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Impact of Peer Learning on the Academic Performance of Civil Engineering Undergraduates: A Case Study from China*

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Structural mechanics is a demanding but very important professional basic course for civil engineering undergraduates. In this study, peer learning was applied to a structural mechanics course through specific methods such as sequential teaming method, randomly selected collective scores method, bonus points, and penalty points. A quasi-experimental study compared the treatment group and the control group using a mixed qualitative and quantitative research method consisting of interviews and questionnaires. The results showed that compared to the control group, peer learning improved the final exam score by 8.2 points and reduced the failure rate by 15.2%. However, the treatment group did not have a higher evaluation of classroom and learning gains than the control group. Peer learning can also play a role in character education, as it improves students' problem-solving skills, communication skills, teamwork skills, time management skills, and teacher-interaction skills. Social avoidance and personal preferences severely restrict more active participation in peer learning, and targeted improvement measures will be implemented in the future.

Keywords: qualitative and quantitative research; cooperative learning; character education; academic performance; psychometric measurement

1. Introduction

Structural mechanics is one of the foundation courses in civil engineering. It is also an assessment course that forms part of the entrance exam for Chinese graduate students who want to study civil engineering. After students have understood the mechanical properties of materials, the structural mechanics course helps them to master the basic concepts and methods required for the stress analysis of bar system structures. It also helps them to grasp the mechanical behaviors of various structures, engage in structural analysis, and conduct calculations. Structural mechanics lays the foundation for subsequent professional courses and forms the basis of structural design and scientific research. The structural mechanics course focuses on logical deduction and mathematics, both of which can be challenging. Consequently, students often find the course boring and may even give up because of a lack of interest, causing many students to fail each year. Thus, it is highly worthwhile to explore how students' exam scores and pass rates can be effectively improved.

The most important factors for graduates majoring in civil engineering are undoubtedly their professional knowledge and skills. However, in addition, there are also skills and character attributes that will have a long-term and vital impact on their career [1]. A study conducted by the Industry Advisory Committee in Australia [2] showed that among 64 generic competencies, communication, teamwork, self-management, and problem solving are the most important [3]. Another survey of 14,429 respondents (i.e., practicing engineers, alumni, students and teachers of engineering schools) [4] identified problem-solving, communication, teamwork, and professional ethics as the most important qualities. These qualities are even more important than mathematics, science, engineering tools, experimentation, and data processing [5].

Problem-based learning (PBL) and character education (CE) have been employed in structural mechanics courses for several years. Specifically, famous buildings and construction cases are used as examples for PBL, while the actions of famous engineers and mechanics are used for CE. However, there has been no breakthrough progress so far. This study was designed to improve the learning process of structural mechanics by adding peer learning on the basis of PBL and CE, thus changing students' learning from passive learning to active learning. In addition to knowledge goals, further gains can be achieved, such as improving teamwork spirit as well as enhancing communication and

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expression skills. Finally, peer learning can also improve students' evaluation and satisfaction with the course. This paper addresses the following four main research questions:

Research Question I: Can peer learning improve the exam score of structural mechanics courses?
Research Question II: Can peer learning improve students' classroom evaluation?
Research Question III: Can peer learning improve students' personal characteristics?
Research Question IV: What are the acceptance level, shortcomings, and improvement measures of peer learning?

2. Literature Review

2.1 Problem-based Learning and Character Education

PBL has been widely adopted in medical and engineering education [6, 7]. Compared with traditional teaching, PBL has been shown to significantly improve students' understanding of physical concepts [8], improve their academic performance [9, 10], and positively impact their ability to learn in more advanced courses [11]. With regard to CE, PBL enables students to cultivate their teamwork and communication skills in a positive learning environment [12].

CE focuses on students' moral characteristics, civic characteristics, performance characteristics, and intellectual characteristics [13]. Many countries, such as the UK, Canada, Australia, Japan, and Singapore, greatly emphasize CE. These countries have conducted considerable research on this topic [14–18]. The Jubilee Centre for Character and Viruses at the University of Birmingham plays a leading role in CE in the UK, arguing that a good character can be taught and learned [19]. Moreover, the exemplarist moral theory of Zagzebski states that people can learn moral character through imitation. Thus, examples can be used as guides for CE [20, 21]. Moreover, MacIntyre argued that a person's morality originates from their unique history, community, and culture; thus, moral inheritance relies on tradition, historical narratives, and a kind of moral genetics [22]. While much research examined CE at primary schools and high schools, research into CE at universities is rare [23]. It has been shown that the effectiveness of CE increases as students get older and that CE significantly improves students' performance and behavior [24]. Therefore, CE should be integrated into university curricula [25]. Structural mechanics courses can use the spiritual values and aesthetic accomplishments contained in case studies and other examples to conduct CE. This involves influencing students' character through their environment. In this way, students can learn the skills of cooperation, teamwork, problem-solving, listening, empathizing, and time management.

2.2 Peer Learning and Cooperative Learning

Peer learning or cooperative learning are umbrella terms [26] that include reciprocal teaching, peer tutoring, peer coaching, jigsaw, and other group-based activities. Peer learning methods can effectively enhance self-regulation as they encompass elements of motivation, self-efficacy, time management, goal setting, meta-cognition, and an associated range of emotions [27]. The advantage of cooperative learning is that it can improve students' self-confidence and motivation as well as their sense of responsibility in learning. While this makes it easier for students to learn, the disadvantage is that it requires more time to prepare, implement, and manage [28].

Many courses in different majors at universities around the world have adopted peer learning or cooperative learning methods, achieving good results. The adoption of peer learning in architecture Bachelor of Science courses that focus on architecture sustainability has been shown to improve students' knowledge and motivation [29]. The pharmacology course for undergraduate nursing students combines offline learning with online peer learning, which improves the learning experience of students [30]. Peer coaching has increased the pass rate of the bioscience course for Bachelor of Nursing and Midwifery students [31]. Students' peer learning in marketing courses has led to objective performance improvements [32]. Science, Technology, Engineering, and Mathematics (STEM) courses adopt the "peer-learning assistant" model, thus enabling students to achieve learning improvement [33]. Peer coaching has improved students' listening and coaching skills in an MBA leadership coaching course [34]. Peer assessment methods have improved students' creative problem-solving skills in an engineering design course [35].

Cooperative learning enables students to learn more, remember more, and be more satisfied with advanced engineering courses [36]. The academic performance, attitude, and memory retention improved in students of a planar dynamics course [37]. Additionally, cooperative learning has improved the examination scores of intermediate macroeconomics by 3–6 points [38]; it has also improved the critical thinking of engineering ethics courses [39], and the positive academic classroom community of natural sciences and other courses [40]. Furthermore, cooperative learning has been shown to improve students' critical analysis, communication, teamwork, and problem-solving skills in food process systems engineering courses [41]. Furthermore, creativity, deep learning, and teamwork skills were also found to improve in chemical engineering students in three courses [42]. Higher learning benefits and transferable skills were obtained in an introductory organic chemistry course [43]. Finally, it is worth emphasizing that a computer systems course for first year undergraduates has not achieved the expected learning outcomes for all students, despite a careful course design [44].

3. Methodology

3.1 Participants and Course Design

3.1.1 Participants

Jiaxing Nanhu University is an applied undergraduate university located in Zhejiang Province, China. At this university, students only need a Bachelor of Civil Engineering to study structural mechanics. The participants in this study are third year students majoring in Civil Engineering (admitted in September 2020), and the structural mechanics course is offered in the 2022–2023-1 semester (i.e., the fifth semester). About 60 Bachelor of Civil Engineering undergraduate students are divided into two classes each year. In this study, one class was randomly selected and allocated to the treatment group (n = 31) and the other class was allocated to the control group (n = 32), taught by two teachers who have taught this course for more than 6 years. All students are Chinese, which means that they have the same historical and cultural background, prior mechanics knowledge, and psychological factors. Specific information is shown in Table 1.

The scores of theoretical mechanics and materials mechanics in Table 1 originate from the teachers of these courses, and the scores of psychological factors originate from the critical thinking scale and social avoidance scale. The meaning of scores is introduced in Section 3.6. Although there was no statistical difference in the data shown in Table 1 between the treatment group and the control group ($p > 0.05$), the average values of theoretical mechanics, material mechanics, and critical thinking of the treatment group are 5.3, 2.6, and 4.7% lower than those of the control group, respectively. This is not conducive to research. If, under these unfavorable conditions, the treatment group achieves better results than the control group, the conclusion of the experiment has strong credibility.

3.1.2 Course Design

Before this study was conducted, PBL and CE have been integrated into the structural mechanics course, but no clear improvement in self-perception was obtained. The teaching period of this structural mechanics course lasted from September to December 2022. The teaching duration and content of both classes were identical, and both were based on PBL and CE. The teaching contents and arrangement are shown in Table 2.

The teaching process of the treatment group used the peer teaching method, while the control group did not. The specific measures and differences are shown in Table 3.

3.2 Sequential Teaming Method and Sequentially Assigned Learning Teams

A study on a massive open online course showed that under free grouping conditions, significant differences exist in the performance between different groups [45]. Peer learning should therefore avoid free grouping, which will lead to homophily [26, 46], which is a phenomenon where homogeneous groups form, which makes peer learning impossible. Therefore, grouping needs to avoid the formation of teams consisting of friends [34], because friends (and family) fear change in members of their group [47]. People should change their learning habits and cultivate good ones in a suitable environment and atmosphere. The dormitory

Table 1. Descriptive statistics

Characteristic	Treatment n = 31		Control n = 32		Difference	
Demographic factors	**n**	**%**	**n**	**%**	**%**	**sig. (2-tailed)**
Female	4	12.9	4	12.5	0.4	0.962
Male	27	87.1	28	87.5		
Prior mechanics knowledge	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**sig. (2-tailed)**
Theoretical mechanics scores (TMS)	62.2	16.2	67.5	14.0	–5.3	0.164
Materials mechanics scores (MMS)	65.6	14.6	68.2	13.1	–2.6	0.461
Promotion from TMS to MMS	3.5	12.1	0.7	14.0	2.8	0.403
Psychological factor						
Critical thinking	75%	0.17	79.7%	0.15	–4.7%	0.274
Social avoidance	–1.2	3.6	–0.9	3.4	–0.3	0.734

Table 2. Teaching arrangement

Chapter	Theoretical content	Class hours	Experimental content	Class hours
1	Introduction	4		
2	Geometric composition analysis	6	Geometric construction analysis of planar systems	2
3	Static beam and rigid frame	10	Internal force calculation of static rigid frames	2
4	Static arch	2		
5	Static determinate truss	6	Internal force calculation of plane truss	2
6	Virtual work principle for structural displacement	10		
7	Force method for hyperstatic structures	10		
8	Displacement method for hyperstatic structures	10	Calculation of internal forces and deformations of hyperstatic structures	2
9	Asymptotic method for hyperstatic structures	6		
10	Influence line	4		
11	Final Review	4		
Amount		72		8

Table 3. Teaching experiment arrangement

Activities	Details	Difference Treatment vs Control	Design purpose
Lectures	Use of PPT and blackboard to explain basic principles and analyze relevant cases	Shorter time vs longer time	Squeeze time for peer learning
Cases and exercises	After students analyzed and calculated, the teacher explains	Peer learning vs independent learning	Discussion and thinking
Homework	Teacher grading homework	Randomly selected, scored by group vs independent	Mutual coaching
Attendance	Skipping classes will result in reduced process grades	Check before class vs check only if necessary	Punctuality concept
Recording courses	Use of two cameras to record teachers and students separately	Yes vs No	Observation and reflection

where students live is arranged according to their student ID; therefore, four students who appear consecutive on the roster often live in the same room. As long as students are arranged in different learning teams according to the order of the list, heterogeneous groups can be formed. This study refers to this grouping method as the *sequential teaming method* and the resulting team is called the *sequentially assigned learning team*. The sequential teaming method allows for a rhythmical list of students in each team, which makes the recording of scores convenient, while random grouping requires a long time to record and input scores. In principle, the number of people in each learning team is 5. The distribution free test is used for hypothesis testing, and the results are shown in Table 4. There is no significant difference among the scores of Theoretical Mechanics, Material Mechanics, and Structural Mechanics of each learning team.

3.3 Assessment and Score

3.3.1 Composition of the Score

The overall evaluation score (*OES*) of the course is determined by the process score (*PS*) and final exam score (*FES*), calculated according to Formulae (1) and (2).

$$OES = FES \times 60\% + PS \times 40\% \quad (1)$$

$$PS = AHS + \text{Bonus points} - \text{Penalty points} \quad (2)$$

The overall evaluation score is the only indicator needed for calculating the grade point average, obtaining scholarships, and determining whether a course has been passed. The process score is

Table 4. Hypothesis testing summary

	Null hypothesis	Test	Sig.	Decision
1	In the team number category, the distribution of Theoretical Mechanics scores is the same	Independent sample Kruskal-Wallis test	0.981	Keep the null hypothesis
2	In the team number category, the distribution of Mechanics of Materials scores is the same	Independent sample Kruskal-Wallis test	0.769	Keep the null hypothesis
3	In the team number category, the distribution of Structural Mechanics scores is the same	Independent sample Kruskal-Wallis test	0.284	Keep the null hypothesis

obtained by subtracting penalty points from the average homework score (*AHS*) and adding bonus points. These bonus points are generated by positive performance in class, such as interactions with teachers and submitting class notes. Penalty points are generated by negative behaviors such as being late, leaving early, sleeping in class, and playing mobile games in class.

In the study, the overall evaluation score was used as an indicator to calculate the failure rate, while the final exam score was used as an indicator to measure students' academic performance. While students with low final exam score may pass the course through good performance, students with high final exam score may fail because of negative behaviors. Therefore, the level of knowledge mastery cannot be evaluated based on the overall evaluation score, but rather based on the final exam score.

3.3.2 Randomly Selected Collective Scores Method

In commonly used group teaching methods, process scores and even overall evaluation scores are scored on a group basis. In other words, each group submits a piece of work, which is scored, and this score is then used as the score for the entire group. However, in reality, the members of the student group with strong academic abilities often complete their homework alone, while other students do nothing but still receive good grades. This phenomenon – which is called social loafing – is almost unavoidable in group teaching [41, 48, 49]. The goal of this study is to combat social loafing and activate learning enthusiasm, which is why an assessment system has been developed: the randomly selected collective score.

The assessment system of the randomly selected collective score was established by the author based on three pillars of peer learning: positive interdependence, individual accountability, and face-to-face promotive interaction [36, 42]. Randomly selected collective score refers to a process where the homework of one member of each learning team is randomly selected (after sufficient discussion and mutual guidance for the homework has been provided), their homework is corrected, and each member receives a homework score. As the students cannot know beforehand whose homework will be selected, everyone has to complete their homework with high quality. For students with strong academic abilities, teaching their team members without concealment will also benefit themselves, as otherwise, they may become implicated in the social loafing of their peers and receive low scores. For students with weak academic abilities, self-esteem drives them to actively study hard, to avoid being the cause of low scores for the entire team. Gradually, this may cultivate learning habits and interests.

It is worth noting that bonus points are set to avoid extreme cases of social loafing that prevent the entire team from passing the exam. In this system, individual students are encouraged to earn additional bonus points by providing lecture notes, actively interacting with their peers and the teacher, actively engaging in class, asking questions, and other means. In the first class, the lecturer introduces the system of peer learning, sequential teaming method, randomly selected collective scores method, bonus points, and penalty points, but did not provide a detailed explanation of the underlying reasons and advantages. Since then, the author has realized the necessity to provide such a detailed explanation. This will be improved in the next round of courses.

3.3.3 Final Exam and the Overall Evaluation Score

Under normal circumstances, there are two final exams – the regular exam and the make-up exam – which are arranged at the end of the semester and the beginning of the next semester, respectively. The calculation method for the overall evaluation score of the regular exam has been introduced earlier (see Section 3.3.1). A student with a total score below 60 will take the make-up exam. If the make-up exam score is greater than or equal to 60, the total score will be adjusted to 60. If it is less than 60, the total score will remain unchanged. In 2022, because of the impact of COVID-19, many students were not able to take the exam, so a postponed exam was added. The three exams were held on December 13, 2022 (the 16th week of the 2022–2023-1 semester), February 13, 2023 (the 1st week of the 2022–2023-2 semester), and March 3, 2023 (the 3rd week of the 2022–2023-2 semester). The relevant arrangements are shown in Table 5, and the calculation process of the overall evaluation score is shown in Fig. 1.

3.4 Research Tools and Instruments

This study used a mixed method of qualitative and quantitative research. The specific tools, schedule, and participants are shown in Table 5.

3.5 Interviews

The purpose of the interviews was to clarify students' feelings about the course and receive their suggestions for the course. According to relevant references and the characteristics of the course, the main axis of semi-structured interviews was preliminarily determined: is peer learning effective and popular, and what are its advantages and disadvantages? As the interview process deepens the understanding of students' thoughts, the focus

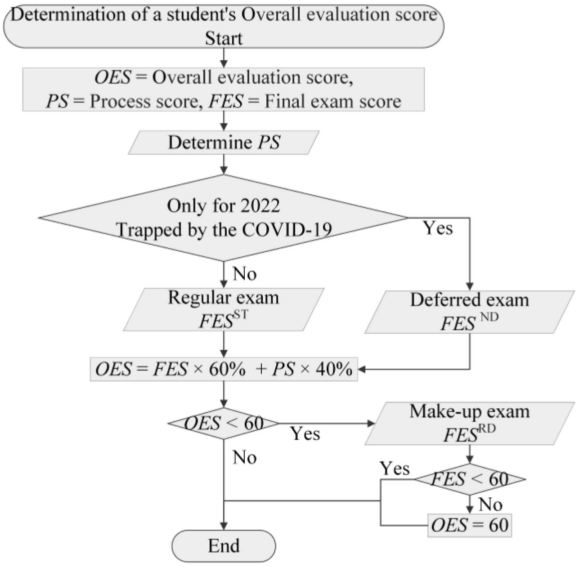

Fig. 1. Calculation process of the overall evaluation score.

and details of the interview were constantly adjusted.

The interview was conducted after process scores had been determined and announced, which, to a certain extent, allows students to express their true thoughts without having to worry that doing so might affect their scores. The interview process was recorded on camera, which is one of the reasons why certain students were unwilling to participate in the interview (there were also other reasons). In addition, because of time limitation, not all students could be invited to participate, and ultimately eight students were interviewed. In the experimental class, the instructor randomly selected students who appeared to be available at the time and asked if they are willing to participate in an interview. After one student's interview had finished, the next student was randomly selected. However, as the interviews progressed, more and more students

Table 5. Overview of research tools

	Activities	**Instrument**		**Content**	**Arrangements**	**Participants**
1	Assignment of study groups			Grouping by student ID	Week 1	Treatment
2	Pretest	Critical thinking scale		α = 0.910 5 items	Week 1	Both
		Social avoidance scale		α = 0.800 5 items		Both
3	Lectures and experiments			See Table 2 for details	Weeks 1–13	Both
4	Determination of process scores			Publishing of process scores	Week 13	Both
5	Students evaluate teachers			Organized by the school; no differentiation	Weeks 13 and 14	Both
6	Interview	Semi-structured interviews		7 themes	Week 13	Treatment
7	Regular exam	Final exam volume A		5 types of questions; centesimal system	Week 15	Both
8	Deferred exam	Final exam volume B		5 types of questions; centesimal system	Week 1 of the next semester (i.e., Week 25)	Both
9	Posttest	Learning gains scale		α = 0.897 10 items	Week 1 of the next semester (i.e., Week 25)	Both
		Classroom evaluation scale		α = 0.949 10 items		Both
		Peer learning effectiveness scale	Closed questions	α = 0.823 5 items		Treatment
			Open questions	1. Nominate the ability that improved the most		Both
				2. Nominate favorite elements		Treatment
				3. How to improve. . .?		Both
10	Make-up exam	Final exam volume C		5 types of questions; centesimal system	Week 3 of the next semester (i.e., Week 27)	Both

Table 6. T-test results of interview sampling and overall sampling

Parameters	**Interview n = 8**		**Treatment n = 31**		**Difference**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**Sig. (2-tailed)**
Theoretical mechanics scores	63.0	9.9	62.2	16.2	0.8	0.890
Materials mechanics scores	68.0	11.8	65.6	14.6	2.4	0.676
Structural mechanics scores	53.4	11.1	57.1	18.5	–3.7	0.592

completed the experiment and left, and fewer and fewer students remained in the classroom, which restricted the overall number of sampled students. The data in Table 6 show that there is no significant difference in academic performance between these eight interviewed individuals and the entire class, and the sampling interview is representative. The results of the interview are shown in Table 8.

3.6 *Questionnaire*

The questionnaires used in this study sampled both pretest and posttest. In the pretest, critical thinking scale and social avoidance scale were used, showing that there was no significant difference between the treatment group and the control group. The posttest used learning gains self-evaluation, classroom evaluation scale, and peer learning effectiveness scale to demonstrate the differences in results between treatment group and control group. The structure and usage instructions of each scale are provided in Table 7. The questionnaire was presented as an all-offline paper version, which was handed out and recovered by the lead author of the study. A total of 63 questionnaires were distributed, and 28 and 29 valid questionnaires were received from the treatment group and control group, respectively.

All courses offered are subject to a student evaluation teaching survey organized by the Academic Affairs Office of Jiaxing Nanhu University every semester. The survey results serve as an important basis for assessments and promotions. The survey results are completely confidential, but to support this study, anonymous survey results were obtained after application and approval. In the treatment group and the control group, 23 and 24 students, respectively, submitted questionnaires, but all students rated all items as A. Although the survey results indicate that both teachers are conscientious and responsible in accordance with the requirements of the University, because of the lack of differentiation, the result of this survey is invalid for the present study and is therefore not included in the analysis below.

The reason for the lack of differentiation in survey results may be that in traditional Chinese culture, benefiting others is considered a good moral character. Therefore, students' worldly wisdom and social experience induce them to give full marks to avoid teachers being punished by the university. In this study, this phenomenon is referred to as the protective instinct. Taking this as a lesson, to avoid students being afraid to tell the truth, instructors maintained an upright personality throughout the semester. For example, students were encouraged to ask questions and point out mistakes in the classroom. If any derivation or clerical errors were found, the instructor always directly acknowledged, apologized, and provided a correction. In addition, right before the questionnaire survey was conducted, the following points were made clear:

(1) Your questionnaire is anonymous, and your teacher will not know who said what.
(2) The questionnaire is a self-investigation by your teacher, and the teacher will not be punished for the results.
(3) Your answer will determine the direction of future course reforms. Future students will benefit from your honest answers.

The lead author and the third author were the lecturers of treatment group and control group, respectively. The lead author, who was unfamiliar to the control group, was responsible for the distribution and recovery of the questionnaire. This may result in a higher score than merited, because of the protective instinct discussed above.

3.6.1 *Critical Thinking Scale*

There are many classic scales that measure critical thinking, such as the California Critical Thinking Disposition Inventory with 75 items [50], Ricketts' Critical Thinking Disposition Inventory with 33 items [51], and Improvements in Critical Thinking Dispositions with 20 items [39]. This study cited and adapted the critical thinking scale, which contains

Table 7. Instructions for the questionnaire

Scale	Calculation	Score	Interpretation	
Critical thinking	$\frac{\sum_1^5 Q}{25}$	0–1	0–24%	Very low
			25–49%	Low
			50–74%	High
			75–100%	Very high
Social avoidance	$-Q_1 - Q_2 + (Q_3 - 2) + Q_4 + Q_5$	–10 to +10	–10 to –4	Social butterfly
			–3 to +3	Neutrality
			+4 to +10	Social avoidance
Learning gains	Each question is analyzed separately	1–5	<3	Negative
Classroom evaluation			=3	Neutrality
Peer learning effectiveness			>3	Positive

five items (α = 0.910), considering the aforementioned references and local cultural characteristics. The scale uses a 5-point Likert scale, where 1 indicates strong opposition and 5 indicates strong agreement. The instructions of the scale are shown in Table 7.

3.6.2 Social Avoidance Scale

The Social Avoidance Scale with 28 items [52] is a classic and widely used. Considering local culture and changes of the times, a social avoidance scale consisting of 5 items was used and adapted (α = 0.8). This scale uses a 5-point Likert scale, where 0 indicates strong opposition and 4 indicates strong agreement.

3.6.3 Learning Gains Self-evaluation Scale

Many disciplines and courses have developed learning gains scales. Examples are the Force Concept Inventory scale in mechanics [53] and the student assessment of learning gains survey scale in Chemistry [43]. Corresponding learning gains questionnaires have also been developed for courses such as civil engineering courses [54], an engineering ethics course [39], a self-leadership course [34], and a food process systems engineering course [41].

According to the characteristics of structural mechanics, a 10-items scale was prepared (α = 0.897). This scale uses a 5-point Likert scale, where 1 indicates strong opposition and 5 indicates strong agreement. The higher the score given by the respondent, the greater their perceived gain for this item. A score exceeding 3 indicates a positive view on this item.

3.6.4 Classroom Evaluation Scale

Many scales have been developed and used for classroom evaluation, such as the Student Perceptions of Teacher Practice questionnaire with 36 items [55–57], the Teachers' Sense of Efficiency Scale with 24 items [58], and the course effectiveness questionnaire with 6 items [41]. This study selected 10 items from these references to form a classroom evaluation scale (α = 0.949). The scale uses a 5-point Likert scale, where 1 indicates strong dissatisfaction and 5 indicates strong satisfaction.

3.6.5 Peer Learning Effectiveness Scale

Many studies on learning methods have developed effectiveness scales, such as open-ended questionnaires on project-based learning [59], the closed questionnaire for cooperative learning [41], the scale for participation in cooperative-learning [38], the learning experience opinions investment scale [39, 60], and the collaboration questionnaire [61]. This study developed a questionnaire consisting of five closed ended questions and three open ended questions. For closed ended questionnaires, a 5-point Likert scale is used, while for open ended questions, in addition to the provided alternatives (extracted from interview results), respondents were allowed to freely nominate.

3.7 Data Analysis

3.7.1 Qualitative Analysis of the Interviews

Gong et al. [33] summarized semi-structured interviews into 2 themes and 23 categories using a combination-encoding path of inductive and summary coding to study the benefits of peer learning. Hsieh et al. [55] designed a semi-structured interview with five questions to study the effectiveness of peer coaching, conducting axial coding on four research axes. Eriksen et al. [34] designed a closed interview consisting of seven questions to improve the peer coaching process, and analyzed the answers to each question using inductive analysis. Brevik et al. [62] designed group interviews that included five questions with which teachers can gain an understanding of differentiated teaching; they used inductive and deductive thematic analyses to obtain various themes from three patterns. The present study adopted a combined coding method of induction and deduction using grounded theory [63], and dialogue analysis [64] was conducted by watching videos. Because of the small amount of data, the analysis was manually coded by the lead author. The specific process was divided into the following four steps:

1. Data transcription: The interview video was segmented and edited according to different interviewees, and subtitles were automatically generated using video processing software; segments were further corrected manually and organized into dialogue text.
2. Open coding: The dialogue text was repeatedly read and then, preliminary saturation coding was performed.
3. Axial coding: The axis of the interview is the evaluation and suggestions for the course, which was classified and merged according to the order of overall feeling, specific measure feeling, method improvement, and course improvement.
4. Selective coding: Topics related to research objectives were filtered out.

3.7.2 Quantitative Analysis of Questionnaires and Exam Scores

The purpose of quantitative analysis in the study was to statistically describe the results of each scale, the differences between treatment group and control group, and the differences between learning teams within the treatment group. The study used SPSS 20 for statistics. Analyses of variance, t-test, nonparametric tests, cross analysis, and reliability analysis were conducted, and frequency, mean, standard deviation, and P-values of the target data were obtained. In all comparisons, $p < 0.05$ indicates a significant difference.

4. Results and Discussion

The data involved in this study include quantitative and qualitative data. Quantitative data originate from exam scores, open scale, and closed scale. Quantitative data originate from the coding and classification of interviews.

4.1 Results of the Interview

A summary of the interview results is shown in Table 8. All respondents said that discussion and mutual assistance in peer learning were helpful. Moreover, 87.5% (n = 7) of respondents preferred peer learning to independent learning and supported the idea that peer learning can be improved through forced sitting together. In the second place, 75% (n = 6) of respondents experienced spontaneous cooperation, but only 37.5% (n = 3) of respondents experienced spontaneous cooperation within the assigned learning team. Various factors restrict more active participation in peer learning.

Table 8. Identified themes and interview transcript

Theme	Outline	Category	Transcript
Theme 1: Effectiveness	Does discussion and mutual assistance benefit you?	Helpful 8	If there is a discussion, it will definitely have a certain effect
			Just discuss certain things that you don't understand, so you can understand them
			First, let's finish the basic knowledge, and then let's talk about an example question. Then, we can discuss it so that we can understand it
Theme 2: Preferences	Do you prefer peer learning or independent learning?	Peer learning 7 Independent 1	That's definitely going to happen. Otherwise, homework would be too difficult and I wouldn't be able to do it
			Ah, there are others who have discussed this with me before, and I will slowly explain it to them until they understand. I feel that helping classmates is quite good
			Whenever I encounter a problem, I will discuss it with others and I will gain something
Theme 3: Randomly selected collective scores	Do you think the randomly selected collective score is fair and has a good effect?	Unfair 1: Be implicated 1, cheating 1 Fair 5: Overall benefits 5, personal benefits 3, neutrality 2	I think group assessment can help students communicate more with each other
			I think group assessment can drive everyone
			You never wake up a person who pretends to sleep, some people just don't want to learn (no matter what you do)
Theme 4: Autonomy – Cooperation	Do your groups collaborate spontaneously except for the tasks arranged by the teacher?	No 2 Yes 3 with acquaintances 3	When we do homework, we will help each other
			As I'm not very good at it, I found some answers online and then [plagiarized]
			I enjoy discussing with people I am familiar with or with the few classmates who are good at learning
Theme 5: Limiting factor	What prevents you from participating more actively in peer learning?	Teamwork 2 Preference for acquaintances 3 Independent 1 Social avoidance 3 No need for help 1 Avoid enterprising 1	I rarely visit others and I'm not very familiar with them
			I feel embarrassed to urge others to do their homework
			Personally, I am not very good at socializing, more introverted
Theme 6: Promoting cohesion	If the teacher stipulates that team members must sit together, do you like or dislike it?	Supported 7 Opposed 1	I may learn better
			Generally speaking, it can urge classmates to learn together
			I prefer to think about the problem myself
Theme 7: Improvement	How do you think the teaching process can be further improved?	More discussion 2 More explanations 1 More exercises 1 More review 1	After giving examples, it is necessary to leave a little time for everyone to digest them
			The time given is actually relatively more, but it's still more difficult, so it should be longer than other courses
			I have already forgotten the previous one, a bit I'm not very clear and I need to review it again

Note: Not every student answered every question, and one student may have provided multiple answers; therefore, $\sum n$ may be greater than the number of respondents.

The first three reasons are the preference to cooperate with acquaintances rather than strangers, social avoidance, and perceived lack of aptitude for teamwork. Ultimately, 62.5% of respondents believe that randomly selected collective scores are fair and provide benefits. The consensus was that the way to improve this course is through more discussion, explanation, practice, and review.

4.2 Results of the Final Exam Scores

To measure the improvement of students' academic performance, not only the scores of this exam, but also the historical scores of the prerequisite mechanics courses were analyzed. The failure rate (using the overall evaluation score as indicator) is shown in Table 9, and the academic improvement (using the final exam score as indicator) is shown in Table 10. It must be clarified that there were 9 and 10 students in the treatment and control groups, who failed the regular and deferred exams, respectively, but only 7 and 4 students participated in the make-up exams, respectively. The reason for giving up on taking the exam is a clear conviction that one cannot pass the exam.

In general, the numbers of failed students in structural mechanics were 4 and 9 in the treatment and control groups, respectively, with failure rates of 12.9% and 28.1%, with a difference of –15.2%. Compared with theoretical mechanics and materials mechanics, the differences between the growth failure rate reached –25% and –18.4%, with an average of –21.7%. This result indicates that the treatment group has made great progress under peer learning.

The average scores of regular examinations, deferred examinations, make-up examinations, and structural mechanics in the treatment group were 3.4, 2.8, 6.3, and 8.2 points higher than those in the control group, respectively, of which structural mechanics scores were statistically different ($p = 0.045$). The increases in scores from theoretical mechanics, material mechanics, and their average values have reached 13.6, 10.8, and 12.2 points, respectively, and these increases are statistically significant ($P = 0.003, 0.006$, and 0.002, respectively).

4.3 Results of the Learning Gains Self-evaluation Scale

Items 1–5 in the learning gains self-evaluation scale are about the mastery of theoretical knowledge in the course, while items 6–10 are about the benefits of CE. The results of the analysis are shown in Table 11. The average value of all items in the scale is greater than 3, which means that all items have positive returns. The treatment group scored the highest in internal force mapping and listening empathy, while the control group scored the highest in internal force mapping and team cooperation.

Table 9. The results of cross analysis of mechanical scores

	Excellence rate (%)			**Failure rate (%)**		
Subject	**Treatment**	**Control**	**Difference**	**Treatment**	**Control**	**Difference**
Structural mechanics	3.2	6.3	–3.1	12.9	28.1	–15.2
Prerequisite courses						
Theoretical mechanics	3.2	9.4	–6.2	12.9	3.1	+9.8
Materials mechanics	9.7	6.3	+3.4	3.2	0	+3.2
Growth from. . .						
Theoretical mechanics	0	–3.1	+3.1	0	25	–25
Materials mechanics	–6.5	0	–6.5	9.7	28.1	–18.4

Note: All scores shown in the table are based on overall evaluation scores.
Excellence: score $\geq$ 90; Pass: score $\geq$ 60; Failure: score < 60.

Table 10. T-test results of final exam scores and observed improvement

	Treatment n = 31		**Control n = 32**		**Difference**	
Parameters	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**sig. (1-tailed)**
Structural mechanics scores	57.3	18.6	49.1	19.2	8.2	0.045
Regular exam (n = 23, 24)	57.1	20.1	53.7	16.8	3.4	0.267
Deferred exam (n = 8, 8)	31.6	12.5	28.8	9.8	2.8	0.309
Make-up exam (n = 7, 4)	55.4	20.4	49.1	19.2	6.3	0.212
Growth from. . .						
Theoretical mechanics	–4.9	17.2	–18.5	19.9	13.6	0.003
Materials mechanics	–8.4	16.0	–19.2	16.8	10.8	0.006
Average of both mechanics	–6.6	15.5	–18.8	17.0	12.2	0.002

Note: All grades shown in the table are based on final exam paper scores.

Although there was no statistical difference between both groups, the scores of most items were lower in the treatment group than in the control group, which is completely opposite to the results presented in Section 4.2. This is a confusing result, and the reasons may be diverse, such as different scoring standards between both groups, issues in the teaching process, or the protective instinct discussed in Section 3.6. Furthermore, based on the results of the interview, it can be inferred that the methods of dividing learning teams and assigning points to groups (assigning learning teams in sequence and randomly selecting collective scores) may be important reasons. In any case, at least this indicates a deviation between students' self-awareness of knowledge mastery and their actual situation.

4.4 Results of the Classroom Evaluation Scale

The analysis results of the classroom evaluation scale are shown in Table 12. Similar to the situation in Section 4.3, the average of each item is greater than 3, and the treatment group is lower than the control group; however, no statistical difference was found. The treatment group scored the highest on item 10, and the control group scored the highest in items 2, 6, and 10.

4.5 Results of the Peer Learning Effectiveness Scale

Because the method of peer learning is only applied to the treatment group, most of the peer learning effectiveness scale are only conducted in the treatment group. The exception is open questions 2 and 3, which could be conducted in both groups. The results of the analysis of closed-ended questions are shown in Table 13, with each item scoring greater than 3 points, with the highest scoring being item 4.

Open-ended question 1 is "Nominate the ability that improved the most". The statistical results are shown in Fig. 2, and the top three abilities that have improved the most are theoretical knowledge (32%), problem-solving skills (20%), and time management skills (16).

Table 11. T-test results of the learning gains scale

Item	Treatment n = 28		Control n = 29		Difference	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**sig. (2-tailed)**
I have mastered the knowledge of. . .						
1. The internal force diagram	3.96	1.07	3.90	0.94	0.06	0.800
2. The principle of virtual work	3.57	1.07	3.55	0.91	0.02	0.940
3. The force method	3.60	1.10	3.97	0.82	–0.37	0.168
4. The displacement method	3.21	1.17	3.55	0.99	–0.34	0.242
5. The moment distribution method	3.32	1.25	3.45	1.02	–0.12	0.676
I have improved my skills of. . .						
6. Confidence	3.46	1.00	3.93	0.88	–0.47	0.067
7. Problem solving	3.50	1.00	3.93	0.84	–0.43	0.084
8. Teamwork	3.32	1.09	4.03	0.90	–0.71	0.009
9. Expression and communication	3.53	0.92	3.82	0.89	–0.29	0.229
10. Listening and empathizing	3.61	0.92	3.93	0.80	–0.32	0.160
Total points	35.11	7.89	38.07	6.15	–2.96	0.119

Table 12. T-test results of the classroom evaluation scale

Item	Treatment n = 28		Control n = 29		Difference	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**sig. (2-tailed)**
1. I understand the purpose of this course	3.79	1.03	3.97	1.02	–0.18	0.271
2. I know the assessment methods before the exam	3.96	0.84	4.38	0.82	–0.42	0.220
3. The assessment methods support the purpose of this course	4.07	0.86	4.34	0.81	–0.27	0.221
4. I received guidance and feedback from my teacher	4.00	0.90	4.34	0.77	–0.34	0.222
5. I am satisfied with the quality of teaching	4.36	0.83	4.34	0.90	+0.02	0.229
My teacher. . .						
6. used appropriate models or familiar analogies to help me	4.21	0.79	4.38	0.78	–0.17	0.207
7. always provided another explanation or example	4.14	0.76	4.10	0.90	+0.04	0.221
8. provided me with an opportunity to express my views	3.71	0.98	4.24	0.83	–0.53	0.240
9. used different methods to determine if I understand	3.96	0.88	4.24	0.99	–0.28	0.248
10. is proficient at what he teaches	4.32	0.82	4.38	0.82	–0.06	0.217
Total points	40.54	7.07	42.72	7.31	–2.18	0.256

Table 13. T-test results of the peer learning effectiveness scale

Item	Treatment (n = 28)	
	Mean	**SD**
. . . achieved good results		
1. Construction cases	3.89	1.13
2. Classroom-recording	3.86	0.93
3. Bonus points for taking notes	3.61	1.20
4. Exercises and experiments	4.11	0.88
5. Seek help from classmates instead of teachers	3.64	1.10

Open-ended question 2 is "Nominate the most favorite element". A comparison of the results between the two groups is shown in Fig. 3. The two most popular elements in these two groups are the lecture process and individual effort, the latter of which is certainly the main reason for learning any course well. Twenty percent of the treatment group preferred homework and peer counseling, which was much higher compared to the control group (4%), while 27% and 35%, respectively, preferred individual effort and face-to-face instruction.

Open-ended question 3 is "How can the course be improved?" The results are shown in Fig. 4. In treatment group (which only had three answers), more practice and more detailed lectures accounted for 93%, while it accounted for only 40% in the control group. The remaining 60% of the control group had a total of five answers that were not mentioned by the treatment group. This result may be due to certain shortcomings of the control group in these five aspects, or it may be due to the overly prominent shortcomings and needs of the treatment group in the two aspects just mentioned. An important difference is that 47% of the treatment group

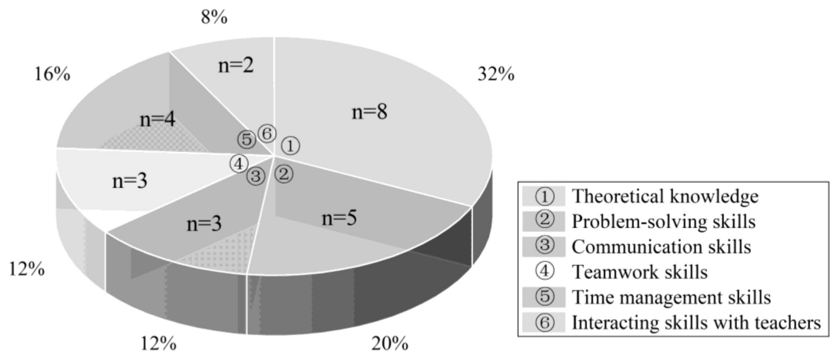

Fig. 2. Results of open-ended question 1.

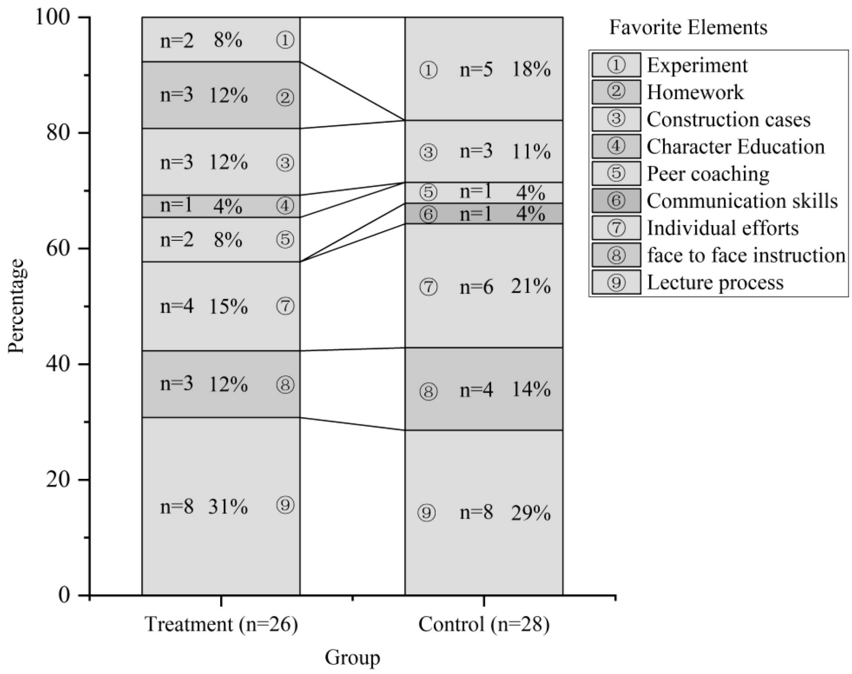

Fig. 3. Results of open-ended question 2.

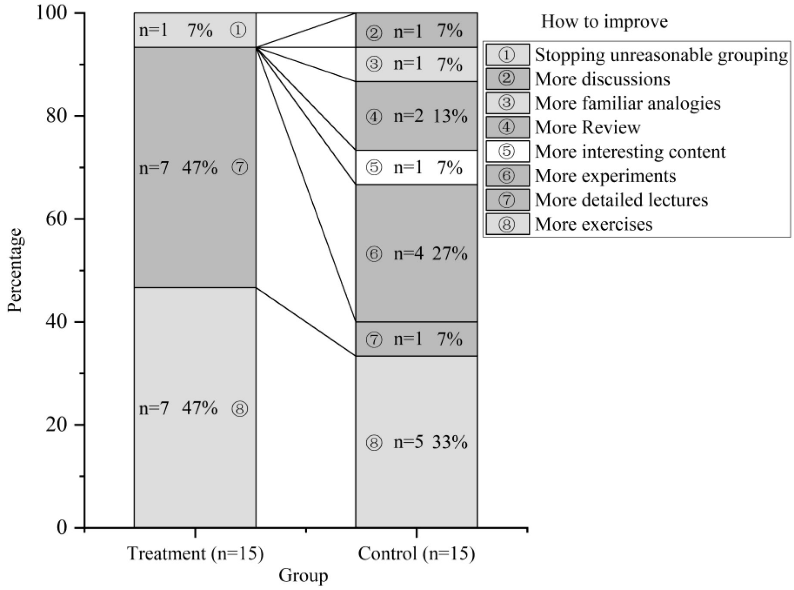

Fig. 4. Results of open-ended question 2.

wanted more detailed lectures, which far exceeded the 7% of the control group. This may be due to students having a better grasp of basic knowledge, which leads to further learning needs. However, it may also be that peer learning requires a large amount of time for discussion and cooperation, and therefore, the content of lectures may not be as rich and detailed as in the control group. Finally, one student in the treatment group clearly stated that he wanted to stop the methods of dividing learning teams and assigning points to groups; however, as these are core contents of peer learning, a corresponding change could not be implemented. However, there are still necessary measures that need to be taken. In next year's course, a specific and detailed explanation will be provided to strive for students' understanding.

5. Findings

In this quasi-experimental study, quantitative and qualitative research was conducted through final exams, interviews, and scales. The benefits of peer learning and CE for academic performance in structural mechanics were studied. The most important finding is that the treatment group scored 8.03 points higher than the control group, based on a 3.98 point lower average in the prerequisite courses, which is a very good result. Detailed findings are presented in Sections 5.1–5.4.

5.1 Research Question I

(1) Can peer learning improve the exam score of structural mechanics?

Peer learning can significantly improve academic performance. According to the data presented in Section 3.2, the treatment group achieved an 8.2 point higher final exam score ($p = 0.045$) and a 15.2% lower failure rate compared to the control group. Considering the differences in knowledge foundations between both groups, the difference in the average increases in scores between both groups relative to the pre-mechanics course is 12.2 points ($p = 0.002$), and the average increase in failure rate is 21.7% lower.

(2) Has there been any imbalance between learning teams?

According to the data presented in Section 3.2, there was no difference in the final exam scores between the learning teams, regardless of whether these were part of the pre-mechanics course or this structural mechanics course. This indicates that the sequentially assigned learning teams were heterogeneous and there was no difference after peer learning. Therefore, the sequential teaming method is just as fair as the random teaming method, but it is more convenient in terms of implementation and recording scores.

5.2 Research Question II

(1) Can peer learning improve students' classroom evaluation?

Unfortunately, this study did not obtain this expected result. According to the results presented in Sections 4.3 and 4.4, no statistical difference was found between the treatment group and the control group in the scores of the learning gains self-evaluation scale and the classroom evaluation scale ($p = 0.119$ and 0.256, respectively). However, even worse, the average score of the treatment group lagged behind the control group in all aspects. Given that the exam scores of the treatment group were 8.2 points higher than those of the control group, the learning gains self-evaluation and the classroom evaluation lag behind. There are four possible reasons to explain this contradiction.

Possible reason 1:

A systematic error may have been introduced by different evaluation criteria between both groups and by the stranger-triggered protective instinct mentioned earlier. The members of the treatment group believed that the purpose of the questionnaire was to improve teaching, which is why they took the questionnaire more seriously and provided more realistic answers. When encountering strangers, the members of the control group might answer the questionnaire with full marks. In fact, several questionnaires indeed provided full marks.

Possible reason 2:

The second reason may be the unfreedom of the randomly selected collective scores method and the sequential teaming method. Sections 4.1 and 4.5 repeatedly mentioned that students are dissatisfied with this because they want to team up with familiar friends and may be burdened by social loafers. Negative emotions of individual classmates may lead to a slight decrease in the scale score.

Possible reason 3:

The third reason may be the pain of learning. The students in treatment group need to maintain considerable concentration during classroom learning and homework after class and have to put in a lot of time and effort, while the control group is relatively relaxed. At the time of the questionnaire survey, the students' exam scores had not yet been announced, so they only felt pain and did not taste the sweetness of their reward.

Possible reason 4:

The more you learn the less you know. Zeno, Plato, and Aristotle have expressed similar views. The control group, however, portrayed the opposite effect, meaning that the more they didn't know, the more they thought they knew. This reason supports that peer learning can improve the depth of students' learning, but for the sake of fairness, unfavorable reasons are preferably selected.

(2) How can the situation be further improved?

Possible reason 1 is a normal phenomenon and no cause for concern. The next time the questionnaire survey is conducted, the respective teachers will conduct their own surveys, striving to eliminate this error.

Possible reason 2 refers to the core methods used in this study and it is the main reason for the improvement of academic performance. The next time the questionnaire survey is conducted, the reasons for various methods and related research results will be explained to students in detail. Regardless of whether students understand and accept these explanations, these methods will be consistently adopted, and there will still be continuous improvement. The next step is to improve the operational details of peer learning, add new methods, improve students' experience, and then re-evaluate the impact peer learning has on teaching.

Possible reason 3 is well understood and its adverse effects can be eliminated easily. When students realize that their score can be 8.2 points higher and their failure rate 15.2% lower, they will immediately change their preference and benefit from their efforts.

5.3 Research Question III

(1) Can peer learning improve students' characteristics?

Peer learning can play a good role in CE. According to the results of open-ended question 1 presented in Section 4.5, in addition to theoretical knowledge, students have improved their problem-solving skills (performance characteristics), communication skills (civic characteristics), teamwork skills (civic characteristics), time management skills (performance characteristics), and interaction skills with teachers (civic characteristics). Additionally, it should be noted that according to the results of open-ended question 2 presented in Section 4.5, the favorite element of one student in the treatment group was CE, while this was not obtained in the control group.

(2) Insufficiency and improvement

Certain students in the treatment group were dissatisfied with the method of peer learning, and not many students could spontaneously cooperate and communicate after class. Therefore, in terms of increasing interest in learning, improving expression and communication skills, enhancing friendships, and improving team cooperation, the expected results have not been achieved. In the future, additional measures will be taken to further improve the aforementioned CE, such as mandatory sitting together in teams.

5.4 Research Question IV

(1) What is the acceptance level of peer learning?

Students liked peer learning. All respondents believed that peer learning is helpful, and according to the interview results in Section 4.1, 87.5% of respondents preferred peer learning to independent learning.

(2) What are the shortcomings and improvement measures of peer learning?

According to the interview results presented in Section 4.1, the reasons that prevent students from participating in cooperative learning more actively are a lack of teamwork, preference to form teams with friends, preference for independent learning, social avoidance, no need for help, and avoidance of being too enterprising. Only 37.5% of respondents reported to have spontaneous after-school cooperation within the learning team. The measures through which this course can be improved are to increase discussion, explanation, practice, and review; a more specific measure is to force learning teams to sit together.

6. Limitations

(1) The number of interviewees was only eight, which is about 26% of the treatment group, and this low participation was mainly the result of students' unwillingness to participate and lack of time. If students are not willing to accept video recording next time, audio recording can be used instead. In terms of time, one or two days of concentrated review can be arranged, and interviews can be conducted during reviews.

(2) The scales used in this study are limited, as some scales were not designed for the control group and some scales were not designed for pre- and post-test comparison. In future research, these insufficiencies will be resolved.

7. Conclusions

Peer learning can significantly improve the examination results of structural mechanics courses, reduce the failure rate, enable CE, and improve problem-solving skills, communication skills, teamwork, and time management. The key to incorporating peer learning is to apply methods such as sequential teaming, random selection of collective scores, bonus points, and individual points. The approach used in this study failed to improve the learning gains self-evaluation and classroom evaluation. Several new measures should be taken to compensate for the shortcomings of the study, such as providing a detailed explanation of the reasons for the new methods, forcing learning teams to sit together, and correcting homework face-to-face.

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