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Flipped Peer Teaching as Part of Active Learning Activities for Process Optimization Subject

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ABSTRACT

Traditional lecture-based methods in engineering education often lead to passive learning, limiting student engagement and the ability to apply complex concepts in practice. This study investigates the implementation of flipped peer teaching (FPT) as an active learning strategy in a Process Optimization course for final-year chemical engineering students. Flipped peer teaching integrates flipped classroom and peer teaching approaches, requiring students to engage with learning materials independently before teaching their peers in structured class sessions. The methodology involved five phases: lecturer preparation, pre-class student preparation, lecturer guidance and review, in-class peer teaching implementation, and post-class feedback collection. Findings showed that 83.3% of students found preparing and delivering teaching materials more effective than conventional lectures for understanding course content. Additionally, 66.7% reported increased confidence in applying concepts during assessments, and 62.5% found peer teaching sessions more engaging than traditional lectures. However, effectiveness ratings varied, with 50% rating the sessions as moderately effective and 41.7% as very effective. Overall, the flipped peer teaching model enhanced student engagement, conceptual understanding, and communication skills, though its integration alongside traditional teaching is recommended to support diverse learner needs. This study contributes to pedagogical innovations in engineering education by demonstrating the feasibility and benefits of flipped peer teaching for technical subject mastery.

1. Introduction

The evolving landscape of engineering education emphasizes the need for pedagogical approaches that foster active student engagement, critical thinking, and collaborative problem-solving skills [1].

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Traditional lecture-based methods, while effective for information dissemination, often fall short in promoting deep learning and student participation [2,3]. Active learning strategies, such as flipped classrooms and peer teaching, have emerged as effective alternatives to traditional instruction, aiming to enhance student learning outcomes and engagement [4,5]. In the context of chemical engineering education, particularly in courses like Process Optimization, students are required to grasp complex mathematical models and apply them to real-world scenarios. Despite the recognized benefits of active learning, many engineering courses continue to rely heavily on traditional lecture-based instruction. This approach often leads to passive learning, where students may struggle to apply theoretical concepts to practical problems [6]. In Process Optimization courses, the nature of the subject matter can further intensify these challenges, resulting in limited student engagement and suboptimal learning outcomes.

This concern aligns with global trends in educational transformation, where emphasis is now placed on active learning approaches that prioritize collaboration, application, and learner autonomy [7]. Among these approaches is peer teaching, where students take on the role of instructor to facilitate the learning of others, has been shown to improve understanding and help students retain knowledge more effectively, because teaching others reinforces their own learning [8,9]. In parallel, flipped classroom pedagogy has gained traction for reversing the traditional instructional sequence: delivering lecture material asynchronously outside the classroom and using class time for discussions, problem-solving, and higher-order thinking tasks [10-12]. While both strategies peer teaching and flipped classroom have demonstrated benefits in various STEM disciplines, there is a noticeable lack of integration between them in existing pedagogical practices, particularly in challenging engineering subjects such as Process Optimization. Most implementations of peer teaching occur after students have been exposed to instructor-led lectures, limiting the development of autonomous learning. Similarly, flipped classrooms, though widely advocated, are often instructor-centric in their in-class activities.

Previous studies have explored flipped learning in engineering contexts, often reporting improvements in student satisfaction and performance. For example, educators have implemented flipped classroom models in subjects such as Statics, Mechanics of Materials, Introductory Mechanical Design, and Statistics, resulting in greater in-class engagement [13-15]. Meanwhile, peer teaching has been widely applied in health sciences [16,17] and teacher education [18] where students gain deeper comprehension through structured collaboration. Research by Sesler *et al.*, [19] found positive outcomes from peer-led team learning in the science subject, while Wibawa [20] emphasized improved outcomes from flipped learning in physics. Yet, few studies combine these two methods in engineering education, and even fewer have examined their impact on highly analytical subjects such as Process Optimization.

This study addresses this gap by implementing a hybrid model—flipped peer teaching—in a final-year Process Optimization course. By requiring students to independently study course material and then teach it to their peers, the approach aims to foster deeper learning, autonomy, and communication skills. Unlike traditional peer teaching, this method places the responsibility for both content acquisition and delivery on students, aligning with constructivist learning principles. Integrating active learning strategies in such courses can potentially improve students' conceptual understanding and application skills.

This study proposes the integration of flipped classroom and peer teaching approaches—referred to as flipped peer teaching—where students first engage with content independently and then deliver the material to their peers in structured teaching sessions, guided by instructors. This hybrid strategy shifts students from passive recipients to active co-constructors of knowledge, aligning with constructivist learning principles. However, empirical evidence on its impact in chemical engineering education, particularly in technically rigorous courses like Process Optimization, remains limited. This study explores the implementation of flipped peer teaching in a final-year Process Optimization course at Universiti Teknologi PETRONAS (UTP), with the aim of evaluating its effectiveness in enhancing student engagement, content mastery, and collaborative learning. It also examines student perceptions of the method and assesses its feasibility for broader adoption in technical engineering education. The study focuses on selected complex topics within the course and applies both qualitative and quantitative methods to assess learning outcomes and instructional challenges. By addressing this gap, the research offers practical insights into the implementation of innovative active learning strategies in engineering curricula.

1.2 Research Question

How does flipped peer teaching influence student engagement and participation in the Process Optimization subject?
What are the perceived benefits and challenges of flipped peer teaching from the students' perspective?
Does flipped peer teaching improve conceptual understanding and application of process optimization methods?

1.3 Research Objectives

Our study objectives are as follows:

1. To design and implement a flipped peer teaching model in a Process Optimization course.
2. To evaluate the impact of this model on student engagement, comprehension, and collaboration.
3. To assess student's perspectives on the flipped peer teaching for an effective learning experience.
4. To investigate the preference of students for flipped peer teaching over the conventional classroom method.
5. To gather student perceptions and feedback on the effectiveness of the flipped peer teaching approach.

2. Methodology

This study adopts a structured pedagogical approach to implement and evaluate flipped peer teaching (FPT) as part of active learning activities in a final-year Process Optimization course. The methodology was designed to encourage student autonomy, foster collaborative learning, and enhance conceptual understanding through peer-led instruction. The teaching intervention was conducted over several weeks and involved five key phases: lecturer preparation, student pre-class engagement, lecturer-student consultation, in-class peer teaching implementation, and post-class feedback collection. Each phase was carefully structured to ensure alignment with the intended learning outcomes and to support both the teaching and learning experiences. The following subsections detail the step-by-step process undertaken throughout the implementation of the FPT model.

2.1 Preparation of Flipped Peer Teaching Module by the Lecturer

The initial phase of implementing the Flipped Peer Teaching (FPT) model involved detailed preparation by the lecturer. This included designing learning objectives tailored to selected topics in the Process Optimization course, emphasizing higher-order cognitive skills such as analysis, synthesis, and application. Figure 1 illustrates the structured preparation framework designed for this study.

Things to be included:
Show how to use the method with examples.

Provide tips and points to be alerted when using the method.

Provide **CANVA digital notes (3%)**

Topic:

1. Simplex – maximation (linear programming)
2. Simplex – minimization (linear programming)
3. Simplex – mixed constraint case (linear programming)
4. Branch and Bound method (integer programming)
5. Newton's method + Direct Substitution (non linear programming)
6. Generalized reduced gradient method (non-linear programming)
7. Langrange function (non-linear programming)

Fig. 1. List of peer teaching topics

High-quality study materials comprising lecture videos, lecture notes, and etc were also given to the students to ensure accessibility and alignment with diverse student learning styles as shown in Figure 2.

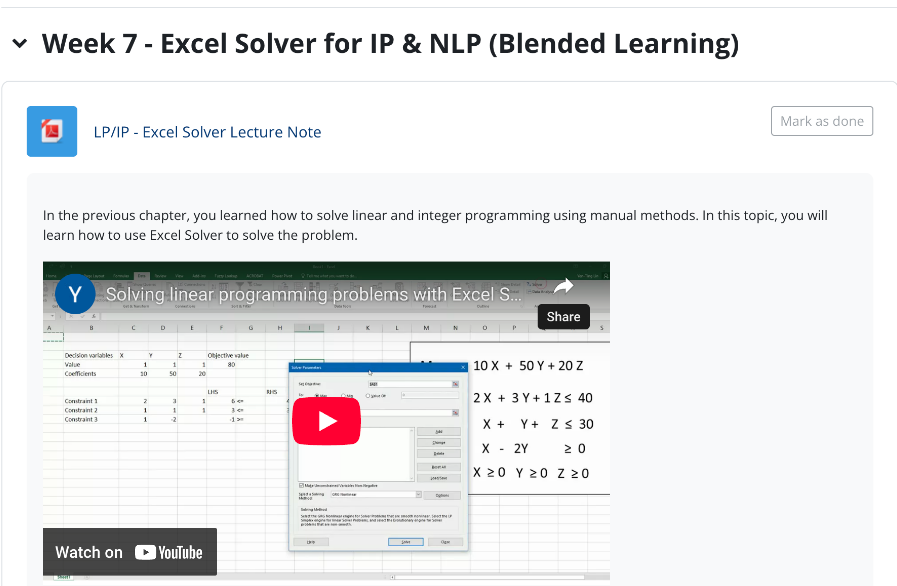

Fig. 2. Snapshot from teaching and learning platform

To support assessment, rubrics were prepared to evaluate both the quality of student-led teaching and the engagement of their peers during class as shown in Table 1. These rubrics addressed criteria such as content accuracy, clarity of presentation, interaction with peers, and the ability to facilitate understanding through discussion.

Table 1
Flipped peer teaching rubric

Aspect	Details	Marks
Comprehensive Presentation	• Provide explanation with examples	1 (fair) – 5 (excellent)
	• Explain in detail how to use the method	1 (fair) – 5 (excellent)
	• Provide tips and know-how on how to understand the method	1 (fair) – 5 (excellent)
Presentation style	• Easy to understand	1 (fair) – 5 (excellent)
	• Confident and eloquent	1 (fair) – 5 (excellent)
	• Able to answer question given	1 (fair) – 5 (excellent)
CANVA Digital Notes	• Effective Design (effective use of colours, fonts and layout; clear and organized visual) • Content	
	Total marks	30

2.2 Pre-Class Student Preparation

Students were divided into small groups consisting of four to five members. Each group was assigned a specific topic or subtopic within the broader Process Optimization framework, with related topics allocated to promote intergroup learning and discussion. Instructions regarding the flipped peer teaching process and group roles were disseminated early through university learning platform, enabling students to allocate preparation tasks efficiently and engage deeply with the assigned content as shown in Figure 3. The flipped model was introduced to students, clarifying that they were responsible for mastering the material independently before teaching it to their peers.

Group Project Activities

1. Flipped Peer Teaching
To enhance your learning experience, we will conduct Flipped Peer Teaching activities during this course. This approach promotes active learning by encouraging you to teach and learn from your peers.

Below are the details and instructions for this activity:

- Form a group of 5-6 members.
- Select your team members and insert their names in the Excel file uploaded to ULEARN under the "Group Formation" section.

Each group will be responsible for one of the following topics:
- Simplex – maximation (linear programming)
- Simplex – minimization (linear programming)
- Simplex – mixed constraint case (linear programming)
- Branch and Bound method (integer programming)
- Lagrange function (non-linear programming)
- Generalized reduced gradient method (non-linear programming)

For your assigned topic, your group must:

1. Explain the Method: Provide a clear and concise explanation of the topic.
2. Demonstrate with Examples: Include detailed examples to show how to apply the method step by step.
3. Prepare Teaching Materials: Use the provided Peer Teaching Materials as a reference and expand them into slides and summary notes.
- Use Canva (or other tools) to design visually engaging slides.
- Create clear summary notes for your peers.

Fig. 3. Flipped Peer Teaching (FPT) instructions

As shown in Figure 4, teaching materials, including lecture notes and reference readings, were provided to all students in advance through the university's learning management system to facilitate their preparation. However, each group was tasked with collaboratively developing their own teaching materials using digital tools, such as Canva to create visually engaging and content-rich slides, summary notes, and illustrative diagrams. Emphasis was placed on creativity, clarity, and alignment with the intended learning objectives to ensure that student-created materials were not only informative but also effective in enhancing peer understanding during in-class teaching sessions.

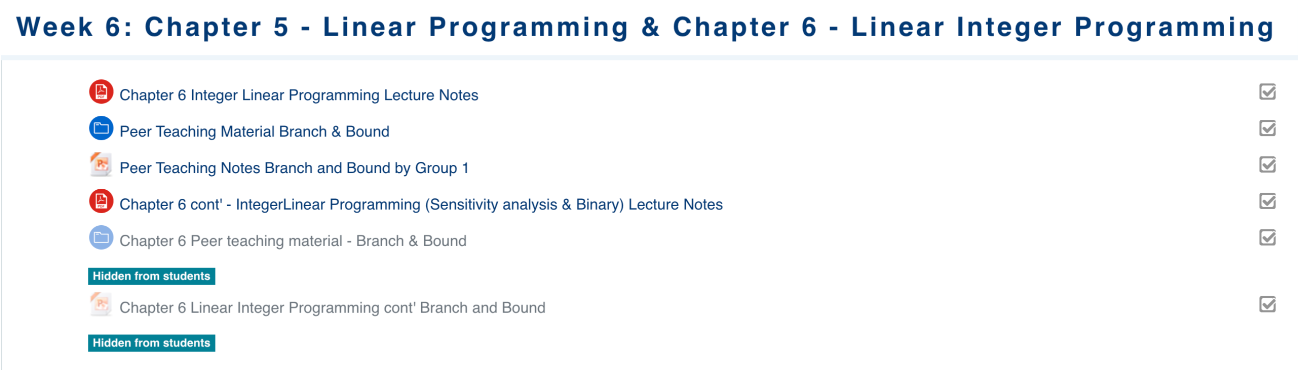

Fig. 4. Example of materials provided for student's preparation

2.3 Review of Peer-Prepared Content with Lecturer Guidance

To ensure the quality and accuracy of student-prepared materials, the lecturer conducted review sessions with each group prior to class presentations. These sessions served as formative checkpoints where students received targeted feedback on both content and delivery style. Suggestions were given to improve technical correctness, visual clarity, flow of information, and strategies to promote classroom interaction. Groups were encouraged to refine their materials based on this feedback before the in-class teaching sessions. Figures 5 and 6 show the final materials prepared by the students after incorporating lecturer feedback.

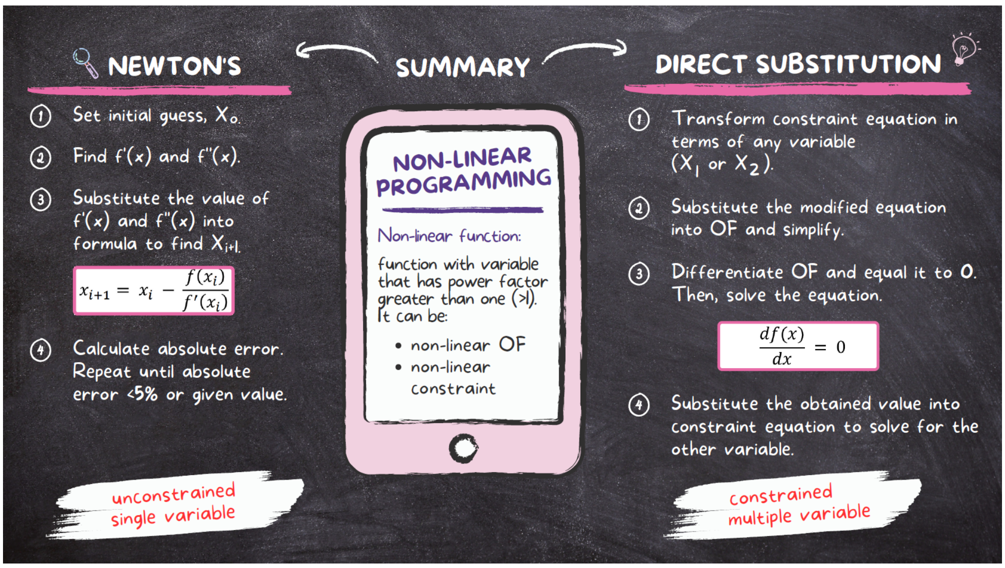

Fig. 5. Example of student-prepared slide materials used during the Flipped Peer Teaching (FPT) session

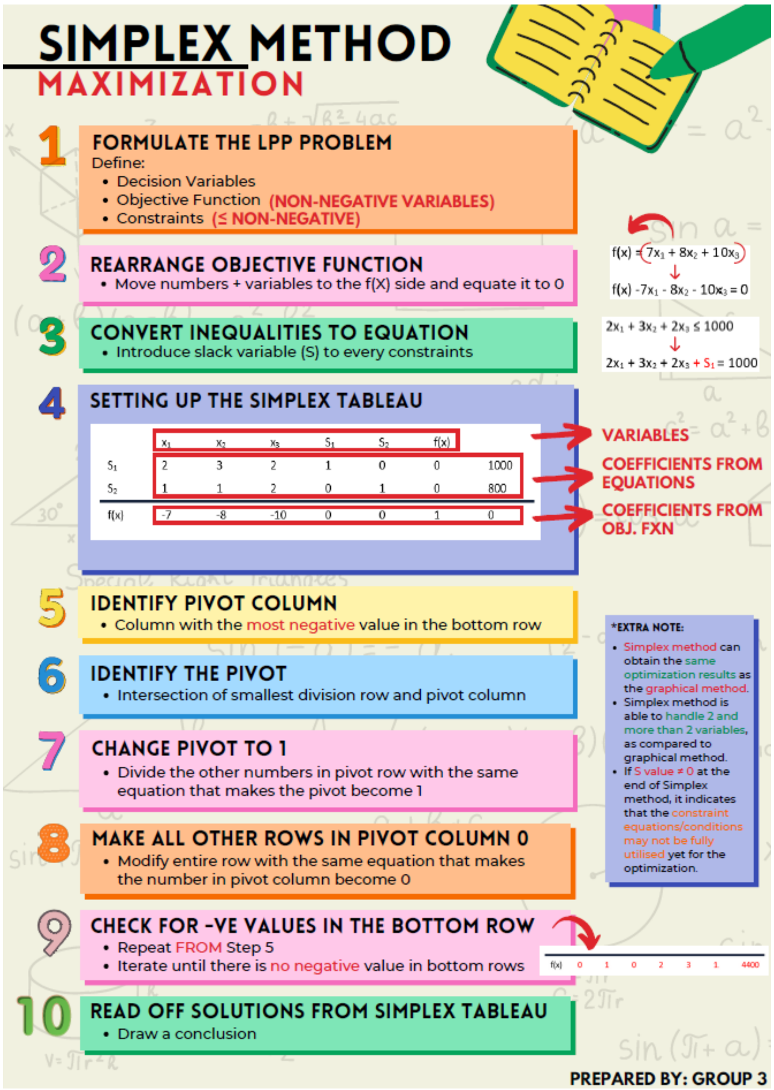

Fig. 6. Example of student-prepared summary note shared during the Flipped Peer Teaching (FPT) session

2.4 Implementation of Peer Teaching During Class Sessions

During class, each group conducted a peer teaching session based on their assigned topic. The structure of these sessions varied, but typically included a brief introduction, explanation of core concepts, and problem-solving demonstrations. Interactive elements such as quizzes, real-time case discussions, and peer questioning were encouraged to promote engagement and reinforce learning. The lecturer served as a facilitator throughout, providing clarification when needed, monitoring time, and ensuring smooth transitions between group presentations. The audience, consisting of their classmates, was actively involved, providing questions, feedback, and participating in problem-solving activities. Figure 7 shows students delivering their teaching sessions and engaging actively with peers during the flipped peer teaching activities.

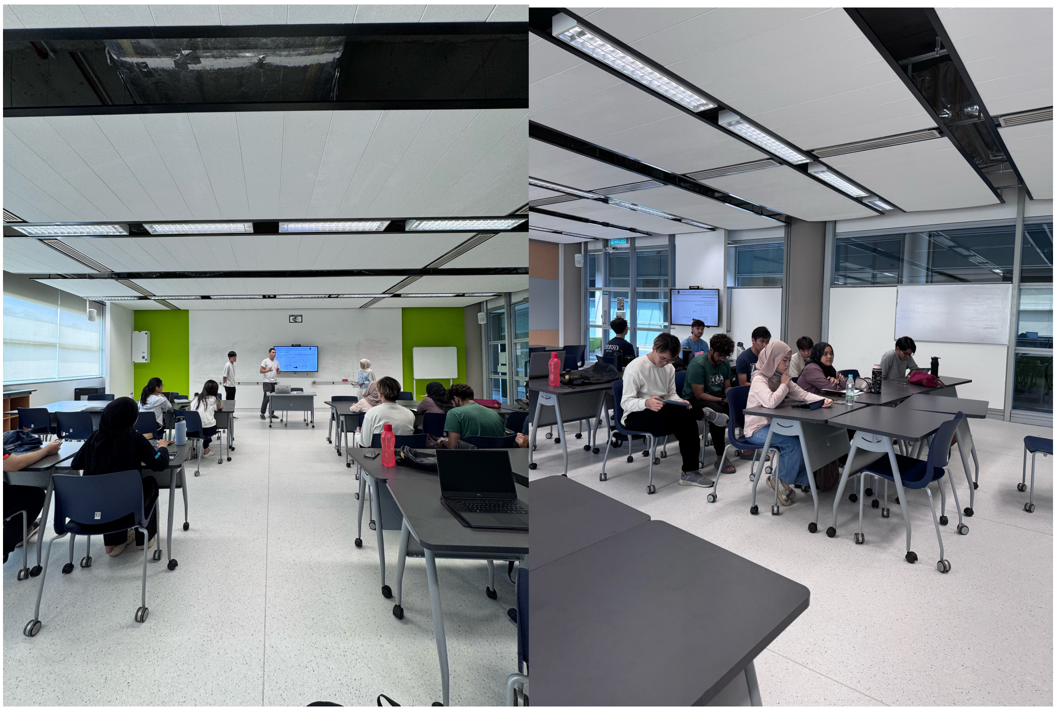

Fig. 7. Peer teaching Implementation

2.5 Post-Class Reflection and Feedback Collection

Following the peer teaching sessions, students were asked to provide structured feedback to each presenting group using a standardized form. This peer assessment focused on the clarity, accuracy, and delivery of the session, as well as the effectiveness of engagement strategies. In addition to individual group feedback, an anonymous post-activity questionnaire was administered to collect students' overall perceptions of the flipped peer teaching experience. The questionnaire included Likert-scale and open-ended questions targeting key aspects such as content understanding, collaborative learning, confidence in communication, and general satisfaction. This feedback served to evaluate the effectiveness of the method and inform future improvements in instructional design.

3. Finding and Discussion

This section presents the results obtained from the implementation of the flipped peer teaching (FPT) model in the Process Optimization course and discusses their implications in the context of engineering education. The findings include analyses of student-prepared teaching materials, classroom implementation observations, and student feedback gathered through post-activity questionnaires.

Figure 8 illustrates student responses to whether this flipped peer teaching technique had been applied in their other classes. Out of 24 respondents, 62.5% indicated that they had never experienced this approach before, while only 37.5% reported prior exposure. This finding highlights the novelty of flipped peer teaching within their learning journey and suggests its implementation fills a pedagogical gap in active learning experiences for engineering students.

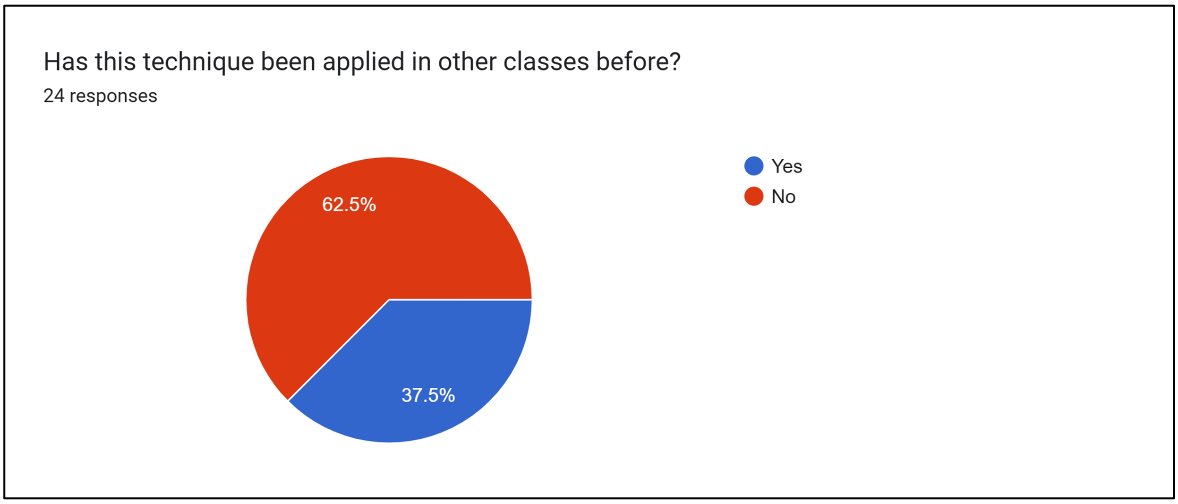

Fig. 8. Previous exposure to Flipped Peer Teaching

Figure 9 shows the distribution of topics selected for peer teaching activities. The subjects chosen were well distributed among linear programming (LP) and nonlinear programming (NLP) topics, including Simplex Minimization (12.5%), Simplex Maximization (20.8%), Simplex Mixed Constraint (16.7%), Integer Programming – Branch and Bound (16.7%), NLP – GRG (20.8%), and NLP – Lagrange (12.5%). This balanced distribution indicates that students engaged with a wide range of process optimization topics, promoting comprehensive coverage of the syllabus through peer-led learning. It also demonstrates that the flipped peer teaching model can be applied effectively across diverse technical topics.

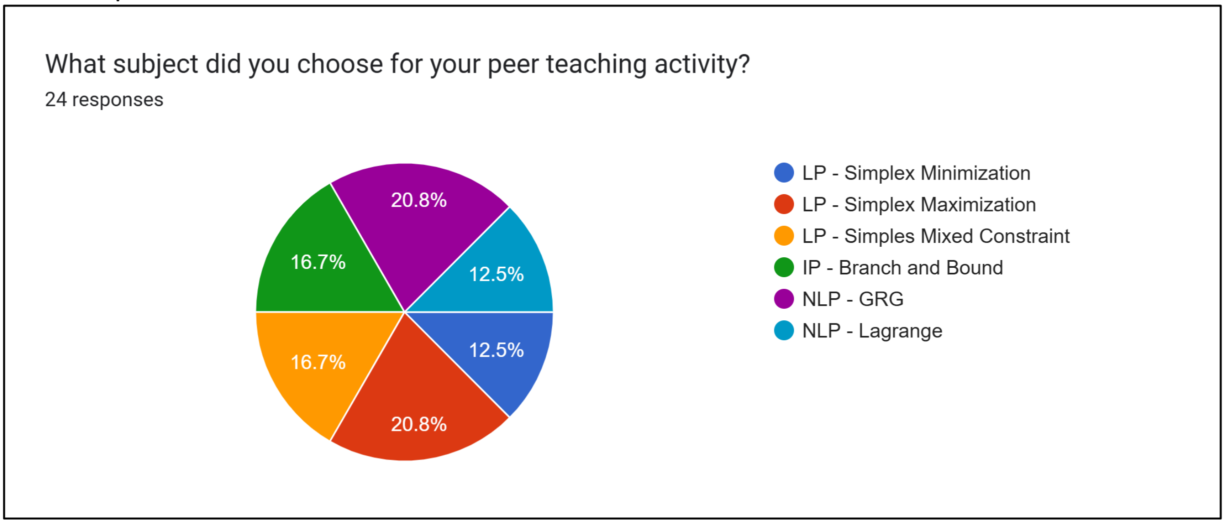

Fig. 9. Subjects chosen for peer teaching

Figure 10 presents students' perceptions of whether flipped peer teaching helped them revise chapters more effectively. While 37.5% fully agreed, a majority of 54.2% responded "kind of," indicating partial agreement, and 8.3% selected "not really." The mixed responses suggest that although many students found the method beneficial for revision, some remained neutral, possibly due to varying levels of preparation or confidence in peer explanations. This aligns with existing literature, which emphasizes the importance of structured lecturer facilitation and preparation time in maximizing the effectiveness of flipped and peer learning strategies [21].

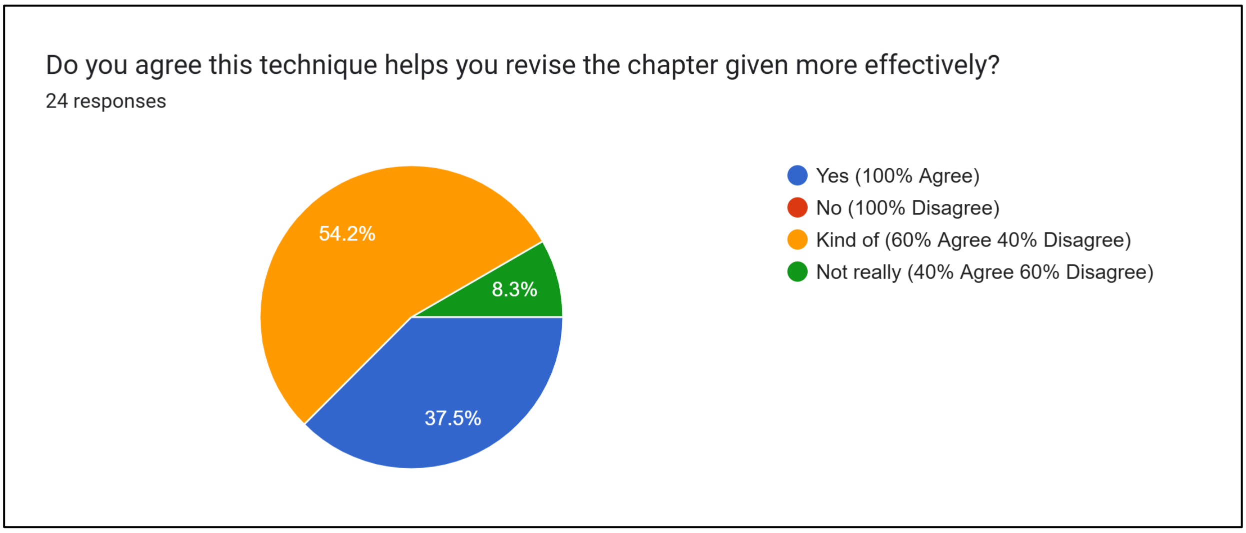

Fig. 10. Perceived effectiveness in revising chapters

Figure 11 shows student preferences for learning activities that helped them understand chapters more effectively. A significant 83.3% (20 students) indicated that preparing teaching materials and delivering chapters as peer teachers was the most effective approach, compared to only 45.8% (11 students) who found conventional lecturer delivery effective. Notably, only 8.3% felt that neither method helped their understanding. This highlights that the flipped peer teaching model enhanced learning effectiveness by encouraging students to engage deeply with content through teaching preparation and delivery.

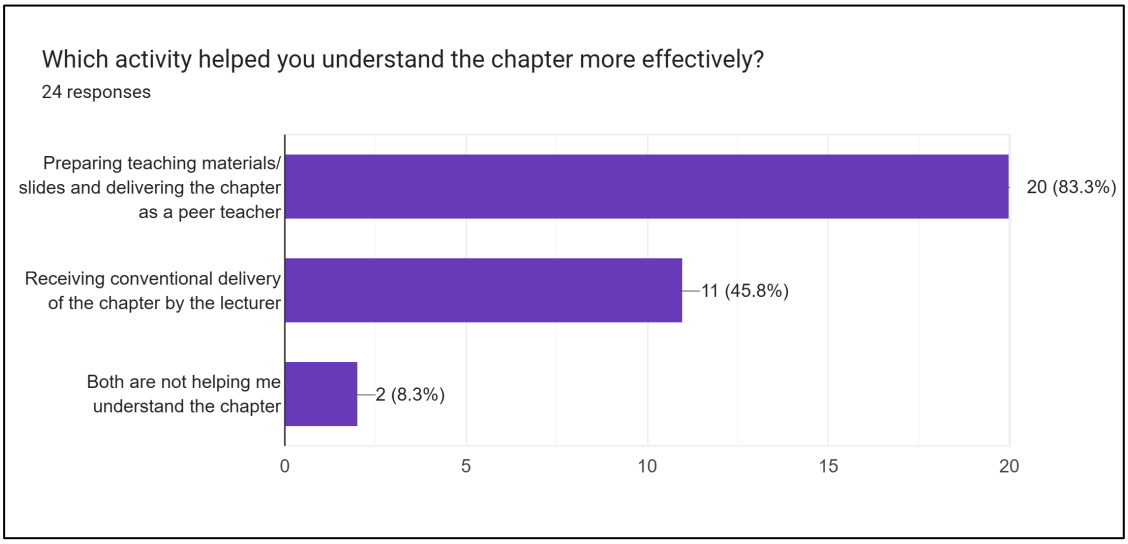

Fig. 11. Activity impact on chapter understanding

Figure 12 illustrates students' confidence in applying concepts taught during peer teaching sessions to solve related problems. While 12.5% reported feeling extremely confident and 37.5% very confident, the majority (41.7%) rated their confidence as moderately effective, and 8.3% as slightly effective. These results suggest that while flipped peer teaching builds conceptual confidence for many students, there remains a portion of students requiring additional practice or lecturer-led reinforcement to reach high confidence levels.

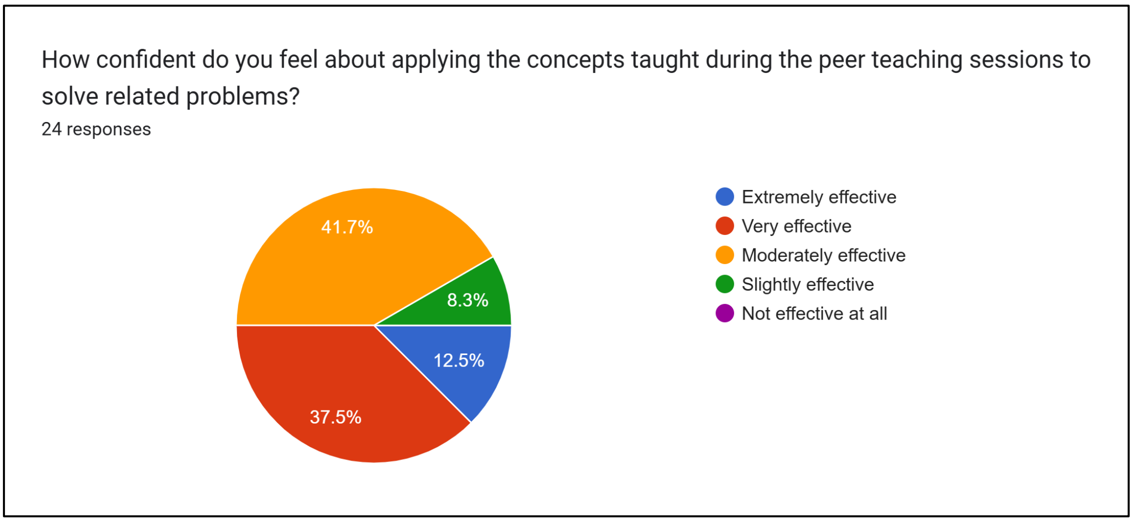

Fig. 12. Confidence in applying concepts

Figure 13 presents students' perceptions of how well peer teaching activities helped them understand key course concepts. About 12.5% found the method extremely effective, 37.5% very effective, and 50% moderately effective. No students selected the "slightly effective" or "not effective at all" options, indicating universal perceived benefit, albeit with varying degrees. These findings are consistent with literature emphasizing that active learning strategies, such as flipped peer teaching, promote deeper understanding by requiring students to engage with, explain, and apply course concepts [22].

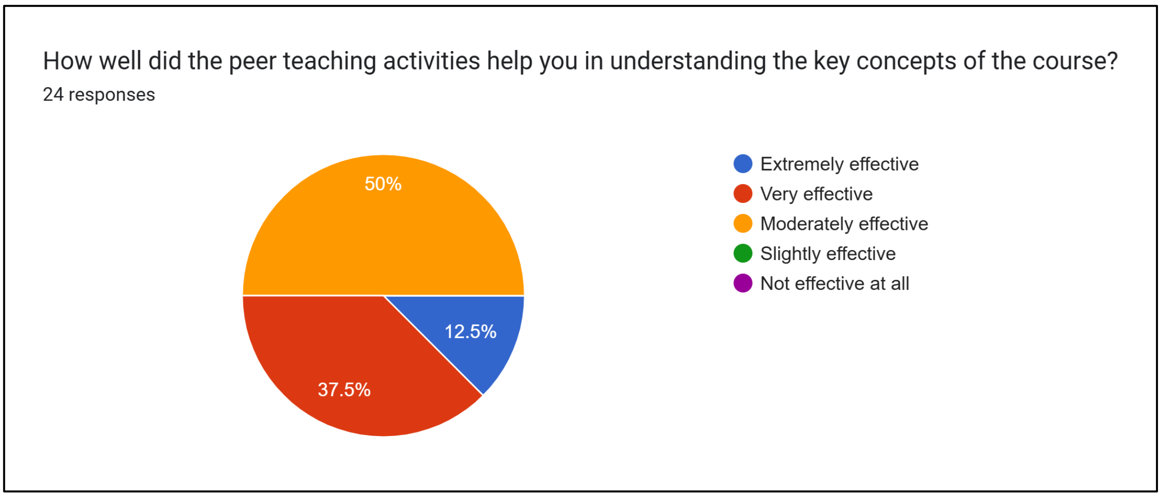

Fig. 13. Perceived effectiveness in understanding key concepts

Figure 14 presents students' perceptions of how participating in peer teaching sessions impacted their confidence during assessments. 12.5% reported that their confidence greatly increased, while 54.2% felt their confidence increased. About 33.3% indicated no change in confidence levels, and importantly, no students reported decreased confidence. These results suggest that flipped peer teaching generally had a positive influence on students' confidence in tackling assessment questions, aligning with constructivist theories that teaching others reinforces mastery [23].

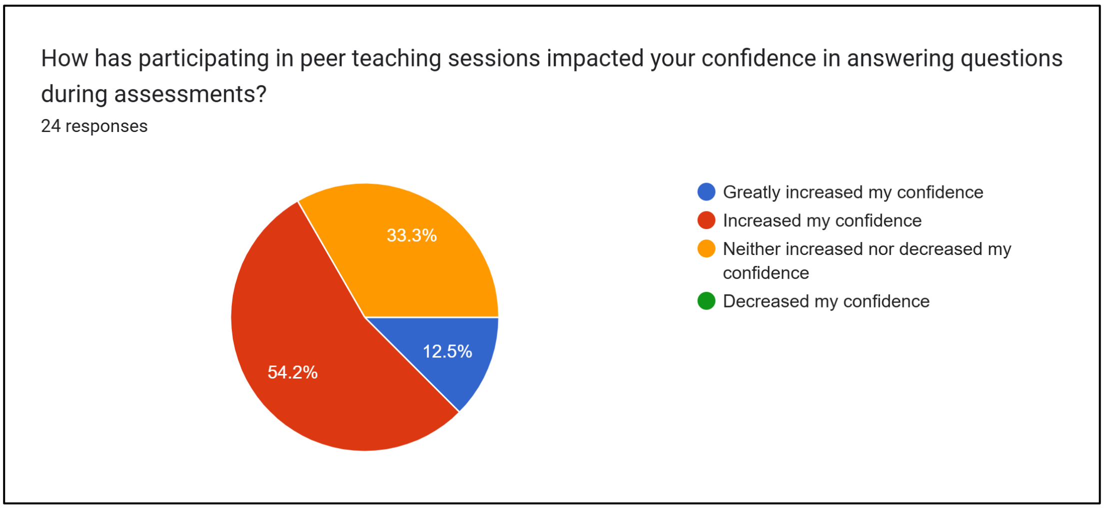

Fig. 14. Confidence in answering assessment questions

Figure 15 illustrates students' perceptions of engagement levels in peer teaching sessions compared to traditional lectures. A combined 62.5% found the sessions either much more engaging (8.3%) or more engaging (54.2%), while 33.3% perceived them as equally engaging, and only 4.2% reported them as less engaging. This indicates that flipped peer teaching is viewed as a more interactive and stimulating method, enhancing overall classroom dynamics and student motivation.

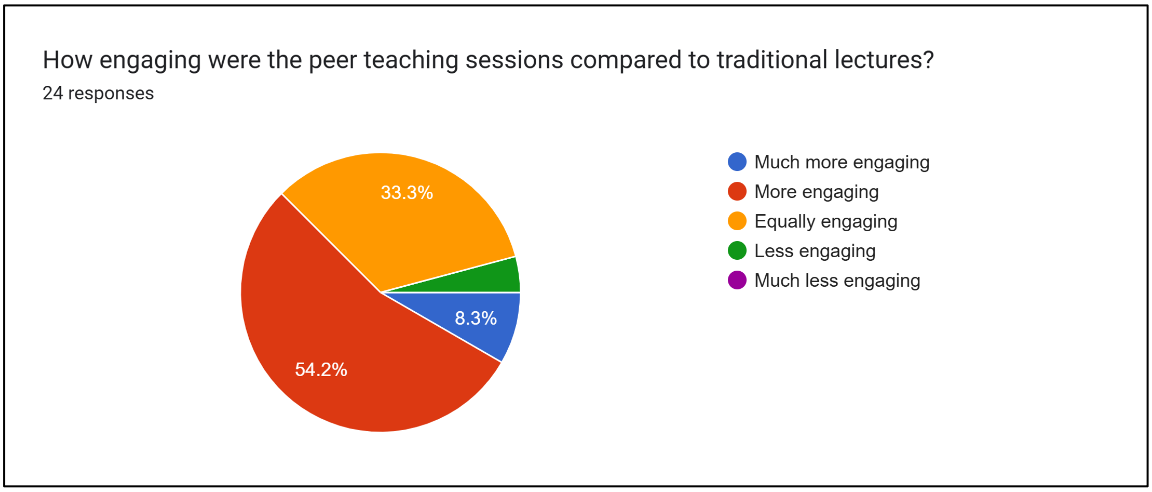

Fig. 15. Engagement compared to traditional lectures

Figure 16 shows student ratings on the clarity of explanations provided by their peers during teaching sessions. 50% rated them as very clear, 45.8% as moderately clear, and 4.2% as slightly clear. No students selected "not clear at all," suggesting general satisfaction with peer explanations, although there remains room for improvement in ensuring technical clarity and depth. This finding highlights the importance of lecturer facilitation in reviewing and refining student-prepared materials prior to peer teaching sessions to optimize learning outcomes.

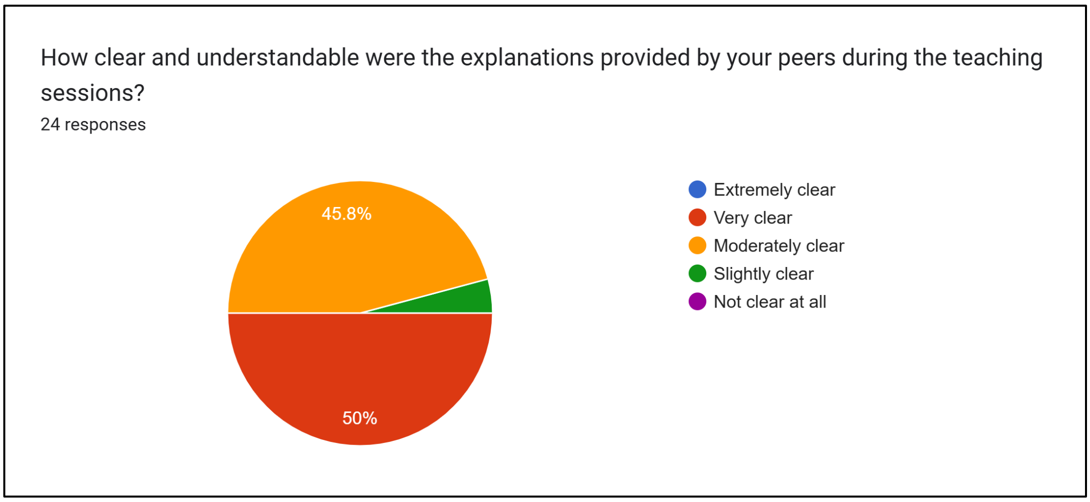

Fig. 16. Clarity and understandability of peer explanations

Figure 17 shows students' likelihood of recommending peer teaching as a learning method to other students. While only 4.2% were extremely likely and 29.2% very likely, a majority of 58.3% responded moderately likely, and 8.3% slightly likely. None selected "not likely at all." This indicates that although students found value in peer teaching, its recommendation strength remains moderate, suggesting that while beneficial, students may perceive it as complementary rather than a sole instructional strategy.

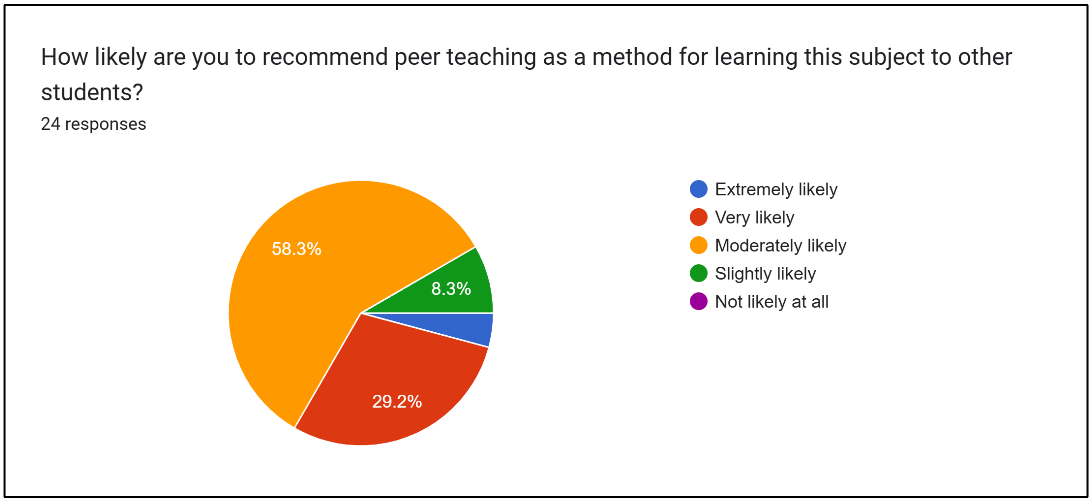

Fig. 17. Likelihood of recommending peer teaching

Figure 18 illustrates how comfortable students felt participating and asking questions during peer teaching sessions. 16.7% felt extremely comfortable, 45.8% very comfortable, 29.2% moderately comfortable, and 8.3% slightly comfortable. The absence of "not comfortable at all" responses indicates that the learning environment fostered inclusivity and psychological safety, critical for active learning effectiveness.

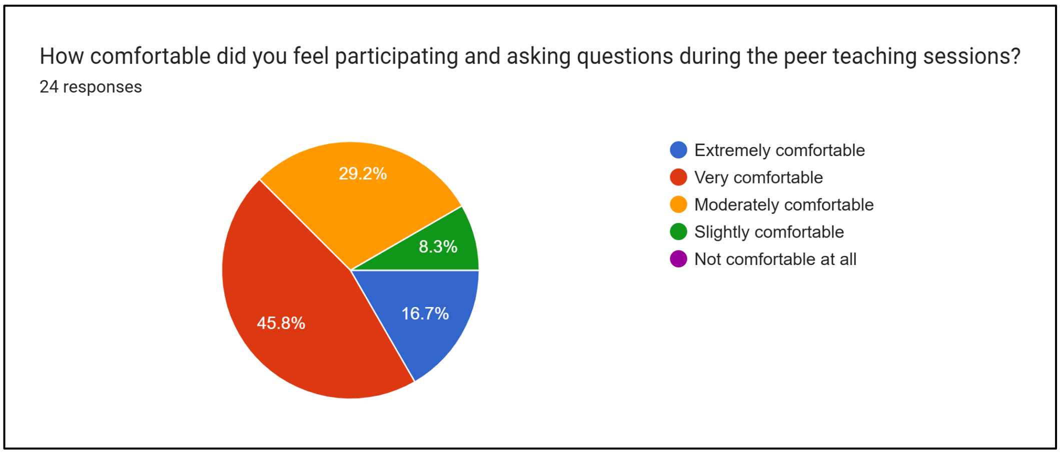

Fig. 18. Comfort in participation and questioning

Figure 19 indicates student preferences regarding incorporating peer teaching more frequently into the curriculum. 58.3% supported its increased inclusion, while 41.7% disagreed. This highlights a split in student preferences, suggesting the importance of balancing peer teaching with traditional and lecturer-led sessions to accommodate diverse learning styles.

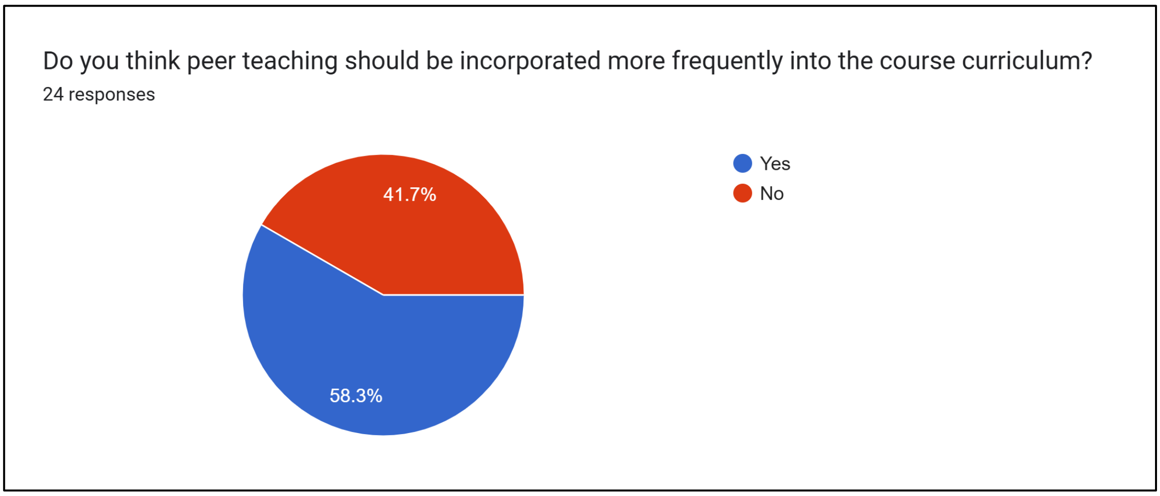

Fig. 19. Incorporation into future curriculum

Figure 20 depicts the overall effectiveness ratings of peer teaching in enhancing understanding of course material. 4.2% rated it extremely effective, 41.7% very effective, 50% moderately effective, and 4.2% slightly effective. No students rated it as “not effective at all.” These results suggest that flipped peer teaching effectively supports learning for most students, though additional scaffolding may be needed to elevate moderate ratings to high effectiveness perceptions.

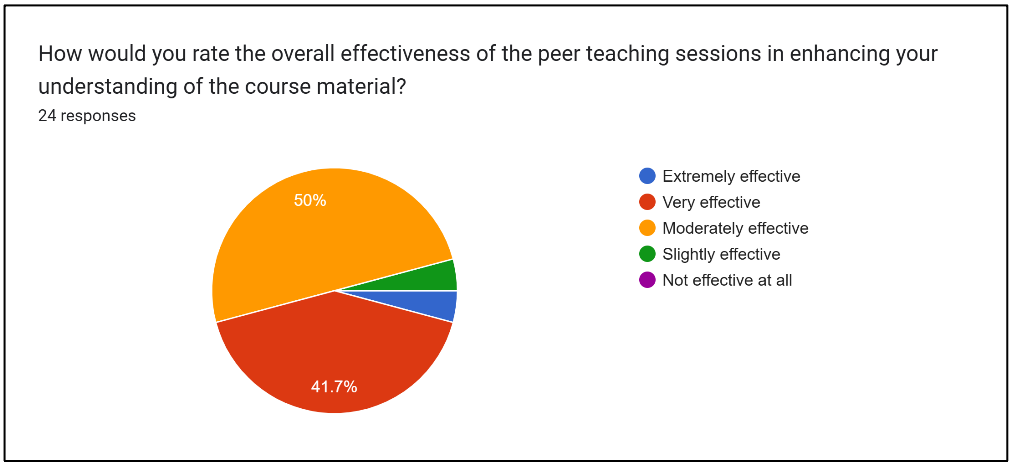

Fig. 20. Overall effectiveness rating

4. Conclusion

This study explored the implementation of flipped peer teaching (FPT) as an active learning strategy in a Process Optimization course for chemical engineering students. The findings demonstrate that integrating flipped learning with peer teaching effectively enhances student engagement, confidence, and understanding of complex topics. Students who participated in FPT activities showed improved clarity in conceptual understanding, greater confidence in answering assessment questions, and stronger communication skills when explaining technical content to their peers. The majority perceived peer teaching sessions as more engaging than traditional lectures and appreciated the opportunity to collaboratively develop and deliver learning materials.

However, the study also revealed that while students generally viewed FPT positively, a significant proportion rated its effectiveness and recommendation likelihood as moderate. This indicates that while FPT enhances active learning, it should be complemented with structured lecturer guidance and additional problem-solving tutorials to ensure deep and comprehensive understanding for all learners.

Overall, this research contributes to the growing body of evidence supporting active learning approaches in engineering education and demonstrates that flipped peer teaching is a promising pedagogical model for fostering student autonomy, collaborative skills, and confidence in technical courses. Future studies are recommended to investigate long-term impacts on academic performance and to explore integration strategies for diverse course structures to maximize learning outcomes.

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