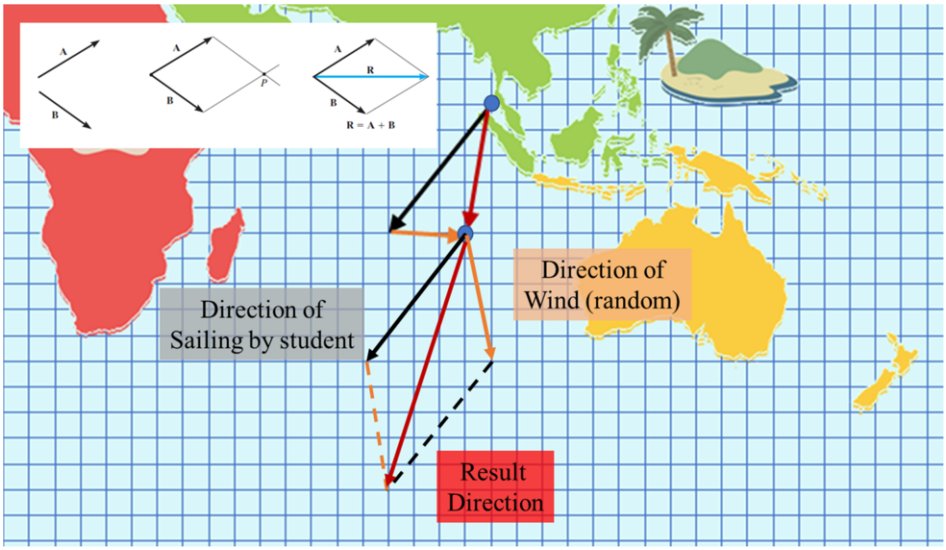


Figure 6. Example of parallel method in boardgame

1.3. Structural analysis: Project-based learning

Project-based learning (PBL) is an instructional approach in which students learn by actively engaging in real-world, complex problems or challenges. Active-learning pedagogies such as project-based learning are examples of learning environments that encourage student engagement. These active-learning methodologies are classified as inductive learning [11]. In PBL, students work on a project over a 5-week period, applying their knowledge and skills to solve a problem or complete a task.

A structure refers to a network of connected elements that serve to sustain external loads. The structural analysis involves forecasting how structures will react to given external loads. In the initial phases of structural design, the probable external load of a structure is assessed, and the size of the interconnected elements is established accordingly.

A group of 4-5 students will be given a problem in designing a bridge across the design gap with the following dimensions: Length range: 35-45 cm, Width range: 10-15 cm, and Maximum depth: 10 cm. Each week, students will receive more requirements to make sure that they can produce the progress of this project. The assessments were performed differently in each task as shown in Figure 7.

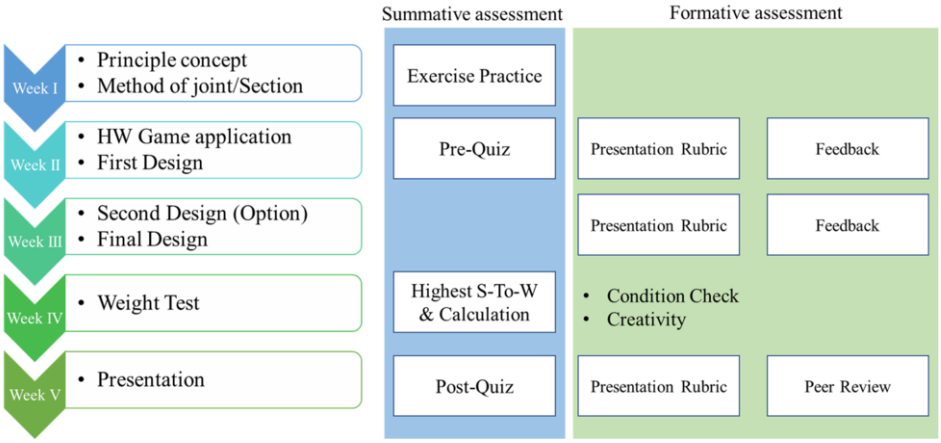


Figure 7. The designed week's tasks and assessments.

For the fourth week (Figure 8), students came to class to test their ability to take the force of their bridge. Each group would receive the worksheets to keep track of the measurements and weight-to-strength ratio testing results for their own bridge. The weight-to-strength ratio testing will be finished when the bridge starts to distort. Finally, all groups presented the test result and analysis, the calculation, and the critical idea to improve their bridge.

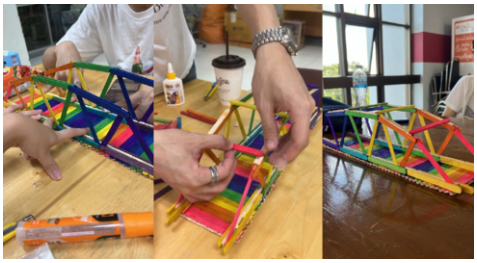


Figure 8. Example of Project-based learning.

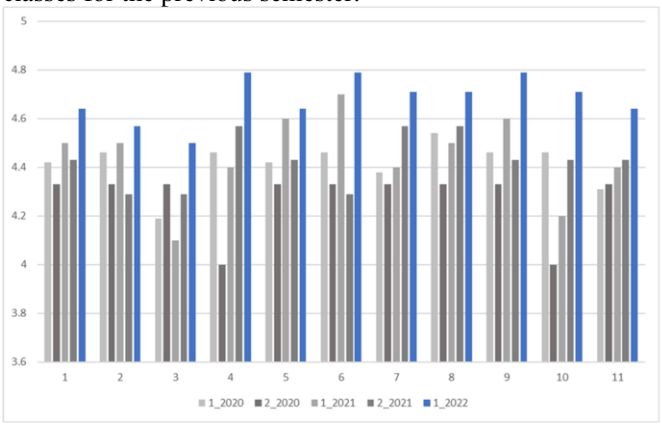
2. Active learning evaluation

Evaluating active learning classes is an important step toward improving the quality of teaching and enhancing the learning outcomes for students. This study used the results of the e-evaluation survey, exam performance, and reflections from the instructor, students, and observers (other instructors in the department) to gain a comprehensive understanding of the effectiveness of active learning classes.

2.1. Improvement of the learning environment: the e-evaluation survey

At the end of the course, students were asked to complete an e-evaluation survey to provide feedback on their experience with active learning. Overall, the feedback was positive, with many students noting that they appreciated the opportunities to work collaboratively and participate in class discussions. The result of active learning was

shown as the blue bar in Figure 9, while the grey ones show the result of lecture-based classes for the previous semester.



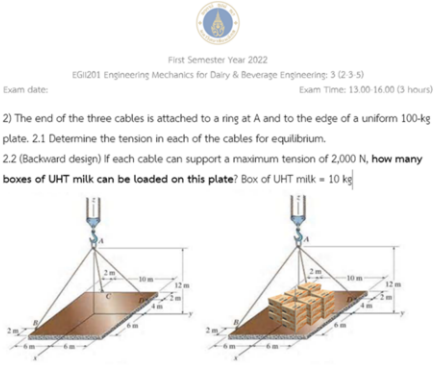
Course contents	
1	Importance & applied to a career
2	Organized continuouslyand appropriately easy to understand
The teaching and evaluation studies	
3	The student was happy in class
4	encouraged self-study and put the emphasis on the students
5	Material were effectively used and appropriate
6	Class environment emphasised students discussion conducive of critical thinking
Course evaluation and exams	
7	Based on principles
8	Accordance with the course objectives
9	Appropriateand accurate
Overall satisfaction towards course	
10	Overall satisfaction towards course
11	the instructor"steaching method and professionalism

Figure 9. The comparisons of e-evaluation survey results between active learning classes and lecturer-based classes.

Active learning can significantly improve class evaluation scores, especially in 'Encouraged self-study and emphasized the students' and 'Overall satisfaction towards course'. Active learning strategies, such as group work, peer teaching, and hands-on activities, create a collaborative and inclusive classroom environment that fosters learning and student success. By encouraging students to take an active role in their education, teachers can increase student engagement, promote a deeper understanding of the material, and ultimately, improve class evaluation scores.

2.2. Improvement of students' understanding: Summative exam results

To assess the impact of active learning on student performance, the exam results of active learning classes were compared with those of students in traditional, lecture-based classes. Even though many educators believe that active learning can improve student engagement and critical thinking skills, there are some worries that without a structured approach focus on content delivery, students may struggle to grasp key concepts and apply them on exams. An example of the exam used to compare the result was shown in Figure 10.


First Semester Year 2022

EGI201 Engineering Mechanics for Dairy & Beverage Engineering: 3 (2-3-5)

Exam date: Exam Time: 13.00-16.00 (3 hours)

2) The end of the three cables is attached to a ring at A and to the edge of a uniform 100-kg plate. 2.1 Determine the tension in each of the cables for equilibrium.

2.2 (Backward design) If each cable can support a maximum tension of 2,000 N, **how many boxes of UHT milk can be loaded on this plate**? Box of UHT milk = 10 kg

Figure 10. Example of the same exam to compare the result.

Research has shown that active learning can result in higher average scores on exams and assessments. The average scores from lecture-based classes in 2019, 2020, and 2021 were 5.5, 6.0, and 5.0 respectively. The active learning class can improve the average score of this exam to 7.5 as shown in Table 1. Moreover, the overall score on the exam increased by about 10-25%.

Table 1. Averages, standard deviations, and t-values of control exam scores of the groups

Group	Year	n	$\bar{x}$ Control exam	$\bar{x}$ Overall scores	SD
Active	2022	18	7.5	81.8	10.9
Traditional	2021	16	5.5	71.6	16.3
Traditional	2020	29	6.0	72.4	17.5
Traditional	2019	16	5.5	66.0	19.7

This discrepancy demonstrates that the active learning technique has positively influenced students' perceptions of the "The Mechanics for Engineering (EGII201)" class. And the active learning approach applied to the 2022 class is more effective in total exam scores and standard deviations than the traditional teaching method. However, the result of the active learning method should be collected continuously to analyze the desired learning outcomes in the future.

average attitude scores than the traditional learning method in teaching science

By actively engaging with the material and constructing their understanding, students are better equipped to apply what they have learned to real-world scenarios and demonstrate their mastery of the material. This result showed that the approach to learning can promote higher-order thinking skills, including analysis, synthesis, and evaluation, which are necessary for deeper understanding and long-term retention of knowledge. Active learning also encourages students to take ownership of their learning, leading to increased motivation and engagement in the classroom.

2.3. Improvement of awareness: Reflections

Reflection activities can be a powerful tool for promoting continuous learning and improvement for students and teachers and observers in the classroom. By engaging in reflective activities, teachers, students, and colleagues can evaluate their performance, identify areas for improvement, and make adjustments to their approach.

For students, reflection activities can help them to better understand their learning process, assess their own strengths and weaknesses, and identify areas where they need to focus their efforts. By reflecting on their performance, students can become more self-aware, develop effective study habits, and improve their overall academic performance one fourth-year student who previously dropped 1 time from this course explained:

> "I feel that Active Learning allows me to understand the content better than sitting in a lecture class. Last two years, I cannot focus on what the teacher tries to teach me. So, I have decided to drop this class. More than that It seems like the teacher encourage me via the reflection activity, I can say comfortably that I don't understand the topic of that week. He provided me with more explanations, and exercises, and check with me again followed week."

For teachers, reflection activities can help to identify areas where instruction may be improved, adapt teaching methods to better suit individual students, and assess the effectiveness of course materials. Additionally, reflecting on their practice can help

teachers to identify professional development opportunities and improve their own teaching skills.

> "Active learning is an approach that not only keeps students engaged, but also gives them the confidence to discuss ideas with their peers without fear of being wrong by allowing students to work at their own pace, encourages conversation, and makes my class more exciting."

For observers, reflection activities can be used to facilitate collaboration, promote sharing of ideas and best practices, and identify areas where the team can work together to improve student outcomes. By reflecting together, colleagues can gain a deeper understanding of the strengths and weaknesses of their team and make adjustments to their approach to better support student learning.

> "I have noticed that students seem engaged and interested in class. It's great to see this subject using a variety of teaching methods to reach different types of learners. Students seem to have a real sense of ownership over their learning."

3. Discussion & Conclusion

Based on the case study presented, it is evident that active learning can greatly enhance the teaching and learning experience for mechanics in engineering. The activities created and implemented successfully achieved their objectives of promoting student engagement, critical thinking, and problem-solving skills. The assessment results showed that active learning activities positively impacted student performance and learning outcomes compared to lecture-based instruction.

Furthermore, the reflections of both the instructor and students provide valuable insights into the benefits of active learning. The instructor reported that active learning activities allowed for more interaction with students and greater satisfaction in teaching. The students also reported feeling more engaged and motivated in the classroom, leading to a deeper understanding of the course material.

The SWOT (strengths, weaknesses, opportunities, and threats) analysis in this study was performed by reflecting on the evaluations and feedback and was shown in Table 2.

Table 2. SWOT analysis of active learning.

	Helpful	**Harmful**
Internal	Strengths - enhance students' engagement and motivation, leading to increased learning outcomes. - provide opportunities for students to apply concepts learned in class to real-world engineering problems - helping to improve their problem-solving and critical-thinking skills.	Weakness - time-consuming to plan and implement, which may be challenging for instructors who already have heavy teaching loads. - requires active participation from students, which may not be preferred or appreciated by all students. - require additional resources, such as technology or equipment, which may not be available in all settings.

	Helpful	Harmful
External	Opportunities - help to diversify teaching methods and create more inclusive classrooms, as it can cater to different learning styles and backgrounds. - improve the reputation of engineering programs, as graduates with strong problem-solving and collaboration skills are in high demand in the job market.	Threats - require a shift in teaching culture, which may be resisted or overlooked by some instructors. - may not be appropriate or effective for all topics or learning objectives and may require careful planning and assessment to ensure its effectiveness.

In conclusion, the implementation of active learning in mechanics for engineering is a valuable pedagogical approach that can benefit both students and instructors. By creating and implementing effective active learning activities and reflecting on their impact, educators can continue to improve their teaching practices and enhance their students' learning experiences.

Acknowledgment

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