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The Effect of the Collaborative Discussion Strategy Think-Pair-Share on Developing Students' Skills in solving Engineering Mathematical Problems

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Abstract: The Think-Pair-Share (TPS) strategy makes the learning environment interactive, lively, collaborative and democratic. It allows students to interact; accept information; develop collaborative discussion skills; refine their thinking; and participate effectively in the classroom. In this study, the researchers investigated the effect of the collaborative discussion strategy (think-pair-share) on developing students' skills in solving engineering mathematical problems. Once we had confirmed the validity and reliability of the tools, we used the quasi-experimental approach. The study sample consisted of 66 students divided into two groups: Namely, an experimental group, which comprised 33 students who studied mathematics using the (think-pair-share) strategy; and a control group, which comprised 33 students who studied in the traditional way. Both groups sat for a pretest and post-test in mathematics. The test results showed that the use of the TPS strategy had a positive effect on developing problem-solving skills compared to the traditional method. In light of these results, the study recommended the use of TPS strategy to improve the skills of students in solving engineering mathematical problems.

Keywords: *Collaborative discussion, engineering education, mathematics education, problem-solving skills, think-pair-share strategy.*

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Introduction

Mathematics is one of the important subjects that facilitates the task of learning and mastering skills. The concepts of mathematics depend on each other in an integrated manner and, therefore, the loss of any mathematical concept or generalization hinders the acquisition of subsequent mathematical skills. Mathematical skills are, also, the basis for reasoning and quantitative solutions used in the physical and biological sciences, engineering, information technology, economics, social sciences, and computer sciences (Tonbuloğlu & Tonbuloğlu, 2019). The teaching of mathematics is very important since it is a subject that offers career opportunities. Without a good mathematical background, it is very difficult to obtain jobs in accounting, banking, data processing, technology, engineering, physics, etc.

Despite the attention given to developing learners' mathematical problem-solving skills, the level of students' performance in solving such problems has not matched the expectations. According to the findings of Osman et al. (2018), there are differences in students' abilities to solve mathematical problems. This makes cooperative learning an excellent method for reducing the individual differences between students in acquiring problem-solving skills and exchanging experiences. Cooperative learning can improve students's achievements, social relationships, tolerance, and respect for others (Alcalá et al., 2019). It also is needed to develop the student's thinking skills and problem-solving abilities (Yulastri & Silalahi, 2019). Additionally, the use of cooperative learning may encourage students to cooperate and help each other. Therefore, the use of cooperative learning is considered useful in the mathematics classroom to overcome individual bias (Kibirige & Lehong, 2016).

The TPS (Think-Pair-Share) strategy is one of the methods of cooperative learning, which may contribute to improving learners' skills in solving mathematical problems (Rifa'i & Lestari, 2018; Wahyuni, 2018).

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TPS facilitates the students' learning process because it allows them, after spending time thinking individually about mathematical problems, to discuss and share with their peers with their individual ideas and solutions (Phungsuk et al., 2017). This strategy also depends on giving students enough time to think individually about a mathematical problem and, then, share their solutions with their partners before presenting them to the class (Irma et al., 2020).

In this study, we used TPS in teaching mathematics in order to discover if this strategy increased students' skills in solving mathematical problems. The first stage of the strategy (Think) was implemented in the school's computer laboratories to allow students to search for the necessary information through the Internet and websites. This is in preparation for the next two stages of the strategy Pair & Share. In this study, the researchers investigated the effect of the collaborative discussion strategy (Think-Pair-Share) on developing students' skills in solving engineering mathematical problems.

Literature Review

Definition of a Think-Pair-Share (TPS) Strategy

The Think-Pair-Share (TPS) strategy is a collaborative teaching strategy that Frank Lyman proposed in 1981 at the University of Maryland. It is based on the idea that many students participate in the class and that each student is given a question to think about on his/her own (Think). Then the student discusses the question with one of his/her colleagues (Pair) and, finally, the teacher invites the whole group of students to share their solutions (Share) (Lyman, 1987). This strategy is based on two principles: namely, the interactions of pairs in cooperative education and giving them time to think (Falentina et al., 2022).

Also, the TPS strategy makes classroom discussions more productive because students already have an idea about what they are going to share with others (Lyman, 1987). In addition, it raises the students' motivations to participate in solving problems and improves the quality of their responses (Ulandari et al., 2019).

The TPS strategy requires the students to think about the educational content because all the students in the classroom benefit from the collaborative group learning processes. The use of TPS gives the students more time to think and prepare themselves to discuss and present their opinions. Another advantage of this technique is that it works as a formative assessment tool for both the teacher and the student (Demirci & Duzenli, 2017).

Yin et al. (2018) proposed three stages to implement TPS. The first stage is to think. At this stage, the teacher asks the students a question to solve and think about individually. The second stage is the pair stage. At this stage, the students are grouped in pairs and asked to discuss their solutions. The duration of this stage ranges from 4–5 minutes. The third stage is "Share," in which the teacher asks each group to share their findings or solutions with the other students. Figure 1 shows the model for implementing the (TPS) strategy.

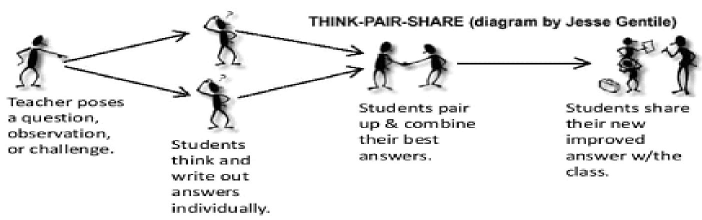

Figure 1. The Developed Think-Pair-Share (TPS) Strategy Model (Drake, 2011)

This strategy is very effective in facilitating deep, meaningful learning (Demirci & Duzenli, 2017; Prahl, 2017; Bamiro, 2015; Falentina et al., 2022; Ulandari et al., 2019). It is noteworthy that, when using this strategy in the classroom, it is necessary to ask the students the correct questions. In constructing the questions, the teacher must take into consideration several conditions. First, before writing the questions, the teacher must consider the learning outcomes. Second, the questions should be open-ended. Third, the questions should support cooperative learning and encourage the students to engage in cooperative learning. Fourth, the focus should be not only on the answers but, also, on how the students figured out these answers (Prahl, 2017).

Hasanah et al. (2022) findings showed that there were several reasons for the students' low competency in solving mathematical problems. First, students may not understand the keywords of the arithmetic problem. Second, students cannot develop a problem-solving strategy based on the given problem. Third, students give up easily when they fail to solve a mathematical problem on their first attempt. Fourth, students dislike reading long and unclear questions. Fifth, students are not careful in the calculation process. Sixth, the students make errors in determining the concept or strategy of completion. Seventh, the students do not verify the concepts, the solution plan, the calculations, and the answers.

It is important for the development of any society to find strategies that enhance students' abilities to learn mathematics and improve their problem-solving mathematical skills. In the Arab region, the educational strategies, used in teaching mathematics, have not significantly improved student competency in mathematics (Alsmadi, 2020). This is confirmed by the inhabitants of Arab countries' poor results in international tests, such as the TIMS test in the last three sessions: 2011, 2015, and 2019 (Martin et al., 2012; Mullis et al., 2020). Therefore, there is a need to develop modern strategies that enhance the participation of students in mathematics classes. The method in which it is taught is one of the reasons for the unsatisfactory results in mathematics. It is taught using traditional teaching methods that focus on memorization (Alsmadi, 2020).

It is noteworthy that teaching practices can make a huge difference to the student's results, and they can improve the students' motivations to learn. Much of the research in the field of mathematics education has indicated the effectiveness of mathematics teachers in integrating a range of instructional methods and strategies to meet their students' learning needs (Chasanah & Usodo, 2020).

The TPS strategy is one of the cooperative learning strategies that gives the students the opportunity to think before answering the questions,to cooperate and share ideas. It gives them opportunities to think, participate actively during the lesson, and cooperatively solve mathematical problems. This strategy motivates students to learn and reduces their anxiety. Students are not afraid to share their ideas with their colleagues.

According to the constructivist theory, knowledge is actively constructed by the student rather than passively received by the teacher (Eppard & Rochdi, 2017). Constructivists believe teachers should not be the sources of knowledge and classroom managers should not be passive recipients (Efgivia et al., 2021).

In accordance with constructivist learning theory and (TPS) strategy, students should be responsible for their learning.A constructivist theory is incorporated into the (TPS) strategy in this study to understand the roles of teachers and students. A teacher's role, for example, is to organize, plan, guide, and facilitate the learning process, while a student's role is to actively participate in the learning process (Samaila et al., 2021).

The Role of Technology in TPS Strategy

Different technologies can be used to help teachers and students in order to integrate technologies into the implementation of the TPS strategy through a set of 2.0 web tools. The most prominent of these tools are:

- The use of blogs such as Edu bogs, Blogger, WordPress, and Tumble to provide a forum for student discussion and idea exchange.
- Cooperative websites such as, Wikipedia, wiki spaces, and Media Wiki.
- Social websites such as, YouTube, Facebook, Google Meet, Google Pulse, and Zoom (Sharif, 2016).
- Educational platforms, such as, Blackboard, Coursera, EdX, and Edmodo, that provide greater opportunities for interactive discussions and exchanges of information.

The main feature of these tools is peer interaction, whereby students are encouraged to interact with and listen to each other (Raba, 2017). It is noteworthy that the use of technology in implementing TPS in online learning patterns goes beyond searching for information or sharing it through online learning platforms. It combines the ability to absorb and understand information from different digital sources (Ng, 2012; Tang & Chaw, 2016).

Depending on their learning experiences and their use of social media, many students can access or share digital content (Tang & Chaw, 2016). However, to use TPS through online learning platforms, students do not only need the ability to use technology on a social level but, also, they need the ability to examine, integrate and share digital information with their peers. Therefore, at the first stage, they share it with the rest of the students in the class. Knowledge of technology alone is insufficient for successful learning. It is equally important that the students have the organizational ability, competencies and appropriate attitudes (Margaryan et al., 2011). Tang and Chaw's (2016) findings indicate that many students can display educational experiences by using technology tools. However, they are unable to gather information from different sources and understand it effectively for the purpose of new learning. Consequently, it is important to train students about self-learning skills; organizing information; choosing appropriate online sources; and evaluating electronic content.

Middle School Mathematics Education in Engineering

Mathematical applications in engineering are referred to as service subjects, usually taught in middle schools, along with surrounding mathematics. Hadi et al. (2018) emphasizes the importance of geometry as a major branch of mathematics that should be taught from kindergarten through grade twelve because it provides learners with the basic skills necessary for practical life, such as problem-solving, spatial perception, exploration, deductive reasoning, guessing, and interpreting other aspects of cognitive learning which are included in the various branches of mathematics.

As a major part of our daily lives, geometry is a major part of the mathematics curriculum in the middle school. Due to its living nature, geometry has spread throughout the entire field of mathematics. Middle school students face difficulties in solving Geometric problems such as a lack of ability to read and therefore failure to comprehend the text of the problem; lack of knowledge of the content; lack of knowledge of complex numbers; lack of experience in arithmetic or difficult contexts; failure to remember concepts, principles, laws and operations and meanings of some mathematical terms; lack of problem-solving skills; and students' weakness in guessing and estimating processes in order to get the answer (Hewson, 2019).

In order to address these difficulties to prepare future engineers, Pepin et al. (2021) presented a conceptualized framework for mathematics curricula in engineering education aims to reformulate the concept of mathematics education in general. A mathematics curriculum should focus on communication, reflection, mathematical modeling, mathematical reasoning, and representation in order to prepare future engineers.

Harris et al. (2015) argued that students can be prepared for careers as engineers by including engineers in the teaching of school mathematics, and mathematics should be taught in an engineering context. General mathematics is not a "tool" that can be taken and used to solve a variety of problems without modification, modeling, or reconstruction of knowledge as needed.

There are two important aspects in solving problems: The first one is mental knowledge, which contains facts, concepts, laws, and theories. The second aspect is the solution strategy, which consists of the steps and processes the individual uses to reach the solution with the help of his mental knowledge.

The process of preparing a strategy to solve the issue is an important process on which the success of solving the issue depends, so there were many strategies developed for solving problems, such as representing them graphically, using graphics and shapes in solving them, writing equations that represent the problems (Rifa'i & Lestari, 2018). The current study examines how the think-pair strategy can improve students' ability to solve geometric mathematical problems.

Previous Studies

Several studies have focused on the effectiveness of the TPS strategy in improving teaching and learning. Sugiharti and Suyitno (2015) investigated the impact of the TPS strategy on improving the Indonesian secondary school students' abilities to solve mathematical problems. the results showed the effectiveness of the TPS strategy in improving secondary school students' mathematical problem-solving skills.

Titsankaew (2015) explored the effect of using the cooperative learning strategy on students' results and the development of their attitudes toward mathematics. This study's results indicated that the use of this cooperative learning strategy had a positive impact on students' achievement and attitudes toward mathematics.

Demirci and Duzenli (2017) examined how a teacher may implement the TPS method to promote active learning and expeditiously complete formative assessments. To accomplish this, a TPS online activity and a rating scale were developed. Before collaborating in groups to debate and write their paragraphs on the online platform, students thought about the assigned topic on their own for 60 minutes. Each group simultaneously shared paragraphs. The results of the assessment successfully highlighted the lessons that needed review, and the responses to the questionnaire supported the teacher evaluations. Most students expressed pleasure with the activity and an interest in doing it again.

Jelatu et al. (2019) investigated the effect of the collaboration TPS Leaning Model and m-Learning based on Android on trigonometry concept understanding, as well as the interaction between collaborative learning and cognitive style on trigonometry concept understanding. According to the research; students who used the TPS Leaning Model and mobile learning applications on Android obtain higher levels of understanding of trigonometric concepts than students who worked in traditional groups (expository), and there was also no connection between the cognitive style of students' grasp of trigonometric topics and collaborative learning.

Samsuriadi and Imron (2019) aimed to determine the effect of the TPS strategy on students' mathematic skills. The results showed that using the TPS learning strategy to teach math was at a medium level. The results revealed that the students' educational communication skills improved more than those of who were taught using traditional learning strategies.

Tanujaya and Mumu (2019) demonstrated that the TPS procedures can be implemented in mathematics education in Manokwari, West Papua, and Indonesia. the researchers used research and development (R&D) methods to improve the TPS strategy to suit the study population's characteristics. This study's findings show that there are two main principles in the application of the pair-participation model in mathematics education in Manukwari, West Papua. These principles include the selection of the group members and the determination of the number of group members. Students first think about finding answers to the tasks that they have submitted individually. The members of the group should consist of students who already know each other well but should not have a similar level of knowledge. Then, the students should work in pairs.

similarly, the present study investigates the use of the TPS strategy in the teaching of mathematics and, in this regard, it relies on the quasi-experimental approach. However, this study differs from other studies since it is interested in applying this strategy in teaching geometric transformations and constructions, and in developing Jordanian students' abilities to solve mathematics problems. The study tries to combine engineering concept instruction with TPS strategy and technology-based links.

Purpose and Study Questions

The study aims to investigate the effect of TPS strategy on enhancing mathematical problem-solving skills. To achieve this goal, the researchers try to answer the following questions

1. Is there a significant difference between the experimental group and control group on pre- mathematical problem-solving test?
2. Is there a significant difference between the post- mathematical problem-solving test of the experimental and control groups in terms of TPS strategy?

Methodology

Implementation of TPS Strategy in Classroom

The Pair Share teaching strategy is an interactive and collaborative method of teaching where students work in pairs to share and discuss their thoughts through a set of 2.0 web tools, ideas and opinions on a materials related to geometric transformations and constructions". The steps to implement the Pair Share strategy in the classroom include:

1. Define the objective: Clearly state the purpose of the Pair Share activity and how it aligns with the overall learning goals of the lesson.
2. Assign roles: Assign each student a role, such as a speaker or the listener, to help guide the conversation and ensure everyone is actively engaged in the activity.
3. Provide a prompt or question: Give students a prompt or question to discuss with their partner. This could be a question related to the topic being studied, a scenario, or a problem to solve.
4. Give time for discussion: Allow students sufficient time to discuss the prompt or question with their partner. Encourage students to listen actively, ask questions and share their thoughts and ideas.
5. Monitor and provide feedback: Walk around the room and listen in on the conversations to make sure students are on track and to provide feedback as needed.
6. Debrief: After the discussion, bring the class back together for a debrief. Encourage students to share what they learned from their partner and to share insights gained from the discussion.
7. Reflect and evaluate: Reflect on the effectiveness of the Pair Share activity and how it helped achieve the learning objectives. Evaluate the process and make changes as needed for future Pair Share activities.

Research Design

In this study, we adopted the quasi-experimental approach and, thereby, used experimental and control groups and a pre/post-test. A TPS strategy was used to teach the "geometric transformations and constructions" unit in the experimental group. In the control group, the same unit was taught using traditional methods.

Sample and Data Collection

The study's population comprised all sixth-grade students (324 students) at the elementary schools (11–12 years old) who were studying in the Ajloun Governorate Directorate of Education government schools in the first semester of the academic year (2020–2021). Purposive sampling was used to select the study sample, which consisted of 66 participants. because this grade represented a very effective stage when compared to the rest of the general education stages. It is the link between primary and secondary education. In addition, at this stage, the student's abilities, inclinations and willingness appear clearly. Therefore, Hammam et al.'s, (2009) findings demonstrate that, while taking into consideration the individual differences between them, educators should enrich school programs so that they motivate students and encourage their tendencies and hobbies. This makes this stage appropriate for this study's variables.

This study's sample comprised two groups of students (experimental and control groups) which we chose from the Ajloun elementary school. Both groups comprised (33) female students. The experimental group was exposed to the TPS strategy, while the control group studied the same material using the traditional method of teaching. We chose another group of students as a pilot study.

Table 1. Descriptive Statistics of the Study Sample

Class	Group	No. of students	Excluded students	Remaining students
A	Experimental	33	-	33
B	Control	33	2	31
Total		66	2	64

The reason why some students were excluded from this study was because they were absent from the pre and post-tests.

After surveying the educational literature, such as (Tanujaya and Mumu, 2019; Samsuriadi and Imrom, 2019), the researchers developed an experimental guide for the teacher to teach the topics of the unit of " geometric transformations and constructions, and they designed a test of solving mathematical problems. They developed, also, an observation card in partnership with the school's leadership. The test contained open-ended questions related to the content of Unit four of the sixth grade's mathematics book, which deals with geometric transformations and constructions. This unit included the following topics: planner coordinate; reflection and shifting; circle; drawing triangle; and engineering constructions. The test consisted of 17 test items. The test specification table was built according to the relative weight of the lessons. The test instructions were also clarified to familiarize the students with the nature of the test, its objectives, and its components. Illustrative examples explained how to answer the questions.

Turning to the test's psychometric characteristics, the researcher sets four scores for each item distributed among the four problem-solving skills (understanding the problem, devising a plan, carrying out the plan, and looking back) (Polya, 1957). Since there are 17 items, the highest score is 68 and the lowest score is zero.

The Validity and Reliability of Problem Solving Test

The test was presented to seven experts in the fields of mathematics, curricula, measurement and evaluation. They were asked to give their opinions concerning:

- The clarity of the test instructions.
- The test's suitability for sixth grade students.
- The clarity of the test items; the appropriateness of the test items for sixth grade students.
- The scientific correctness of these items.

We verified the validity of the test by conducting a pilot study with thirty female students from the study's community and outside the study's sample. The pilot study aimed to verify the validity of this test before applying it to the research sample and to verify the clarity of the test instructions and items.

The pilot study's findings showed that, according to the Pearson correlation coefficient between each item and the whole test, all test items were linked to the test's total score with a statistically significant relationship at the level of significance (.01). The coefficients of difficulty, ease, and discrimination were calculated, also, for the test items. The values of the difficulty coefficients ranged between .22 and .69; these were appropriate and statistically significant values. The values of the discrimination coefficients for all test items were positive and ranged between.35 and .78 and, therefore, they could be used. We used the repetition method (TEST-RETEST) to verify the stability of the test. This showed that the reliability coefficients' values ranged between .64 and .77 and that the test's overall reliability was .82. These are significant stability values that indicate the reliability of the test results.

The Equivalence of Study Groups

A t-test for two independent samples was used to confirm the equivalence of this study's two groups before the experiment. As shown in Table 2 below, the two groups are equivalent.

Table.2. T-test Results for Two Independent Samples of the Performance of the Experimental and Control Group Students on the Pre-test

	Group	N	Mean	Std. Dev	Std. Error.	t	Sig.
Understanding problem	Experimental	33	5.30	0.85	0.15	0.211	.833
	Control	31	5.26	0.86	0.15		
Devising a plan	Experimental	33	4.21	0.65	0.11	0.080	.936
	Control	31	4.23	0.72	0.13		
Carrying out the plan	Experimental	33	0.12	0.33	0.06	0.454	.651
	Control	31	0.16	0.37	0.07		
Looking back (validating the solution)	Experimental	33	.09	0.29	0.05	0.079	.937
	Control	31	1.00	0.30	0.05		
Pre-test	Experimental	33	9.73	1.48	0.26	0.039	.969
	Control	31	9.74	1.50	0.27		

As shown in Table 2, there are no statistically significant differences between the mean performance of the experimental and control groups on the pre-test and in the four problem-solving skills (understanding the problem, devising a plan, carrying out a plan, and looking back). The statistic (T) value of the students' performance on the pre-test is .039, The significance level is 0.969 which is greater than the significance level (α = 0.05). This means that the experimental and control groups have equivalent competence in mathematical problem-solving skills.

Analyzing of Data

A normality test was conducted to examine the normality of the participant's distribution. The Kolmogorov-Smirnov test shows the Significant level of the Experimental and Control group; respectively is (0.120, 0.09). This indicates that the students distributed normally across each study group. A t-test of the independent sample was used to determine whether the control and experimental groups were equivalent before using the new strategy. To investigate the effect of TPS strategy on enhancing mathematical problem-solving skills, another independent sample t-test was used after teaching the experimental group TPS strategy.

Result

The Results of The Pre-Post T-Test of Experimental Group

We used the test Results for Paired Samples of the Performance of the Experimental Group Students in the Pre-Test and Post-Test, as shown in Table 4 below.

Table 3. T-test Results for Paired Samples of the Performance of the Experimental Group Students on the Pre-Test and Post-Test

	Test	N	Mean	Std. Dev	Std. Error.	t	Sig.
Understanding the problem	Post-test	33	14.48	3.72	0.65	13.467	.000
	Pre-test	31	5.30	0.85	0.15		
Devising a plan	Post-test	33	14.36	3.68	0.64	16.131	.000
	Pre-test	31	4.21	0.65	0.11		
Carrying out the plan	Post-test	33	13.09	3.78	0.66	19.462	.000
	Pre-test	33	0.12	0.33	0.06		
Looking back	Post-test	33	12.79	4.03	0.70	17.906	.000
	Pre-test	33	0.09	0.29	0.05		
Post-test	Post-test	33	54.73	14.18	2.47	18.091	.000
	Pre-test	33	9.73	1.48	0.26		

Table 3 showed statistically significant differences (α= 0.05) between the pre-test and the post-test of the experimental a group (total score, understanding a plan, devising a plan, carrying out a plan, looking back). As a total score for the test, the value of "t" is 18.091. The T value for the skill of understanding the problem was 13.467; 16.131 for the skill of devising a solution plan; 19.462 for the skill of carrying out a plan; and 17.906 for the skill of looking back. At the 0.05 significance level, all these were statistically significant values in favor of the post-test. This shows that, at the 0.05 level of significance in the post-test, there was a statistically significant difference between the pre-test and the post-test mean scores in favor of the post-test. These findings showed that the TPS strategy improving the students' solving of mathematics problems since the differences were statistically significant in favor of the post-test.

The Results of The Pre-Post T-Test of Control Group

Table 4. T-test Results for Paired Samples of the Performance of the Control Group Students on the Pre-Test and Post-Test

	Test	N	Mean	Std. Dev	Std. Error.	t	Sig.
Understanding the problem	Post-test	31	12.45	3.48	0.63	10.668	.000
	Pre-test	31	5.26	0.86	0.15		
Devising a plan	Post-test	31	12.39	3.43	0.62	13.114	.000
	Pre-test	31	4.23	0.72	0.13		
Carrying out the plan	Post-test	31	11.26	3.23	0.58	18.665	.000
	Pre-test	31	0.16	0.37	0.07		
Looking back	Post-test	31	10.68	3.03	0.54	19.230	.000
	Pre-test	31	0.10	0.30	0.05		
Post-test	Post-test	31	46.77	12.02	2.16	16.724	.000
	Pre-test	31	9.71	1.51	0.27		

Table 4 showed statistically significant differences (α= 0.05) between the pre-test and the post-test of the experimental a group (total score, understanding a plan, devising a plan, carrying out a plan, looking back). As a total score for the test, the value of "t" is 2.413. The T value for the skill of understanding the problem was 2,255; 2.218 for the skill of devising a solution plan; 2.078 for the skill of carrying out a plan; and 2.357 for the skill of looking back. At the 0.05 significance level, all these were statistically significant values in favor of the post- test. This shows that, at the 0.05 level of significance in the post-test, there was a statistically significant difference between the pre-test's and the post-test mean scores in favor of the post-test. These findings showed that the TPS strategy improved the students' solving of mathematics problems since the differences were statistically significant in favor of the post-test.

The Results of The Post T-Test of Control and Experimental Groups

The results also indicated when compared to the control group, an improvement in the experimental group's level of performance. The data showed that, when the post-test results were compared with the pre-test results, there was an improvement in each of the experimental group's problem-solving skills. As shown in Table 5 below, we used the t-test for independent samples to verify if these differences exist between the experimental and control groups in the post-test.

Table 5. T-test Results for Two Independent Samples of the Performance of the Experimental and Control Group Students on the Post-Test

	Group	N	Mean	Std. Dev	Std. Error.	t	Sig.	Eta square
Understanding the problem	Experimental	33	14.48	3.71	0.65	2.255	.028	.076
	Control	31	12.45	3.48	0.63			
Devising a plan	Experimental	33	14.36	3.68	0.64	2.218	.030	.074
	Control	31	12.39	3.43	0.62			
Carrying out the plan	Experimental	33	13.09	3.78	0.66	2.078	.042	.065
	Control	31	11.26	3.23	0.58			
Looking back	Experimental	33	12.79	4.03	0.70	2.357	.022	.082
	Control	31	10.68	3.03	0.54			
Post-test	Experimental	33	54.73	14.18	2.47	2.413	.019	.086
	Control	31	46.77	12.02	2.16			

Table 5 showed statistically significant differences (α= 0.05) between the experimental and control groups in the post-test (total score, understanding a plan, devising a plan, carrying out a plan, looking back). As a total score for the test, the value of "t" is 2.413. The t value for the skill of understanding the problem was 2,255; 2.218 for the skill of devising a solution plan; 2.078 for the skill of carrying out a plan; and 2.357 for the skill of looking back. At the 0.05 significance level, all these were statistically significant values in favor of the experimental group students. These results demonstrated that the experimental group's problem-solving skills improved more than the control group's problem-solving skills. Therefore, we reject the first null hypothesis and accept the alternative hypothesis. This shows that, at the 0.05 level of significance in the post-test, there was a statistically significant difference between the experimental group's and the control group's mean scores in favor of the experimental group students. These findings showed that the TPS strategy was better than the traditional method in improving the students' solving of mathematics problems since the differences were statistically significant in favor of the experimental group.

In the first week of the study, in which the TPS strategy was not used, the average number of student comments was 19.75 and the average number of long explanations while solving math problems was 2.5. On the other hand, the average number of student comments in the second week after using the TPS strategy was 25.25 and the average number of long explanations while solving math problems was 6.65.

The collected data showed that the use of the TPS strategy increased student participation in collaborative problem-solving and discussion of mathematical problems. It also improved the quality of the students' solutions of mathematical problems.

Accordingly, since there are statistically significant differences between the pre-test and post-test, the students in the experimental group have developed the four problem-solving skills (understanding the problem, devising a plan, carrying out the plan, and looking back) from using the TPS strategy. Moreover, the experimental group does better than the control group, as there are statistically significant differences between the performances of both groups in favor of the experimental group. These results are in agreement with what was stated in Khotimah et al. (2019).

Discussion

It is common for students to have problems with learning materials of different kinds. It is impossible to avoid a problem in this regard, particularly when it comes to math. By avoiding mathematical problems, students are thought to think practically when solving problems.

Students' mathematical problem-solving abilities, like their cognitive abilities in general, are suboptimal. Mathematical engineering problems are typically solved by students using their problem-solving skills acquired through teaching mathematics using the TPS strategy.

Table 3's results reveal, at the 0.05 level of significance, statistically significant differences between the experimental group's and control group's mean scores in the post-test at the total score and all sub-skills, and in favor of the experimental group. As shown in Table 2, this result confirms the equivalence of the experimental and control groups. This result can be explained by the fact that the TPS strategy used in the experimental treatment gave the students the opportunity to think individually. The TPS strategy strengthened their self-confidence and gave them more time to organize their ideas which made learning meaningful. Based on the findings of Lee et al. (2018), the TPS has proven to be a success when it is used to help students express their difficulties in probability. This is especially true for students with dyslexia and other learning disabilities. According to Kusuma et al. (2020), the TPS strategy allows students in the second stage (pair) to exchange experiences and have discussions with their partners so that undesirable solutions are excluded, and this discussion can deepen the meaning of the answers they have thought inter-subjectively with their partners. In the third stage, the correct solutions are shared with the other members of the group. These steps take place in each step of problem-solving: understanding the problem, devising a plan, carrying out the plan, and looking back.

As the statistical difference shows, the experimental group's performance is better than that of the control group. This result contributes to the nature of the TPS strategy, which, after giving them enough time to think independently and in pairs, gives the students the opportunities to share their strategies in devising and carrying out solution plans. Students prepare themselves very well to understand the problem; retrieve all the mathematical relationships related to the problem, and devise a set of solution plans. In terms of the skill of carrying out a solution plan, the TPS strategy helps the students discover errors in carrying out the solution plan and, more especially, in arithmetic operations. The TPS strategy also contributes to the sharing of solving problem experiences among all group members when thinking aloud plays a role in the student's mastery of problem-solving skills. This is consistent with the results of Rifa'i and Lestari (2018), which demonstrated the effectiveness of the TPS strategy in developing problem-solving skills in mathematics.

Think-Pair-Share is an instructional strategy that encourages active learning and interaction among students. It provides an opportunity for students to think critically, solve problems, and share their ideas with others, which can help develop various skills related to engineering mathematics. Here are some ways in which the Think-Pair-Share strategy can help develop students' skills in solving engineering mathematical problems:

1. Encourages critical thinking: By giving students time to think about a problem independently, the strategy promotes the development of critical thinking skills. Students are encouraged to analyze and evaluate the information and develop their own solutions to the problem.
2. Enhances collaboration: The "pair" part of the strategy involves students working together to discuss their solutions. This encourages students to collaborate and communicate with each other, which is an essential skill in engineering. Students learn how to listen to others' perspectives, provide constructive feedback, and work together to develop solutions.
3. Develops problem-solving skills: The strategy provides an opportunity for students to practice solving engineering mathematical problems. By working independently and then sharing their solutions with others, students are able to identify their strengths and weaknesses and learn from each other.

4. Improves understanding: The "share" part of the strategy gives students an opportunity to share their solutions and explain their reasoning with the class. This helps other students understand the problem and develop their own solutions. It also provides the instructor with an opportunity to assess the students' understanding and provide feedback.

Overall, the Think-Pair-Share strategy is a valuable tool for developing students' skills in solving engineering mathematical problems. By promoting critical thinking, collaboration, problem-solving, and understanding, the strategy can help students become more confident and effective problem-solvers.

Conclusion

This study's findings provide evidence that the employment of the TPS strategy in teaching mathematics has resulted in a clear improvement in the students' abilities to solve mathematical problems. This is represented by the four skills: namely, understanding the problem; devising a plan; carrying it out; and looking back. The TPS strategy has increased, also, the students' participation in solving mathematical problems by encouraging them to think individually and motivating them to share their solutions with their partners and discuss their solutions with the other students in the class. The TPS strategy's several benefits include: Providing opportunities for students to think independently, Learning from one other, Practice using their own mathematical concepts and generalizations, Practice using mathematical thinking skills, Providing formative assessment to them, and Making students actively involved in their learning.

From this study, we concluded, also, that the use of the TPS strategy helps students to acquire mathematical problem-solving skills, such as asking questions while understanding the problem, giving long comments and explanations while carrying out a plan. The TPS strategy increases students' confidence in solving mathematical problems. All these findings and the positive results gained in this study are due to the use of TPS.

Recommendations

We recommend that teachers be encouraged to use TPS in mathematics education as a new and interesting method for collaborative learning. It is important to highlight that the use of the TPS strategy in teaching mathematics has had a positive impact on students who, previously, had experienced difficulties solving mathematical problems. This is reflected in their clear progress after using TPS and their increased enjoyment of learning mathematics. In view of this study's findings, we recommend that the TPS strategy be used in school teaching to develop the students' competencies in solving mathematical problems. Researchers recommend integrating blended learning and flipped learning with the TPS strategy in future studies.

Limitations

Study limitations can be summarized by the validity and item-discrimination difficulty of the problem-solving skills test used in the study. In addition, the seriousness of the responses of the sample members can also pose a limitation.This study was restricted to sixth-grade students at the elementary schools (11–12 years old) who were studying in the Ajloun Governorate Directorate of Education government schools in the first semester of the academic year (2020).

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Ethical statement

The authors stated that there are no sensitive or confidential personal data in this study. Therefore, ethics committee approval is not required.

Declaration of interest

No conflict of interest is declared by authors.

Authorship Contribution Statement

Alsmadi: Conceptualization, design, writing, supervision, final approval. Tabieh: Statistical analysis / interpretation, critical revision of manuscript. Alsaifi and Al-Nawaiseh: Data acquisition, technical or material support, referencing, Editing/reviewing.

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