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Analysis of students' cognitive physics learning outcomes on the material of substances and their forms using think-pair-share

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Abstract: In the last decade, many studies of physics learning at the junior high school level seem to show that student-centered interactions have a greater effect than teacher-centered interactions in improving physics learning outcomes. Based on this premise,Think-pair-share (TPS) which is one type of cooperative learning model developed by Frank Lyman and his colleagues from the University of Maryland (1981) is a teaching strategy that promotes active and collaborative learning; however, its effectiveness and application are very good in physics learning. The purpose of this study is to analyze student learning outcomes using the TPS type cooperative model on the material of substances and their forms. This study uses a descriptive model with 24 students as subjects divided into four groups. The implementation of the study on SMP Xaverius Passo. Data were collected through tests, namely pretest and posttest and observations using student worksheets and affective and psychomotor assessments of students. The results showed that there was a significant increase in student learning outcomes after the implementation of the TPS model, both from cognitive, affective, and psychomotor aspects. This study recommends the use of the TPS cooperative learning model as a solution to improve the quality of physics learning in schools.

Keywords: Student learning outcomes; Physics learning; Think-pair-share.

Introduction

Research has shown that most students hold beliefs about physics and physics learning that are very different from those of expert physicists. Some students view physics as a collection of interrelated pieces of information to be learned separately, while others view physics as a coherent set of ideas to be learned together (Batlolona et al., 2024). Some students view learning physics as memorizing formulas and problem-solving algorithms, while others view learning as involving the development of deeper conceptual understanding. Different terminologies are used to refer to students' attitudes, beliefs, and thoughts about what they learn and how they learn (Sahin, 2010). The large number of physics problems that must be solved directly or offline is an obstacle that results in increasing difficulty for students in solving physics problems. This can be seen from the still weak Problem Solving Skills (PSS) of students in online learning during the pandemic. In the process of learning physics, visualization of material is needed for problem solving (Abtokhi et al., 2021).

Physics learning tends to still be teacher-oriented. This results in students becoming passive and less motivated to learn physics, and considering physics as a difficult and boring subject, which has a negative impact on student learning outcomes (Korur & Eryilmaz, 2019). Students' attention to physics tends to be low because of conventional and non-innovative learning, so it does not motivate students. Active involvement of students in the learning process is very important so that their learning outcomes can be optimal (Williams et al., 2014). Male and female students' desire to learn increases when teachers provide them with more applicable and career-related instruction (Lock et al., 2015). Meanwhile, urban students have higher achievement in academic

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performance compared to rural students in physics where urban students are more enthusiastic than rural students (Barthelemy, 2019). In general, rural students lag behind in terms of academic achievement and have lower educational aspirations compared to urban students (Liao et al., 2013).

The results of a study in South Africa show that students still have difficulty learning physics as evidenced by the low quality of student achievement in national assessments and international exams Trends in International Mathematics and Science Study (TIMSS) (Ogegbo & Ramnarain, 2022). Some of these challenges include low levels of teacher competence in the use of information communication technology in teaching and learning, as well as teaching values and attitudes that influence the choice of teaching strategies and contribute to the low quality of student achievement in physics (Ramnarain & Hlatswayo, 2018). Some may argue that physics is too difficult for young children. Physics is often associated with complicated calculations and decontextualized models of the world, which leaves little possibility for integrating physics education with children's everyday lives (Areljung et al., 2023). The Tanzanian government has increased its efforts to provide physics laboratories in schools to support practical activities. However, the quality and utilization of some schools, especially in rural areas, are not satisfactory (Kihwele, 2014). Improvements have been made, but only in some schools. The quality of physics laboratories in private schools is different from public schools, where learning and motivation are disabled (Mabula, 2012).

The use of appropriate and suitable learning models can provide opportunities for students to actualize their potential and develop in cognitive, affective, and psychomotor aspects, so that learning objectives can be achieved. However, the presentation of dense and complex physics material requires variations in teaching models to be more effective (Batlolona, 2023). Using an appropriate model for each concept is very important, because a good model for one concept may not be effective for another concept (Daniel Mollel et al., 2022). One of the junior high school physics materials that is still considered difficult by students is substances and their forms which are directly related to everyday life (Furió et al., 2000). However, commonly used learning models, such as lectures and examples from life, are often not enough to achieve optimal learning outcomes. Students need to be guided to understand concepts through group discussions, not just receiving explanations (Jamaludin & Batlolona, 2021).

The essential principles of cooperative learning necessary for successful implementation are interpersonal and small group skills, positive interdependence, individual and group accountability, face-to-face interaction, and group processing (Johnson & Johnson, 2009). One such strategy is Think-Pair-Share (TPS) which was first developed by Lyman and colleagues in 1981 to improve learning, problem-solving, and critical thinking skills through active participation and collaboration of students in a special education setting. Since then, this activity has grown in popularity and is used in a variety of higher education settings. Typically the teacher poses a question, students write about the topic (think), then pair up to discuss their answers (pair share), and then present their answers to the whole class (Prahl, 2017). To make the TPS more student-centered, I have modified it slightly by doing it at the beginning of class, and asking students to develop two questions based on the reading they have done before class. I emphasize that the questions should seek insight rather than simply recall.return (F. Cooper, 2018).

TPS includes three main interrelated phases: thinking, pairing, and sharing (Kaddoura, 2007;Lange et al., 2016). In the thinking phase, students are given a certain amount of time depending on the complexity of the task to think independently about the question or other prompt posed by the instructor. During this time, students process information, think about their responses, and organize and formulate their thoughts. In the next step, students pair up with a nearby or designated student to discuss their responses. During this interaction, they listen to each other and compare and challenge their thinking. They may be asked to reach a response through consensus (collaborative response), generate multiple responses/solutions, and take on and take turns playing different roles (e.g., listener, speaker, challenger) (Fitzgerald, 2013). Finally, pairs of students, all or part of them, share their collaborative thinking or responses with the entire class and engage in instructor-led group discussions. Some evidence suggests that TPS increases student participation, academic achievement, and critical thinking and is superior to traditional lecture in terms of engagement and learning outcomes (Fitzgerald, 2013).

TPS has also been found to promote equal participation through individual thinking, pair interaction, and role reversal. In addition, TPS does not require a lot of time and resources to prepare, involves the entire class, can be used to address multiple content issues, and increases not only social interaction but also personal accountability during the learning process. Despite these benefits, there is little current research on the application of TPS in health professions education, especially the specific conditions that TPS must meet to promote active and collaborative learning (Pluta et al., 2013). Modified collaborative learning strategies have been advocated to enhance student learning in a variety of settings as long as they maintain the general

principles of collaborative learning such as positive interdependence (mutual benefit), appropriate grouping (e.g., heterogeneous classes), individual accountability, and optimal interaction. For example, TPS promotes critical thinking and problem-solving skills. TPS is an instructional strategy that promotes active and collaborative learning; however, the effectiveness and applicability of this strategy in its original or modified form remain to be established, particularly in health professions education (Ganatra et al., 2021). The TPS model has been recognized in various fields, namely dentistry (Ramesh et al., 2021). This is because medical students are increasingly apathetic towards lecture-based teaching methods that make them increasingly passive. Therefore, through the creation of active learning pedagogy in biochemistry consisting of flipped class modules integrated with TPS (Carpenter et al., 2020).

Therefore, it is important for teachers to use a learning approach that makes students active and directly involved in the material being studied. One of the learning models that can overcome learning problems is TPS. This model is designed to increase interaction between students, respect differences, and help each other in learning. Therefore, the purpose of this study is to analyze student learning outcomes using the TPS type cooperative model on the material of substances and their forms

Method

The research used in this study is a descriptive study that aims to describe student learning outcomes after the application of TPS to the material of substances and their forms. The study was conducted at SMP Xaverius Passo, Baguala District, Ambon City. The subjects of this study were 24 seventh grade students, who were divided into four groups, each consisting of six students. The variables in this study were the learning outcomes achieved by students after being taught with the TPS type cooperative learning model. To measure student learning outcomes, the instruments used consisted of two types, namely test instruments and non-test instruments. The test instruments included a pretest and posttest consisting of 10 multiple-choice questions and three essay questions, which were taken from a question bank that was relevant to the concept of substances and their forms. Meanwhile, non-test instruments included observation sheets and student worksheets (LKS). Observation sheets were used to assess students' affective and psychomotor aspects, while LKS helped students understand the concepts taught. Data collection techniques were carried out through tests and observations. The pretest was given before learning began, and the posttest was conducted after learning activities using the TPS model to evaluate students' understanding of the material.

Table 1. Learning Outcome Categories

Range	Category
85-100	Very high
70 – 84	Tall
55 – 69	Currently
50 – 54	Low
0 – 49	Very low

Source:(Dwiwansyah Musa et al., 2022)

Results and Discussion

Expert Mundelsee & Jurkowski (2021)explains that TPS stimulates students to think about how to answer questions posed by the teacher in the following three steps: (1) Thinking: each student thinks about the question individually and is encouraged to take notes. (2) Pairing: students are then grouped into pairs to exchange and discuss their ideas. (3) Sharing: students share their validated ideas and may be extended to a larger group or to the whole class. In addition, Cooper et al., (2021) explains the TPS steps that have a very important impact on supporting student engagement and learning. Students are then asked to pair up and discuss their thinking with others giving students the opportunity to remember, process, practice, and communicate what they have learned in a low-risk environment.(Tanner, 2009). At the beginning of learning, students have high levels of physics misconceptions as shown in Table 1.

Table 1. Description of the score obtained (%) of students' answers to understanding the concept of substances and their forms at the microscopic level

Draft	Percentage (%) of Students Who Answered Correctly (N=24)			Amount
	Solid-Liquid	Liquid-Gas	Solid-Gas	
Particle Size	20.5	20.5	18.0	19.7
Particle Weight	30.5	28.5	35.5	31.5
Distance between Particles	40.5	50.5	56.5	49.1
Particle Movement	52.8	58.5	70.6	60.6

Table 1 data shows that students' weaknesses are difficult in explaining a phenomenon of changes in the state of an object. In this study, the initial test was carried out before the teacher explained the learning material to

be studied. The initial test aims to determine students' initial abilities, as well as students' readiness related to the material being taught. The questions given are the scope of the material to be taught, namely substances and their forms. Based on the results obtained at the beginning of the learning process, it shows that students have not been able to understand and master the material on substances and their forms. This is evident from the results of the initial test showing that most students answered only guessing the answer and unscientific explanations that are far from the views of experts. This is because there is no learning readiness from the students themselves, so the results obtained are not optimal. In addition, the initial test scores achieved by students are the lowest score of 12 and the highest 65 as shown in Figure 1. This is because there is no learning readiness from students and students do not have any knowledge about the material on substances and their forms, so that students in answering each question simply guess the answer, there are even students who ask their friends. This condition is in line with what was stated Felder & Brent (2005), that a student has difficulty in understanding a certain knowledge, one of the causes of which is because the new knowledge received is not connected to previous knowledge or perhaps the previous initial knowledge has not been possessed. How much students learn in class is determined in part by the innate abilities and previous preparation of the student. In addition, the failure of students in the initial test provides an initial picture for teachers to know what will be done in learning in order to lead students to understand the material that will be taught to them.

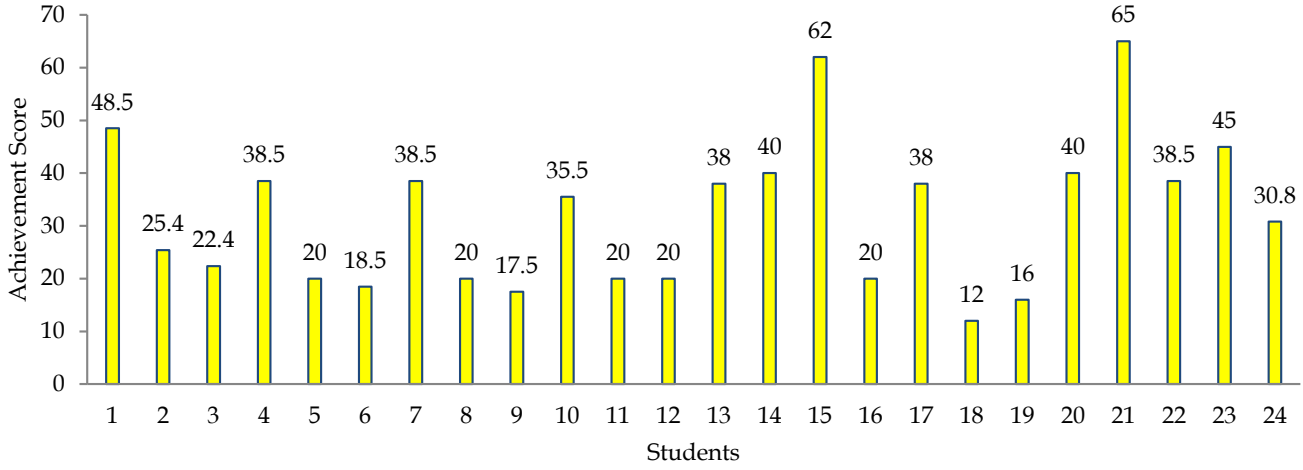

Figure 1. Qualification of student achievement scores on the initial test

During the learning process, the teacher has directed students to focus on learning related to the topic of substances and their forms. Theoretical explanations about the differences in the properties of solids, liquids and gases can use particle theory which states that all substances are composed of particles (molecules) that are so small that they are invisible to the eye. Between one particle and another, there is always an attractive force that varies in magnitude in each type of substance. As a result, the distance between one particle and another and the freedom of movement of each particle are also different in each type of substance. It can be shown in Figure 1. With the simulation shown in the link:https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_all.html
By using particle theory Dhar (2010), we can also explain the process of changes in the state of matter. For example, if we heat a solid, it will receive some energy that can accelerate the movement of the particles of the substance. If heating is done continuously, the particles of the substance will move faster and the distance between the particles will be further apart. As a result, the attractive force between particles in the solid will be smaller, so that the solid will melt. If heating continues, at some point many particles of the substance can escape from the influence of the attractive force that binds them, then evaporation occurs. All of these conceptual explanations are simulated to students so that they can understand them well. The explanation is as follows:

a) For the concept of on namely the attractive force between solid particles is the largest, so that the distance between the particles is very close (dense) and each particle has very little freedom of movement (only vibrates in place). That is what causes the shape of solids to remain with a relatively large density.
b) The attractive force between liquid particles is relatively small compared to solids. So the distance between liquid particles is quite far apart and each particle has quite a large freedom of movement. That is what causes the shape of liquids to change easily with a relatively small density compared to solids.

c) The attractive force between particles in gas is the smallest. So the distance between particles in gas is very far apart (loose) and each particle has a very large freedom of movement. That is what causes the shape of liquids to change very easily with a very small density.

(a) (b) (c)

Figure 2. Changes in the state of water at the microscopic level using Phet simulation; a) solid, b) liquid, c) gas

Final tests are very necessary because teachers need to know the extent to which students have mastered the learning material after going through the teaching and learning process. The final assessment is intended to help students' learning abilities. After the teaching and learning activities using the TPS type cooperative learning model have taken place, a formative test is carried out which aims to determine the overall abilities of students. The results obtained show a picture of the qualifications of student achievement results in the formative assessment. The function of the final test is to determine the level of student mastery of the competencies that have been determined, both individually and in groups (Dikli, 2003). The results obtained from the students' formative tests have increased as shown in Figure 3. In this cognitive taxonomy, it is included in the low-level thinking level. However, the majority of students are able to master the material on substances and their forms. The learning difficulties of students on the material on substances and their forms are certainly caused by many factors. The factors that influence students' learning difficulties are internal factors and external factors. After being analyzed between these two factors, the internal factors that have the most influence on students' learning difficulties are intelligence, interest and learning motivation. As professional educators, teachers must distinguish students' abilities about what they need. In addition, teachers are able to distinguish concepts by properly applying one or more specific concepts which are important components of a teacher's professional practice (Adom et al., 2020).

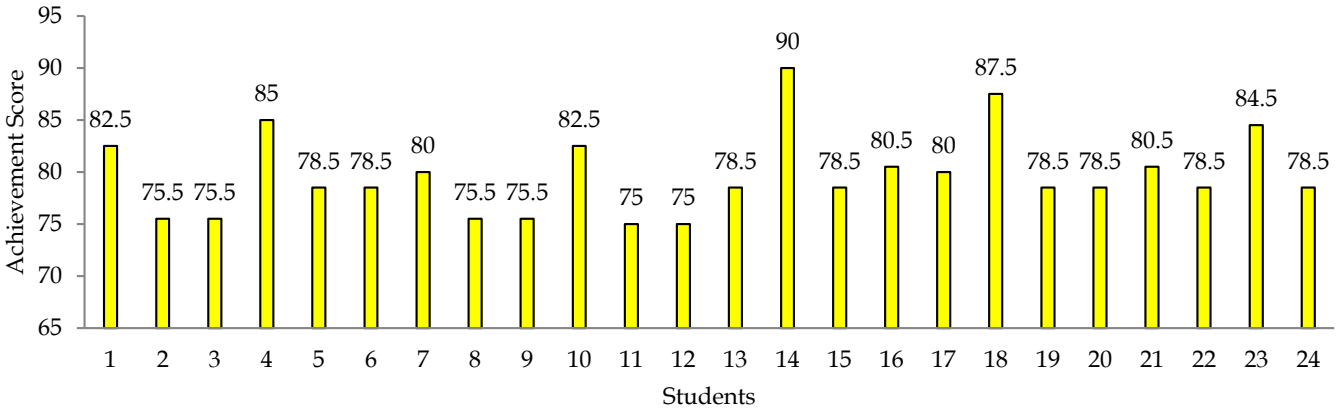

Figure 3. Qualification of student achievement scores on the final test

Figure 1 shows the final outcome of physics learning. Outcomes are consequences or results related to the learning experience. Outcome-based education is a series of activities at the end and the teacher will assess the final outcome as part of the learning that has been done. This statement of student learning outcomes guides the teaching, learning, and assessment process and will reflect what the program expects from their students when completing the learning (Anderson et al., 2005). The essence of the idea of expected learning

outcomes is that education should be planned based on the competencies that students want to develop, and not on the content that teachers want to teach. Learning outcomes thus help us shift the focus from the teacher to the results of the student learning process (Erikson & Erikson, 2019).

Many educators who support cooperative learning have adopted this procedure or a similar teaching method. The TPS procedure is designed to provide time and structure for students to think about a particular topic, then pair up with a peer to discuss responses to the topic, and finally in a third step, they synthesize and share their ideas with the group or class (Shih & Reynolds, 2015). The results of the study in Nigeria showed that the use of guided discovery strategies and think-pair-share strategies, were able to encourage learning through discovery, which ultimately led to the development of high-quality cognitive skills, which essentially improved problem-solving skills in students. Based on the findings of this study, it is hereby recommended that teachers should make guided discovery strategies and think-pair-share strategies a fundamental part of their teaching strategies and that science teachers (Shih & Reynolds, 2015).

TPS as a cooperative learning strategy provides benefits for students' academic development, self-esteem, peer acceptance, and increased enjoyment in learning (Patel et al., 2023; Robertson, 2006). As a cooperative learning strategy, TPS provides students with activities that demand accountability and encourage interaction. This form of engagement aims to improve students' critical thinking skills. Teachers encourage students to write down their thoughts before sharing them with friends during TPS activities to increase individual accountability. The TPS approach will force students to reflect deeply on what they are doing. Quiet students can answer questions without standing out from their peers because the teacher can ask a variety of questions, involving the entire class. Students are more enthusiastic about participating in TPS because there is no peer pressure to answer questions in front of the class. This active teaching and learning strategy encourages student participation in their learning (Hernando et al., 2023).Interaction between teachers and students is a fundamental part of the teaching and learning process used in Physics. Interaction is not only a guide in teaching but can also help students' achievement and positive attitudes towards Physics (Achor et al., 2019).

Conclusion

Based on the results of the study and the discussion obtained, it can be concluded that the use of TPS type Cooperative Learning can help improve the learning outcomes of physics students. The TPS strategy allows students to be involved in the learning process. Teachers encourage learning rather than being the only source of knowledge for students. Through collaborative learning, students have the opportunity to exchange ideas, respond, think creatively, discuss, criticize, and help their peers in making better essays. The researcher found that many students were able to think creatively and were able to write extensively after educating children using the TPS technique compared to before the experiment. They had difficulty finding words to start the presentation before the experiment, and some of them were hesitant and worried about making mistakes. The teacher's questions and guidance allowed students to successfully respond to the cues. Teachers find it difficult to let go of the traditional teaching strategies they have been using for a long time. However, the benefits of using student-centered solutions far outweigh the work required to make the transition to this cutting-edge tactic. Based on the findings of this study, it is recommended that: 1) Schools should ensure that teachers are trained on how to use the TPS strategy periodically. 2) Teachers should not be fixated on conventional methods, but teachers should be learning facilitators by encouraging students to participate freely in class.

Author Contributions

This manuscript was only written by the team (Jony Taihuttu, John Rafafy Batlolona, Herman Semuel Wattimena, Jamaludin, Stevi Silahooy, and Frandy Akyuwen)

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Conflict of Interest

The authors declare no conflict of interest

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