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Impact of a Collaborative Flipped Classroom with Think-Pair-Share on Physics Problem-Solving Skills

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Abstract

This study aims to enhance students' problem-solving skills in physics, specifically in simple harmonic motion, by implementing a collaborative flipped classroom (FC) model based on discovery learning and the think-pair-share (TPS) method. Using a quasi-experimental design with a non-equivalent control group, the research involved 30 high school students in West Java across two classes. The experimental group participated in flipped classroom activities that incorporated TPS, where students worked in pairs to discuss and explain concepts. Pre-class sessions focused on conceptual understanding, while in-class activities emphasized problem-solving. Both groups received an e-learning module developed by the researchers, which included material descriptions, instructional videos, and guided worksheets. The experimental group showed a significantly higher N-gain (0.85) compared to the control group (0.64), with statistical analysis (independent T test, p<0.005) confirming a significant improvement in problem-solving skills.

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INTRODUCTION

In the modern era of learning, students must acquire skills that are in accordance with 21st-century skills, such as (1) critical thinking and problem-solving skills, (2) communication and collaboration skills, (3) creativity and innovation skills, and (4) knowledge of information and communication technology. Problem-solving skills are one of the skills that have emerged as a 21st-century requirement. Physics education serves a strategic function in fostering students' intellectual growth by advancing their conceptual understanding, analytical reasoning, and higher-order cognitive abilities. To effectively address complex, real-world challenges, learners must be equipped with sophisticated cognitive skills—namely, creative thinking, critical evaluation, and systematic problem-solving.

When trying to solve physics problems, students often claim that they understand the problem, comprehend the underlying laws of physics, and have solved many similar problems. However, when confronted with a new problem that differs from the ones they have encountered before, they struggle to find a solution. Based on the study's results, students face difficulties in identifying problems (Halim et al., 2016). Poor math skills and a lack of understanding of problems are the primary obstacles to physics problem-solving skills (Reddy & Panacharoensawad, 2017). The difficulties students experience in solving problems are caused by several factors, including the material they study, classroom learning activities, and the teacher's teaching style (Azizah, Yuliati). Problem-solving skills require students to apply their knowledge to solve and find solutions to specific problems. To solve a particular problem, students must gain a deep understanding of the topic, knowledge construction, and new insights, enabling them to make informed decisions (Docktor et al., 2016). The success of students in solving physics problems is not only useful for improving their understanding of physics concepts, but also for building relationships between all information and problem concepts (Ince, 2018). Problem-solving skills are an ability that focuses on analysis in the process of selecting concepts needed by students to solve a problem. These skills can make it easier for students to view physics problems from multiple contexts, thereby making learning more meaningful (Ismiati et al., 2020).

Today, technology has become a vital component of learning resources. Referring to the analysis of learners, such as their characteristics and learning styles, Prensky (2012) stated that the phenomenon of the era has given rise to a new generation with distinct needs. This generation is known as digital natives, who grew up in a world dominated by digital technology. The characteristics of digital natives include being dependent on technology, enjoying the online environment, and having the ability to adapt to new technologies. Based on these characteristics of digital natives, there is a need for a new approach to learning activities. The blended learning model is becoming increasingly relevant in teaching digital native learners. The blended learning model, combined with the flipped classroom approach, provides a viable pedagogy that makes learning active and creates a stimulating learning experience for students. The flipped classroom approach combines online learning at home and traditional face-to-face learning in the classroom. According to Bergmann and Sams (2012), the concept of a flipped classroom (FC) entails that activities typically done at home in traditional learning are conducted during class periods, and activities traditionally done during class periods are completed at home. It implies that students complete new learning activities that are usually done at home (e.g., as homework) in class, while learning about procedures and concepts that are typically carried out at school is done at home. In FC, the content of learning materials is presented to students outside of class hours through technological tools, such as videos created or developed by teachers to explain specific information related to the learning materials' content.

Through FC, students are expected to come to class well prepared and with a basic understanding of the material, usually by watching a recording of the lesson or reading the material before the lesson takes place. (Ozdamli & Asiksoy, 2016). Students review before class materials, such as videos or readings, before class. Class time is usually used for interactive activities, such as problem-solving or group work, where students apply concepts learned from the previous class material. During class, the teacher can then provide more individualized and targeted support to students, answering questions, facilitating discussions, and helping students overcome problems. In general, this also means that in class, most of the teacher's activities focus on guiding students who are having trouble with assignments and paying more attention to low-achieving students (Bergmann & Samm, 2012). Before class activities are to stimulate students' curiosity and motivation, and to highlight potential difficulties or misunderstandings in class, to understand the topic of the material (Yough et al., 2019). Then, classroom activities prioritize two-way communication, involving both receiving and providing feedback between teachers and students. The study's results have shown that students are generally satisfied with the use of FC. Qualitative comments from the survey indicate that the new way of watching pre-class videos and working on advanced problems in class with peers contributes to student satisfaction in FC (Çelik et al., 2021; Chen et al., 2023; Nacaroğlu & Bektaş, 2023).

For the flipped classroom approach to be effective, it is recommended that suitable teaching models be adopted. Previous studies related to FC implementation have demonstrated the ability to improve problem-solving skills at the secondary school level, including through the integration of FC with the problem-based learning model (e.g., Santyasa et al., 2021). Based on the literature review related to flipped classroom strategies and innovative teaching approaches in physics education conducted by Tunggyshbay et al. (2023), several researchers have combined FC with project-based learning, the integration of FC with gamified learning, and the integration of FC with cooperative learning.

Permendikbud Number 22 of 2016 concerning Elementary and Secondary Education Process Standards states that "To encourage students' ability to produce contextual work, both individually and in groups, it is highly recommended to use a learning approach that produces work based on problem solving." This research employed a recommended instructional strategy known as discovery learning, which underpins the implementation of the FC. While the FC model promotes flexibility and places students at the center of the learning process, it also presents certain drawbacks. A key limitation is the absence of immediate teacher support during the at-home learning phase. As highlighted by Lai et al. (2020), students may face difficulties when they are unable to ask questions or receive clarification in real time, potentially affecting their comprehension and motivation. To overcome this challenge and improve the FC experience, the study incorporated the Think-Pair-Share (TPS) technique as a collaborative learning tool. TPS introduces an interactive element by pairing students to engage in shared reflection. After viewing a physics video lesson, each student writes an individual response based on their understanding of the material. They then exchange ideas with their partner, discuss areas of agreement and disagreement, and refine their thoughts through conversation. This peer-to-peer interaction enhances conceptual understanding and critical thinking, while also mitigating the lack of direct teacher input during the initial learning phase.

By integrating FC with TPS, the study aims to foster a more engaging and supportive educational setting—one that balances independent exploration with meaningful collaboration, thereby bridging the gap between autonomous learning and interpersonal dialogue. This study aims to determine how to improve problem-solving skills in simple harmonic motion material using a discovery learning-based collaborative flipped classroom learning model. Simple harmonic motion (SHM) was chosen as the focus of this research due to its fundamental role in understanding oscillatory systems in physics and engineering. It underlies a wide range of real-world phenomena, such as pendulums, springs, sound waves, and molecular vibrations, and provides essential groundwork for exploring more advanced physics concepts.

METHODS

This study employs a quasi-experimental design with a nonequivalent control group. The population in this study consisted of all students in class X MIPA at one of the high schools in West Java. The research sample was selected using a convenience sampling technique, comprising 30 students from classes X MIPA A and X MIPA B. In the convenience sampling technique, a researcher might decide to study two second-grade courses at a nearby high school. In convenience sampling, results are often limited to the specific group studied, which can lead to conclusions that lack accuracy and relevance for the broader population.

The treatment in the experimental class utilized FC based on the discovery learning model, employing the TPS method. In the TPS method, students work in pairs to carry out activities to provide explanations or ideas between the two students. This learning activity involves explaining concepts to other students. Students respond to questions asked by the teacher, and then one student shares them with other students nearby.

Another class, serving as a control, applies the Discovery learning model without FC and TPS. The learning scenario implemented in the experimental class is presented in Table 1. Considering that students' conceptual knowledge is essential, because in solving problems, mature concepts are needed (Docktor et al., 2016), then in this developed model, the learning scenario of learning outside the classroom (before class) is focused on understanding physics concepts, and learning in the school (during class) is focused on problem-solving skills. For after-class activities, the teacher assigns additional homework to help students improve their problem-solving skills.

During the implementation of the learning module, an electronic learning module was provided that could be accessed by both students in the experimental class and the control class. The researcher prepared the learning module. The development of this electronic teaching module used the Triple Step Writing Strategy teaching material development strategy by Handayani et al. (2020). This electronic learning module presents instructional content on SHM, supplemented with integrated video materials, contextual real-world problems that illustrate the application of SHM concepts, and student worksheets designed to guide learners through assigned tasks. Concrete examples of real-world phenomena that illustrate the principles of SHM include the following: (1) the oscillation of a pendulum in a grandfather clock, where the length of the pendulum directly influences the period of motion; (2) the operation of a spring-loaded fitness device, in which a mass undergoes periodic motion with a period determined by the spring constant and the attached mass; and (3) the function of a seismograph, which detects ground vibrations through a mass-spring system that oscillates at a frequency governed by its mechanical properties.

In contrast to the students in the control class, who were not assigned any preparatory tasks before classroom instruction, those in the experimental class were required to engage with the learning module before class. This included watching instructional videos, reading relevant material descriptions, and completing pre-class worksheets through peer discussion. These preparatory activities were conducted outside the classroom, typically at home, and formed part of the flipped classroom (FC) model, which was integrated with the Think-Pair-Share (TPS) strategy. Meanwhile, the control group followed a traditional approach to physics instruction, utilizing the discovery learning model wherein all six instructional phases were carried out in a face-to-face classroom setting.

Table 1. Discovery learning scenario based on a collaborative flipped classroom

Phase of Discovery Learning	**Learning Activities**	
	Outside the Classroom	**In the classroom**
Stimulation	The teacher stimulates students by giving problems through videos and assigning students (in pairs) to note down important terms related to physics concepts.	Teachers pose real-world problems to develop investigations. Students (in pairs) are involved in discussions to answer questions posed by the teacher.
Problem Statement	The teacher assigns students to describe and summarize the key information related to the problem in the video.	The teacher provides real-world problems for students to explore and tasks students with describing information and summarizing important information. symbolically and visually
Data collection	Teachers provide teaching materials that are integrated with videos to introduce relevant physics concepts that students may not understand, thereby fostering a deeper understanding.	The teacher encourages students to explore relevant physics concepts and guides them in applying the appropriate concepts to solve the presented problems.

Phase of Discovery Learning	Learning Activities	
	Outside the Classroom	**In the classroom**
Data processing	The teacher provides guidance to students to apply physics concepts that are appropriate to the problems presented.	The teacher stimulates students to determine the correct physics equation and then apply it to solve the problems presented.
Proof	The teacher provides guidance to students to clarify the concepts that students have used to determine whether they are appropriate to the problems presented.	The teacher provides guidance to students to clarify whether the equations that students have used are appropriate to the problems presented.
Formulating Conclusions	The teacher provides guidance so that students make logical decisions based on the conclusions to answer the problems provided.	Stimulate students to make logical decisions based on conclusions to answer real-world problems.

The research instruments used consist of treatment instruments and measurement instruments. The treatment instrument is used during the learning process using student worksheets. Experts previously reviewed student worksheets during this class as a form of feasibility testing before they were used during the learning process. The review encompasses aspects of material, construction, and language, as well as its suitability in relation to the learning syntax model.

Student activity data during the process learning is the students' answers to the questions prepared by the teacher in the student worksheets. Student activity data during the learning process is a representation of student activity during the learning process, given a score based on the students' answers to the questions prepared by the teacher in the student worksheets. Student worksheets contain answers from students representing each stage of learning, then calculated using a scoring rubric with a score range of 0-4. The score is then converted into a value with a number range of 0-100.

Lembar Kerja

Mari menonton video !
Yuk Tonton video pada link:
https://www.youtube.com/watch?v=0w7CyoLwMKM&pp=ygUVdHJ1ayBrZWxlYmloYW4gbXVhdGFu
dan jawablah pertanyaan dibawah !

Deskripsi yang Berguna
Dari video tersebut, deskripsikan menurutmu permasalahan apa yang timbul akibat beban bawaan truk yang *overweight* ?
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tuliskan informasi penting apa saja yang dapat kamu ambil!
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Rubrik Penilaian

Skor	Kriteria
4	Jika jawaban sesuai atau sempurna
3	Jika jawaban yang diberikan benar, dan lengkap tetapi belum sempurna sesuai yang diharapkan
2	Jika jawaban yang diberikan benar namun tidak lengkap
1	Jika responden memberikan jawaban salah
0	Jika responden tidak memberikan jawaban

Pedoman Penskoran :

$$Nilai\ Keterlaksanaan = \frac{Skor\ yang\ diperoleh}{Skor\ maksimum} \times 100\%$$

Figure 1. Example of student worksheet and rubric scoring

The measurement instrument used an essay test consisting of three questions on the material of simple harmonic motion. The questions were consulted and validated by expert lecturers (judgment experts) and tested using the Pearson Product-Moment correlation technique. The results of the test questions obtained a correlation coefficient (r_{xy}) of 0,85, indicating a strong positive correlation.

Problem-solving skills data, measured from initial test scores to final test scores, are scored using a problem-solving skills rubric that refers to the one developed by Docktor et al. (2016). The increase in students' problem-solving skills after learning is obtained by calculating the average normalized gain value or N-gain (<g>) using the formula from Hake (1998):

$$< g >= \frac{\% < G >}{\% < G >_{mak}} = \frac{\left(\% < S_f > - \% < S_i >\right)}{(100 - \% < S_i >)}$$

To determine whether the research hypothesis is accepted or rejected, a hypothesis test is conducted using a statistical test. To determine whether students' problem-solving skills have improved, the average scores from the pre-test and post-test are compared. For data analysis, the Kolmogorov-Smirnov test is employed to assess normality, while the Shapiro-Wilk test is used to evaluate homogeneity. Considering the relatively small sample size of 35 students, the Shapiro-Wilk test is conducted using the Exact method to verify whether the data follow a normal distribution (Mehta & Patel, 2013). Once normality is confirmed, the data are subjected to hypothesis testing using the independent sample t-test.

RESULTS AND DISCUSSION

Before implementing the learning, both in the experimental class and the control class, a pre-test was conducted to determine the level of equality in problem-solving skills. Furthermore, learning in the experimental class was implemented using the discovery learning model based on a collaborative flipped classroom, whereas learning in the control class followed the same discovery learning model. Learning in the experimental class and the control class was carried out over 3 meetings, each meeting lasting 2 credits (2 × 45 minutes). During the learning process in the classroom, student activities are reflected in the student worksheet answers, which represent each stage of the discovery learning model. The average score for three meetings, based on the answers to each student's worksheet questions in the experimental class and the control class, is presented in Figure 2. Student worksheets include responses that reflect various stages of student learning. These responses are evaluated using a scoring rubric with a scale from 0 to 4. The resulting score is then translated into a numerical value ranging from 0 to 100.

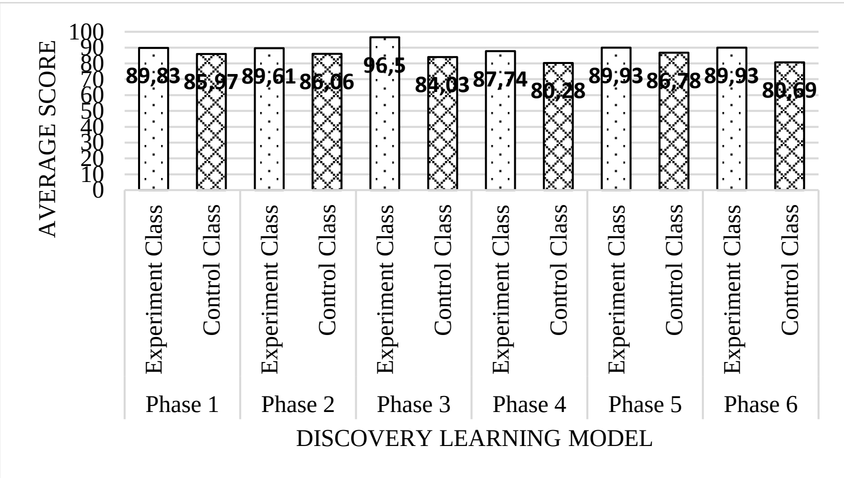

Figure 2. Students answer in the worksheet for the experimental class and the control class

Learning in the experimental and control classes ended with a post-test. The pre- and post-test data were scored based on the problem-solving skills scoring rubric consisting of five aspects: 1) useful descriptions, 2) physics approaches, 3) specific physics applications, 4) appropriate mathematical procedures, and 5) logical progression (Docktor et al, 2016) with a score of zero to five. The score was then converted into a value with a range of 0-100 and interpreted based on the criteria presented by Azwar (2010) in Table 2.

Table 2. Problem-solving skills criteria

No	**Percentage**	**Criteria**
1	$75\% < X \leq 100\%$	Very high
2	$58\% < X \leq 75\%$	High
3	$42\% < X \leq 58\%$	Medium
4	$25\% < X \leq 42\%$	Low
5	$0\ \% < X \leq 25\ \%$	Very Low

The range of problem-solving skill scores achieved by students in the pre- and post-tests in the experimental and control classes is presented in Table 3.

Table 3. Criteria for problem-solving skills of the experimental class and the control class

Criteria	**Number of students in Experimental Class**		**Number of students in Control Class**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Very high	0	1	0	1
High	1	32	0	8
Medium	2	2	1	25
Low	16	2	12	1
Very Low	16	0	22	0

The normalized gain value achieved through problem-solving skills in the experimental class was <g> = 0.85, and in the control class, it was <g> = 0.64. The increase in problem-solving skills is presented in Table 4.

Table 4. Improvement in the problem-solving skills of the experimental class and the control class

Experimental Class		**<g>**	**Control Class**		**<g>**
Average Score			**Average Score**		
Pre-test	**Post-test**		**Pre-test**	**Post-test**	
29.9	92.48	0.85	26.5	73.3	0.64

The number of students who achieved the level of problem-solving skills based on the N-Gain category in the experimental and control classes is presented in Table 5.

Table 5. N-Gain categories in the experimental class and control class

Category <g>	**Experimental Class**		**Control Class**	
	Number of students	**Percentage (%)**	**Number of students**	**Percentage (%)**
High	32	91.4	9	26
Medium	3	8.6	25	71
Low	0	0	1	3

The results of the hypothesis test using the independent sample t-test obtained t count (8.58) > t table (2.04) and the significance level. Value (2-tailed) was 0.000019>0.0005, which means that there is a difference in problem-solving skills between learning using the discovery learning-based collaborative flipped classroom learning model and traditional discovery learning.

Educators are constantly challenged to find new strategies to engage students in the classroom, thereby improving the effectiveness of the learning process. For this purpose, in this study, a discovery learning-based collaborative flipped classroom with the TPS method was implemented, with the hope of improving students' problem-solving skills in the context of simple harmonic motion material. The discovery learning-based collaborative flipped classroom learning procedure, utilizing the TPS method, employed the TPS method for all student activities, both in and outside the classroom. Based on Figure 2, it appears that the scores of students in the experimental class are higher than those of students in the control class in each phase of the discovery learning model. This condition suggests that students in the experimental class appear more prepared to participate in classroom learning. Through activities before class assignments, students in the experimental class gain better initial knowledge through watching videos, reading teaching materials, and are required to learn new skills. The results of this study align with empirical findings by Musva (2023), which indicate that students who learn with FC exhibit increased problem-solving skills and overall satisfaction with their learning experience. Other studies suggest that the effectiveness of FC depends on students' commitment to completing in-class assignments, including their involvement with the material presented before class (Chen et al., 2017). Students who actively prepare themselves are more prepared to participate in meaningful discussions and apply their knowledge in practical scenarios during class (Steen-Utheim & Foldness, 2018; Tomas et al., 2019). The TPS method, as included in this study, appears to contribute to the preparation of classroom learning by enhancing cognitive outcomes while also improving interpersonal skills as students collaborate and communicate with their peers (Mushtaq et al., 2021). By studying the class materials before class, students become better prepared to solve challenging physics problems, resulting in better learning outcomes (Özdamlı & Aşıksoy, 2016).

The design of learning materials is essential in FC. To reduce the burden on students in extracurricular activities that can affect student performance and the time spent studying the material, the quantity and type of teaching modules must consider the needs of students, including by presenting material descriptions using multimodal representation. (Handayani et al., 2021). In addition, the integration of technology in FC enables a variety of learning resources that cater to different learning styles, thereby increasing accessibility and understanding (Özdamlı & Aşıksoy, 2016). Before class activities not only encourage active learning but also encourage students to take responsibility for their own learning, creating a more collaborative and engaging classroom environment (Astuti et al., 2019).

Based on the initial and final test scores obtained, it is evident that students in the experimental class demonstrated an increase in problem-solving skills on simple harmonic motion material with <g> in the high category. This finding shows that the Discovery Learning model based on Collaborative Flipped Classroom with the TPS method can improve students' skills in solving problems in a high category. It can be said that this is due to the reduction of class time spent on explaining the lesson content, shifting the focus to discussions, problem-solving activities, and the use of simulations to practice theoretical knowledge in the flipped classroom approach.

The TPS method included in this study appears to contribute to facilitating students' understanding both before and during class. The results of this study align with Karabulut-Ilgu et al. (2018) 's opinion that the peer instruction method, a form of formative assessment, has been proven to facilitate deeper understanding through collaborative problem-solving among students. The use of the TPS method aligns with Vygotsky's learning theory, which posits that students acquire new information through social interaction with others. This encourages students to participate in the learning process actively. The increase in problem-solving skills achieved in this study supports Bandura's social learning theory, which states that a person learns new knowledge and behavior by observing and collaborating with others.

One significant advantage of FC is the increased opportunities for active learning during class activities. By having students complete preparatory work in advance, teachers can utilize class time for interactive activities, such as problem-solving and discussion (Hwang, Lai, & Wang, 2015). Additionally, FC has been linked to increased student responsibility and autonomy in the learning process. Urquiza-Fuentes reported that students in FC partially showed greater responsibility for learning, leading to improved academic performance (Urquiza-Fuentes, 2020). The same thing was conveyed by Nouri, who emphasized that FC encourages students to learn at their own pace, actively engage with the material, and participate in collaborative problem-solving during class. (Nouri et al., 2017). The discovery learning based collaborative flipped classroom learning model with the TPS method is expected to develop high-level thinking skills.

CONCLUSION

It can be concluded that the collaborative flipped classroom based on discovery learning applied to simple harmonic motion material improves students' problem-solving skills. The collaborative flipped classroom model improved students' preparedness and problem-solving skills. Students who completed pre-class assignments were more engaged in class discussions. The TPS method fostered collaboration and communication among students. Students who completed pre-class assignments were more engaged in class discussions. The results of the N-gain average score in the experimental group were higher than the control group in the medium category, indicating that the collaborative flipped classroom based on discovery learning applied to simple harmonic motion material improves students' problem-solving skills.

SUGGESTION

Adopting a Flipped Classroom enables educators to shift from teacher-driven instruction to a more student-focused learning experience. In this setup, classroom activities are tailored around students' interests and learning preferences, making the in-class environment more responsive than traditional lectures. As a result, physics education can become more inclusive, helping to support learners who may feel anxious or uneasy about studying the subject.

Future research should explore the impact of the collaborative flipped classroom based on discovery learning in different subjects. The potential future study can be conducted on the effectiveness of using various specific tools of digital content to support diverse learning styles and address challenges related to students' commitment to pre-class activities.

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