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Students' perception of peer teaching in engineering education: a mixed-method case study

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Background: Engineering education is constantly evolving and adapting to meet the demand for diverse skills and competencies in graduates, in response to the changing global economy and technological advancements. This requires shifting from a traditional content-oriented and professor-focused approach towards a more interactive, student-centered approach in which students actively engage in all process stages. The study's main objective was to examine the students' perceptions of peer teaching and better understand the method's perceived advantages and disadvantages. The research was conducted over two academic years (2021 and 2022) and involved 96 students. The research incorporated quantitative and qualitative data collected through online questionnaires completed by the students at the end of the semester. The results showed a cumulative positive response rate for all close-ended questions of over 60%. The correlation analysis revealed medium positive relationships among the variables, including self-confidence, academic performance, communication and active listening, teamwork, knowledge consolidation, student-teacher benefits, and teaching activity. The thematic analysis of the open-ended questions showed that 87% of the respondents perceived the peer-teaching experience as positive and valuable. The main advantages listed by students were better communication, practicality, increased attention and interaction, and overcoming student-teacher anxiety. The main disadvantage was the perceived lack of structure and experience in coordinating laboratory work. The study results indicate that peer-based instructional methods can lead to more effective dissemination of knowledge among students, as evidenced by the high percentage of respondents who reported improved comprehension through peer-to-peer explanations. At the same time, the efficacy of this approach is contingent upon the instructor's preparation and support, which facilitates the learning process and enhances the classroom's social dynamics.

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Introduction

The engineering educational landscape has undergone significant shifts in recent years, with a growing emphasis on developing a broad range of skills and competencies in engineering students beyond technical expertise. The demand for engineers with diverse skills and competencies has risen in response to the increasing complexity of the global economy and technological advancement (Jamieson and Lohman, 2012).

This poses multiple challenges for more traditional and content-focused engineering education institutions, which predominately use lectures and demonstrations, teaching methods that no longer meet students' 21st-century competencies and academic needs (Orji and Ogbuanya, 2018). To meet this demand, educational institutions have had to adapt curricula and teaching methods to better prepare students for success in the modern workforce.

Changes have been made in the instructional process in engineering schools worldwide, recognising the need for a more holistic approach to preparing engineers for the challenges and opportunities of the modern world. This has involved a shift from the content-oriented and instructor-focused approach (Lindblom-Ylänne et al. 2006) towards a more hands-on, active learning approach, such as cooperative learning and peer teaching, which effectively develops critical thinking, problem-solving, and communication skills in engineers, essential for success in the 21st century (Lima et al. 2017; Hartikainen et al. 2019; Tomkin et al. 2019; Tullis and Goldstone, 2020).

In this study, we investigate using a specific active learning technique, namely student peer teaching, in the context of an elective laboratory class on Hydropneumatics Drives offered within the bachelor's degree program in Automation and Applied Informatics at the Faculty of Automatic Control and Computer Engineering. The course aims to give students a comprehensive understanding of pneumatic drives and their advantages over mechanical, hydraulic, or electrical equipment. The study was conducted over two consecutive academic years, 2021 and 2022, and focuses specifically on the laboratory component of the course.

The current paper is structured into five sections, each providing a comprehensive overview of the study's objectives and methods. The first section examines the literature on peer learning and peer teaching in higher education. The second section presents the research setting and the specific peer teaching process and activities utilized in the Hydropneumatics Drives laboratory. The third section describes the methodology employed throughout the study, including the techniques and methods used to collect and analyse data. The fourth section presents the study's findings, including a detailed discussion of the outcomes. Finally, the fifth section concludes the paper by highlighting the study's limitations, providing recommendations for future research, and discussing the implications of the findings for Higher Education Institution (HEI) professors.

Peer learning and peer teaching. The word "peer" comes from the Latin word "par," meaning equal and describes someone who is a member of the same social group, profession, or age range as oneself. Learning with and from one's peers is a natural and common human activity, and this type of learning has been proven to be very beneficial for all parties involved (Meeuwisse et al. 2010; Soldner et al. 2012; Snyder et al. 2016; Gong et al. 2020).

Peer learning can be defined as "the use of teaching and learning strategies in which students learn with and from each other without the immediate intervention of a teacher" (Boud et al. 1999).

Peer learning is becoming increasingly popular in various disciplines and contexts because it offers many advantages for students as it allows them to learn by explaining their ideas to others and engaging in activities where they can learn from their peers. It creates a non-competitive empowering environment (Egbochuku and Obiunu, 2006) and helps them to develop skills such as organizing and planning learning activities, working effectively in teams, providing and receiving feedback, and evaluating their learning (Boud, 2001; Bene and Bergus, 2014; Williams and Reddy, 2016).

One critical benefit of peer learning is that it allows students to take on active roles in their education rather than being passive recipients of information. This can increase motivation and engagement, as students are more likely to be invested in the material when actively participating in the learning process (Glynn et al. 2006; Lucas, 2009; Rusli et al. 2020). Multiple previous studies have demonstrated that these programs not only enhance students' self-assurance and better equip them for assessments/exams but also enhance academic achievements and encourage further academic pursuits (Altintas et al. 2016; Rohrbeck et al. 2003; Elshami et al. 2020; Williams and Reddy, 2016; Porter et al. 2013).

At the same time, peer teaching is a mutually beneficial process for both student learners and student teachers as it allows for revising and deepening knowledge (Boud, 2001; Capstick, 2004; Ramaswamy et al. 2001; Tullis and Goldstone, 2020; Boud, 2001). Student-teachers can improve their communication skills by explaining complex ideas to others, which is crucial for working in groups and with colleagues. The need to explain the material to others can increase both the willingness to acquire knowledge (Daud and Ali, 2014) and actual learning by allowing one to understand better, clarify, and internalize the information, identify misconceptions, and gain new perspectives (Webb, et al. 2009; Bene and Bergus, 2014; Erlich and Shaughnessy, 2014).

A widely recognized educational tool, the Learning Pyramid, suggests that the most effective way to learn and gain skills so necessary in engineering is by practicing or actively participating - with the most significant value of 90% retention, teaching the material to someone else - with 70% retention, and discussing the material with others - with 50% retention (Al-Badrawy, 2017; Gabor et al. 2022).

These methods have been the subject of significant research in recent years, with studies showing that they can effectively enhance student engagement, motivation, and achievement in various educational contexts (Felder and Silverman, 1988; Prince, 2004; Roseth et al. 2008; Secomb, 2008).

The studies focusing on engineering education revealed that active learning methods and, significantly, peer teaching effectively improved engineering students' conceptual understanding and problem-solving skills (Felder and Silverman, 1988; Smith, et al. 2009), overall academic performance, and attitude toward learning (Prince, 2004; Freeman, et al. 2014; Tullis and Goldstone, 2020; Bene and Bergus, 2014; Hailikari et al. 2021).

The research setting. In the era of rapid technological advancement, engineering graduates are expected to have a strong innovative mindset and be equipped to tackle complex challenges posed by new technologies. The quality of education students receive during their studies, including acquiring essential skills and competencies, will play a significant role in meeting these demands. Revamping the way laboratory hours are conducted, using new and effective methods, provides students with an in-depth understanding of their chosen engineering field and boosts

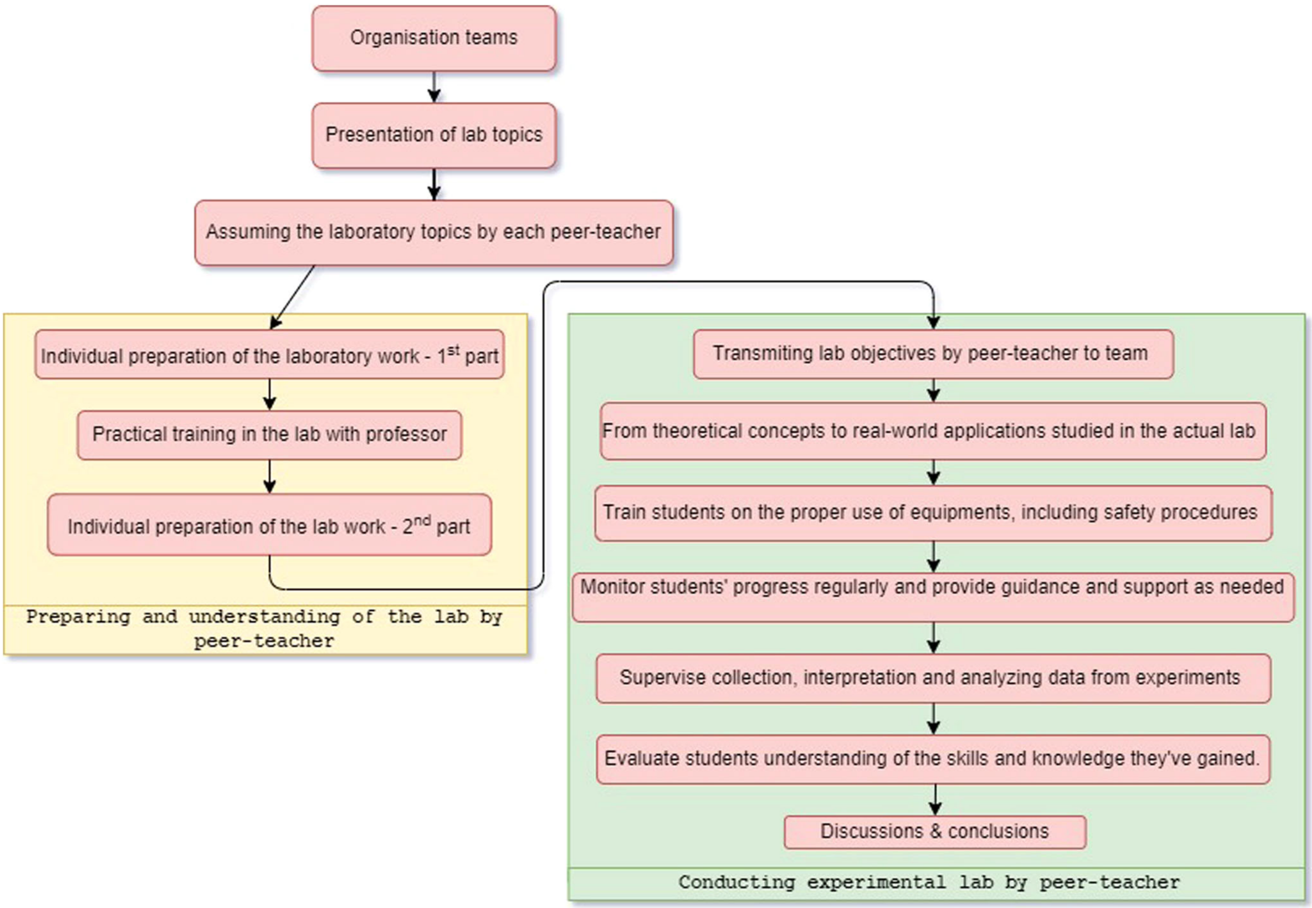

Fig. 1 The workflow in the experimental laboratory for Student Peer Teaching.

their confidence in their abilities. Therefore, laboratories are considered essential to engineering programs and are used as part of an active learning strategy (Rodgers, et al. 2020).

The experimental laboratory is critical to engineering education as it enables students to apply theoretical concepts to real-life scenarios. By allowing students to observe, measure, and analyse real-world phenomena, they gain a deeper understanding of engineering principles. Hands-on learning opportunities and exposure to the dynamic engineering field through the laboratory can significantly enhance student engagement and intrinsic motivation (Snětinová and Kácovský, 2019).

The Hydropneumatics Drives laboratory is used to test and study pneumatic drive systems. Pneumatic drives use pressurized gas, typically air, to power and control mechanical devices. These systems are used in various applications, including manufacturing, material handling, and automation. In a hydropneumatics drives laboratory, future engineers might test and analyse the performance of pneumatic actuators, valves, and other components and study the design and operation of pneumatic drive systems.

The Hydropneumatics Drives laboratory is a “hands-on” lab where the students learn through interactive activities or exercises that allow them to gain practical experience by performing a task or series of tasks, typically using didactic or industrial equipment and/or software for pneumatic circuit designing. With access to the latest equipment and technology, students can conduct experiments and research that would otherwise not be possible, providing a more authentic and valuable learning experience. In parallel with the new setting and equipment, in 2021, reciprocal peer teaching was introduced as a learning method. This approach can be effective in helping students to better understand concepts and retain information, as it allows them to actively engage with the material and learn from a peer who may have a different perspective or approach to the subject (Deslauriers et al. 2011).

Additionally, reciprocal peer teaching helps students develop essential soft skills, such as communication, critical thinking, problem-solving, teamwork, and collaboration, which are becoming more important in the new economic and industrial context (Tullis and Goldstone, 2020).

The laboratory is conducted with a group of students (usually four groups) formed out of 12–15, divided into three teams according to the student’s preferences. It is necessary to make an appointment for each student to take on the laboratory teacher role. Each student must take on this role at least once. After a complete rotation, when each student has taken on this role, for the remaining laboratory sessions, it is up to them to select the role, no longer being a requirement.

Considering an experimental laboratory’s complexity, the student-teachers must prepare for the working lab in advance. This training consists of two parts: first, they must read the laboratory description independently. In the second part, all student-teachers meet with the professor to highlight essential things from the next lab, starting with the learning goals and students’ expectations and ending with the results of the experiments and conclusions drawn from the results of the laboratory assignment. The entire process is presented in Fig. 1.

Through performing experiments and collecting data before the lab, student-teachers can apply and reinforce their understanding of scientific concepts and principles, which they will present and discuss with their colleagues in time of the laboratory. In the equipment portfolio, there are transparent or cut-away versions of teaching equipment which are imperative for understanding the principles of operation of a particular piece of equipment. These allow students to visualize the concepts they are learning about and can be used to demonstrate the principles of operation in a safe and controlled environment. It also allows peer teachers in the laboratory to focus on specific parts of the equipment, making the explanation more detailed and accurate for their colleagues to understand. Another tool for learning is the animation of working for each piece of equipment available from the equipment producer or the Internet.

However, the student-teachers can still use various other online resources to enhance their explanations and make them more detailed and precise, so that their colleagues can better understand.

During the labs, when the weight centre is shifted from the professor to the student-teachers, the professor can observe the entire learning process and act as a guide and facilitator, helping student-teachers present the procedures of the laboratory and providing guidance as needed. This is the basis of the pedagogy of engagement in which the professor assumes the role of designing and facilitating the learning experiences (Smith et al. 2005).

Methods

The study's main objective was to examine the computer science student's perception of peer teaching and better understand the method's perceived advantages and disadvantages in a Hydropneumatics Drives laboratory context.

To evaluate the effectiveness of the chosen method of instruction, the research team aimed to provide answers to two research questions:

1. How do students perceive the peer-teaching experience?
2. What are the perceived advantages and disadvantages of the method from the student's perspective?

To achieve this objective, the research team employed a pragmatic approach, incorporating both quantitative and qualitative data, to gain deeper insight into students' views on the peer-teaching process.

Participants. The study participants were computer science students enrolled in the Hydropneumatics Drives laboratory course during two consecutive academic years: 2021 and 2022. There were 96 students in total, 42 students in the 2021 academic year and 54 students in the 2022 academic year. All students participated in the peer teaching process as both student teachers and learners, and therefore, they all had to complete the two questionnaires.

As seen from Tables 1 and 2, 59 students completed the student-learner questionnaire, representing a 61% response rate, while 62 students completed the student–teacher questionnaire, representing a 65% response rate.

For context, 30.5% of the respondents completed the course in the 1st Semester of 2021, while 69.5% completed the course in the 1st Semester of 2022.

The student–teacher questionnaire is presented in Table 2.

For the second questionnaire, 27.4% of the respondents completed the course in the 1st Semester of 2021, and 72.6% of the students completed the course in the 1st Semester of 2022.

Data collection. In the data collection stage, the students completed two questionnaires, one from the student-learner perspective and one from the student-teacher perspective. The students were asked to complete the online survey at the end of the semester, and the data was collected via Google Forms.

Both questionnaires had two parts, one that included close-ended questions using a 5-point liker scale (1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree) and open-ended questions regarding the advantages and disadvantages of the instructional process and recommendations.

The student-learners questionnaire included:

(1) 13 close-ended questions using a 5-point Likert scale for each evaluation criteria (see Table 3).

Table 1 Student-learners questionnaire.

		Frequency	Percent	Cumulative Percent
Valid	1st semester 2021	18	30.5	30.5
	1st semester 2022	41	69.5	100.0
	Total	59	100.0	

Table 2 Student-teachers questionnaire.

		Frequency	Percent	Cumulative Percent
Valid	1st semester 2021	17	27.4	27.4
	1st semester 2022	45	72.6	100.0
	Total	62	100.0	

Table 3 Student–learners - Cumulative positive response rate (CPRR).

Question	CPRR
Q1 The content of the laboratories was appropriate for the student's level.	86,4%
Q2 The Peer teacher's methods were helpful.	83%
Q3 I understood the subject better after the laboratory sessions.	88,1%
Q4 I understood the laboratory better when a classmate explained it.	71,2%
Q5 I am more willing to engage in sessions taught by peers compared to faculty teachers.	60,4%
Q6 The laboratories were better than I had expected.	61%
Q7 The Peer teacher's selection process was fair.	83%
Q8 The Peer teachers were correctly trained to be able to teach.	74,6%
Q9 The peer teachers were well-prepared and knowledgeable about the topic.	72,9%
Q10 The laboratory equipment was adequate.	98,3%
Q11 The number of students in the laboratory groups was appropriate.	88,1%
Q12 The laboratory rooms were appropriate for the activity.	100%
Q13 We should have more peer-led laboratories.	74,6%

Table 4 Student–teachers - Cumulative positive response rate (CPRR).

Question	CPRR
Q1 Serving as a peer teacher increased my self-confidence.	64,5%
Q2 Serving as a peer teacher improved my academic performance	62,9%
Q3 Serving as a peer teacher improved my communication and active listening skills.	75,8%
Q4 I had the opportunity to consolidate my own knowledge.	95,1%
Q5 I have a better understanding of teamwork and understanding roles within the team.	82,2%
Q6 I gained many benefits from this experience and am willing to repeat it.	75,8%
Q7 Teaching is complex, and I felt myself getting better each time.	62,9%
Q8 The students were actively engaged during the teaching sessions.	72,6%
Q9 Serving as a peer teacher requested a lot of effort on my part.	69,3%
Q10 I think the students benefited from this teaching experience.	85,4%

(2) One open-ended question referred to the perceived advantages and disadvantages of the peer teaching method.

The student–teachers' questionnaire included:

(1) 10 close-ended questions using a 5-point Likert scale for each evaluation criteria (see Table 4).
(2) 4 open-ended questions referred to the reasons they chose/did not choose to teach more than one seminar, the difficulties they faced, and the things they would do differently if given the opportunity.

Data analysis. The analysis was based on two main categories: quantitative and qualitative.

The quantitative analysis was executed using multiple tests in SPSS, while the qualitative one used manual coding in Excel on both student-teacher and student-learner questionnaires, with the same analysis steps being considered. For the quantitative analysis, 13 questions were designed to be studied on the student-learners scale and 10 for the student-teachers scale, respectively. As a first step, to validate the questionnaire items, a Reliability Analysis was run and the Cronbach's Alpha values indicate there is a correspondence between the questions selected and they are relevant for the survey. The Alpha values being compared with the 0.8 threshold (0.891 > 0.8 for student-learners), (0.818 > 0.8 for student-teachers). Based on the validated items, a series of Descriptive Statistics determined an average cumulative positive impact on student-teachers of 74.66% based on the interval (62.9–95.1%) and the same average cumulative positive impact had a value of 80.12% (60.4% - 100%) for the student-learners scale. The last step in the quantitative section was to apply a correlation analysis to measure the strength of the relationship between the variables. Testing the Pearson Correlation Coefficient with a significance level chosen (p-value < 0.05), a group of positive, strong relationships (r > 0.5) were described on both scales. For the student-learner questionnaire, 6 relationships are identified, with Pearson Correlation values between (r = 0.516 – r = 0.625) and 14 relationships for the student-teacher scale, having values between (r = 0.503 – r = 0.654).

The qualitative analysis reports four main themes grouped as two factors on each scale: the student-teacher scale describes Advantages and Disadvantages, and the student-learners define Difficulties and Improvements. The first step outlines going through the open-ended questions and manually coding the responses into keywords. Following this, each keyword, based on frequency, is grouped within its relevant theme.

Results and discussions

Insights from the quantitative analysis. As presented in Table 3, the cumulative positive response rate for all close-ended questions was over 60%.

According to the table, the positive response regarding the laboratory room was 100%, followed by the laboratory equipment used, with a cumulative positive value of 98.3%. The results show the importance of the laboratory setting and equipment for technical labs. The correlation analysis also supports this, as medium positive relationships (> 0.5) between the following variables were identified: a strong relationship between laboratory equipment (Q10) and laboratory room (Q12) (r = 0.625) and a medium relationship between the number of students (Q11) and laboratory room (Q12) (r = 0.622). Other relevant statistical relationships were between the following variables: a medium relationship between student-teaching methods (Q2) and training (Q8) (r = 0.546), a medium relationship between preparation and knowledge (Q9), and an explanation by a colleague of the material (Q4) (r = 0.516), a medium relationship between expectations (Q6) and training (Q8) (r = 0.593) and medium relationship between expectations (Q6) and peer-led laboratories (Q13) (r = 0.572).

According to the data in Table 4, a positive impact was observed for all questions regarding the respondents' opinions, with a cumulative value of the first two response options (Agree and Strongly Agree) exceeding 60%.

According to the Pearson correlation coefficient (r), medium relationships exist among the items used in the analysis. Medium relationships were identified between self-confidence (Q1) and each of the following variables: academic performance (Q2) (r = 0.580), communication and active listening (Q3) (r = 0.580), student-teacher benefits (Q6) (r = 0.654), and teaching activity (Q7) (r = 0.513). Additionally, medium relationships were identified for academic performance with the following variables: communication and active listening (Q3) (r = 0.543), knowledge consolidation (Q4) (r = 0.522), teamwork (Q5) (r = 0.524), and student-teacher benefits (Q6) (r = 0.605). For communication and active listening skills, medium relationships were identified with the following variables: knowledge consolidation (Q4) (r = 0.576), teamwork (Q5) (r = 0.594), and teaching activity (Q7) (r = 0.503). For the knowledge consolidation variable, medium relationships were identified with teamwork (Q5) (r = 0.573) and student-learner benefits (Q10) (r = 0.554). A medium relationship was also identified between student-teacher benefits (Q6) and teaching activity (Q7) (r = 0.642).

Insights from the qualitative analysis. The responses from the open-ended questions were transcribed, divided into meaningful fragments, coded manually, and analysed using a thematic analysis, which represents the process of "identifying, analysing, and reporting patterns (themes) within data" (Braun and Clarke, 2006). The first step of the process consisted of a review of the initial transcribed versions done by the authors. The goal was to better understand the students' perceptions regarding the overall value of the peer-teaching process and the method's strengths and

Table 5 Peer teaching advantages - categories.

Main themes	No. of nominations	Relevant quotes
Better communication	22	*„Yes. Personally, if I don't understand, I feel like I can more easily ask about any confusion I have, feeling more connected to the teacher".* *„It is easier to communicate with a colleague when we have confusion than with a teacher, because the colleague knows what it's like not to know or understand, because he goes through the same experiences as I do".* *„Yes. It was a new experience, I understood very well from our colleagues. They explained things in a way that was more understandable to us. I felt much more comfortable asking my own colleague, everything was more open and relaxed".* *„I think the way our colleagues teach is a valuable learning experience, because they are able to express their ideas in simpler terms that are easier to understand than a teacher would".*
Practicality	8	*"Yes, because we get used to working in a team, as well as in a leadership position".* *"It's an unusual but good different experience as it will prepare us for the training that will follow in the workplace where we are not explained by a teacher but by a colleague".* *"It is very valuable because it develops the vocabulary of an aspiring engineer".*
Increased attention & interaction	8	*„This form of teaching is quite unique for me, and the fact that I was taught by a colleague made me more attentive".* *„I consider that the method of teaching by peers is a way for students to interact better, and the knowledge transmitted is better understood by those who listen, and those who teach consolidate the information much better".*
Overcoming "student-teacher anxiety"	4	*„I consider the way our colleagues teach valuable, because there are people who have a small "anxiety" about teachers, perhaps due to some less pleasant experiences with certain teachers who have adopted a less worthy attitude of a good teacher. This opportunity can help them overcome their small "fears"; fear of expression, fear of making mistakes, fear of criticism, fear of being laughed at by classmates/teacher, etc".*

Table 6 Peer teaching disadvantages - categories.

Main themes	Relevant quotes
Lack of structure	*"I don't think students are sufficiently prepared to coordinate a laboratory work. Although I sometimes understood a little more than I would have from a teacher, it was not very well-organized teaching".*
Lack of experience	*"Some colleagues had weaker and others better teaching methods, but my preferred method is when the person teaching me can simplify the subject so I can then more easily get into the rigorous details. When presented with much new information it is easy for me to lose focus and fall behind".*

weaknesses. The open-ended question in the student–learner questionnaire referred to the perceived advantages and disadvantages of the peer teaching method, and several themes emerged predominantly from the 57 valid answers received. Detailed information on the number of themes and sample responses from the respondents is presented in Tables 5 to 8.

When asked whether they think the method has proved valuable, 87% answered that the peer-teaching experience was positive and valuable mainly because they felt more comfortable interacting and asking questions. Two students considered that there was no value in the instructional method, and two gave neutral answers (both yes and no). The thematic analysis of the main advantages of the peer-teaching process listed by students is presented in Table 5.

The main disadvantages of the method perceived by student-learners are presented in Table 6.

In terms of disadvantages perceived by students, some listed the difference in expertise between student-teachers and professors, leading to students not trusting their peer teachers and, consequently, not learning as much from peers as they do from professors. This result is in line with other studies (Boud et al. 2001; Lelis, 2017; Sim, 2003). Several students mentioned this is a valuable instructional method, but it should be used occasionally. The results also highlight the relevance of several contextual factors, such as individualized teaching-learning style, confidence level, or motivation, that significantly impact the learning-teaching process (Ramm et al. 2015; Zarifnejad et al. 2018).

The open-ended questions in the student-teacher questionnaire asked about the reasons they chose/did not choose to teach more than one seminar, the difficulties they faced, and the things they would do differently if given the opportunity.

Out of the 62 students who completed the questionnaire, only 34% chose to teach a second time. Over 80% of the students who chose not to teach again did this due to busy academic schedules and inability to participate in the training sessions with the professor (10), impossibility due to activity format and team organization (10), lack of perceived incentives (2), lack of enjoyment of teaching activity (2), perceived lack of talent and lack of confidence (2). An important aspect to mention is the extra work and time student-teachers must put into participating in and delivering the class.

Out of the 34% who decided to teach more than one laboratory, most listed that they learn better when explaining the subject to a colleague because they feel a certain responsibility toward their peers.

However, the main advantages perceived by most peer teachers, regardless of whether they taught more than one laboratory, revolved around two aspects: gaining an in-depth understanding of the subject and developing better communication and presentation skills, both elements confirmed by previous studies on the matter (Tullis and Goldstone, 2020; Daud and Ali, 2014; Smith, et al. 2009).

In terms of the difficulties encountered in the teaching process, 20 students declared that they encountered no difficulties; for the other answers, the main categories identified are listed in Table 7.

Table 7 Difficulties encountered in the process – categories.

Main themes	No. of nominations	Relevant quotes
Lack of experience & knowledge	18	*"The need to fully understand the lesson in order to be able to explain it correctly to my colleagues". "The large amount of information I had to master while learning because if a teammate had confusion, I had to clarify it, if they couldn't understand something, it was my fault". "My colleagues' curiosities often exceeded my knowledge, so I believe that the assistance of a teacher is necessary.*
Lack of confidence	6	*"I was nervous to speak in front of my colleagues". „I was speaking too quietly and it was uncomfortable to speak loudly so that the rest of the class could hear me. I had forgotten some concepts even though I had learned them before".*
Lack of authority and interest from students	8	*"Capturing the attention of my students". "A small lack of "authority" in front of my colleagues, to make them pay attention to what I have to say".*

Table 8 Corrective actions and improvements – categories.

Main themes	No. of nominations	Relevant quotes
Improving the documentation process	14	*"I would prepare better. Not just for my peers who I would explain to, but also for myself". "I would have more confidence, research more thoroughly, and structure the presented material better".*
Improving practical activities	13	*"Try to capture their attention through multiple videos or GIFs that explain the proposed material in a visual way. Show more videos". "A higher level of interaction with hardware components where possible, and small tests to assess understanding".*
Improving presentation skills	10	*"I would practice on my presentation more and pay more attention to the way I teach". "...By making them interested, the teaching would take place much more easily, and it would be a plus for me (the satisfaction of being successful as a teacher), but also for the students who would learn something new and remember, because everything would take place in a pleasant environment. I think that the students' attention during a laboratory depends a lot on the teacher's attitude, who, regardless of their knowledge or actions, should adopt an equal attitude, not one of superiority".*
Require more support	6	*"If I were put back in the teaching position, I would try to ask the teacher for more help".*

Although the instructional method has multiple benefits, the study revealed a series of drawbacks and challenges.

The first refers to the level of expertise and the need for consistent preparation to deliver quality content. Student responses reinforce the findings of prior research that emphasize the importance for peer-teachers to thoroughly understand the subject matter in order to teach effectively (Stigmar, 2016; Menezes and Premnath, 2016). The lack of confidence and perceived authority among their peers have also been listed in previous studies as challenges of the method (Irvine et al. 2018), as students are sometimes unsure of the tone to use to appear knowledgeable on the subject without seeming arrogant.

When asked what they would do differently if given the opportunity to teach again, nine out of 62 students said that they wouldn't change anything, while the rest of the 53 listed aspects are included in the categories presented in Table 8.

After looking across all the comments and comparing the perspectives from both roles, student and teacher, some interesting results arose on the perceived value of the peer teaching instructional method. First, from the student-learner perspective, the aspect of increased engagement and better communication mentioned by students participating in the study was listed by other studies as well (Boud, 2001; Lelis, 2017; Bulte et al. 2007; Lucas, 2009; Tullis and Goldstone, 2020). Another relevant aspect refers to the student-teacher benefits, namely, learning better by explaining the subject to a colleague. Through teaching, they gained an in-depth understanding of the subject and developed better communication and presentation skills.

The positive impact is also highlighted by the fact that students who participated in the laboratory sessions in the previous academic year showed an increased interest in pursuing bachelor thesis projects related to the pneumatic automation field over the past year.

Conclusions

This study aimed to examine engineering students' perceptions of the advantages and disadvantages of peer teaching after implementing the method in a specific setting, namely a Hydropneumatics Drives laboratory. Although the analysis is limited to a specific context, the results are promising and support the available literature on peer teaching methods in engineering education.

The results show that students respond positively to the social elements of the peer teaching process, as many highlighted positive aspects related to „better communication" or „increased attention and interaction." These outcomes are confirmed by previous studies on this matter (Hammond et al. 2010; Tullis and Goldstone, 2020) and highlight the importance of feeling comfortable asking questions and receiving answers in relevant and applicable terms. Furthermore, the fact that over 70% of respondents declared that they understood the laboratory better when a classmate explained it reinforces the results of previous research highlighting the impact of peer teaching on academic performance (Tullis and Goldstone, 2020; Rusli et al. 2020). However, the fact that there is a strong positive relationship between preparation and knowledge (Q9) and explanation by a colleague of the material (Q4), means that the success of the instructional method is highly dependent on the preparation of all stages and the professor's ability to guide and provide support for student-teachers in the preparation and delivering process. An additional benefit of this method lies in the enhancement of empathy between students and professors, as the practicality of the teaching experience offers students a different viewpoint and promotes a deeper understanding of the pedagogical process.

An effective learning process is characterized by its ability to foster student independence, enhance confidence, and elevate motivation. Our results show that peer teaching can be a valuable method for training students to develop independence, enhance their confidence, and increase their enthusiasm to learn, as these are directly related to students assuming responsibility for their own learning. Overall, the study reveals that taking on the teacher role comes with both academic benefits (gaining an in-depth understanding of the subject) and personal benefits (developing better communication and presentation skills). This can further lead to another benefit for the students and the institution: opening the possibility to follow an academic career. This is important as the industry represents a more appealing option, especially for computer science graduates, and fewer decide to continue with a Ph.D. and remain as professors.

The study also has some limitations as it was conducted in a specific setting with a restricted number of computer science students who enrolled in the Hydropneumatics Drives laboratory. Students were all assigned both roles as teachers and as learners, and the demographic data was not included in the analysis. Future studies should be conducted on other courses with larger sample sizes and random assignments. Another useful direction for future studies is investigating the long-term effects of peer teaching on students' academic performance and retention rates. This can provide valuable information regarding the long-term sustainability of this instructional method, as more research is needed to fully understand its potential impact and optimal implementation strategies.

Data availability
All data generated or analyzed during this study are included in this published article.

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Author contributions

The authors contributed equally to the article writing process, from formulating the research plan to writing and editing the manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethical approval

All procedures performed in our study were in accordance with the ethical standards of the Gheorghe Asachi Technical University of Iasi. The research was conducted in accordance with the Code of ethics and professional deontology of the Gheorghe Asachi Technical University of Iasi - TUIASI.COD.01, approved on 21.01.2016, edition 3, rev. 0.

Informed consent

Informed consent was obtained from all individual participants involved in the study. Participants were involved in an information session about the study and had the opportunity to ask questions before fill-up the questionnaire. Participants were informed that they could refuse to complete the questionnaire without penalty or consequences. The questionnaire ensured participants' anonymity, as no identifying details were required.

Additional information

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