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Implementation of Conceptual Problem Solving (CPS) in The 5E Learning Cycle to Improve Students' Understanding of Archimedes Principle

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Abstract. The focus of the study is to test the effectiveness of the Conceptual Problem Solving (CPS) learning approach. This study used a mixed-method with embedded experimental design. The quantitative data were obtained from the pretest and posttest results, while the qualitative data were obtained through observation from all activities during the learning process. This study involved 35 XIth students from Science Program. The results showed that the students' average pretest score is 2,66 (SD = 0,97) and the posttest is 5,54 (SD = 1,33). *T-test* results obtained a significance value of 0,00. Therefore the difference in the pretest and posttest scores is significant. The *d-effect size* value is calculated to know how big the influence of learning for students' understanding. The *d-effect* size value is 2,51 and is categorized higher than than the standard limit. To describe how strong the improvement of students' conceptual understanding based on the pretest and posttest scores, the average gain of normalized (*N-gain*) is calculated. The *N-gain* obtained 0,39 under the criteria of the lower medium. This research concludes that learning with conceptual problem solving on the 5E learning cycle can improve the XIth student's understanding of the Archimedes principle.

INTRODUCTION

Concepts mastery is one of the aspects that is often being the object of research in the world of physics education [1]–[5]. That is because physics is not a subject that requires students to memorize but instead prioritizes understanding the basic concepts and their applications in everyday life. Furthermore, one of the physics learning competencies is mastering the physics concept. Physics concepts mastery is given priority to the problem of how students understand concepts [6] and how students can use these concepts in the process of problem-solving [7].

Physics subjects strongly emphasize conceptual and analytical skills to find a new concept and that mastery of concepts is the ability to record, understand, capture information and then change it into different forms and apply it to the problems found in everyday life [8]. So, the core of concept mastery is the ability to apply principles or concepts of physics to solve problems in daily life related to technology and natural phenomenon [9].

One of the essential goals of learning physics is to deliver a deep understanding to students in regard to the basic physics concepts so that they can apply them to solve problems [10]. Among these basic concepts is the Archimedes Principle, which is close to various events in students' daily lives. Students' ability to understand these principles will significantly support success in understanding other principles in fluid mechanics. However, students' problems with misconceptions and difficulties in mastering Archimedes's principles still frequently occur.

Wagner et al. identified three misconceptions experienced by students on the Archimedes topic [11]. First, the assumption that Archimedes' force is influenced by the area of the container and the amount of fluid around the

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object. Second, Archimedes' force on objects immersed entirely in the fluid is influenced by the depth of the object's position. Third, Archimedes' force depends on the forces acting on the object. Recent research by Berek et al. also found several misconceptions experienced by students on the topic of the Archimedes principle [12]. Among them are submerged objects that do not have buoyancy, and the magnitude of buoyancy is equal to the volume of liquid. In addition, Loverude, Kautz, and Heron also found students' difficulties in identifying the force by the fluid that urges the object and identifying the factors influencing it [13]. Although students have learned the equation $F_b = \rho_f \ g \ V_f$, but if no numbers are given, the students cannot use the equation correctly.

The students' misconceptions and difficulties will be able to hinder the process in achieving the learning objectives, particularly to understand the Archimedes Principle topic deeply. Therefore, it is necessary to implement a learning method to help students in utilizing the Archimedes principle concept to be applied to the daily phenomenon. So the purpose of learning on these topics can be achieved with the maximum.

Several researchers have tried to design learning in order to develop students' concept mastery on Archimedes Principle and overcome the misconceptions risk. Heron et al. in their work "*Helping Students Develop an Understanding of Archives of Principles*," develops three different learning strategies in physics students and teachers [13], namely: (1) laboratory-based learning to prepare candidates and K-12 practicing teachers to teach physics with the inquiry-based learning, (2) interactive tutorials as a supplementary material in college, and (3) experiments in laboratory practice. All of these learning strategies are accompanied by structured questions to guide students to develop the reasoning needed in understanding the concept of the objects floating and sinking behavior. These three teachings have been proven effective in developing students' understanding and overcoming misconceptions. However, there are some misconceptions left untouched, such as students' difficulties in analyzing the force on the state of matter [13].

Further research tried to answer the Heron's research limitation by providing a learning method by modeling the Archimedes Principle. In which students are required to create a model by associating previous principles such as Newton's law, pressure, and so forth. The students' difficulties are still apparent, particularly in applying the analytical style in the object's position in a fluid learning by modeling.

By providing an appropriate learning method, students will be helped to understand the Archimedes principle and be able to solve the problem correctly. Learning the problem-solving conceptually in the 5E learning cycle model becomes one alternative to improve students' concept mastery. CPS is a learning approach that aims to train students in solving problems related to physics with a full understanding of the relevant concepts. A conceptual approach to problem-solving is flexibly applicable to various ways of learning (one of them on the 5E learning cycle model) and applicable at the middle school [14]. Referring to the learning model stage, CPS can guide students to identify the principle, justify its use, plan written solutions before solving the problem, and finally solve the problem.

Through this research, we have developed conceptual problem-solving learning on Archimedes' principle topic. The learning method was designed with the 5E Learning Cycle to train the problem-solving process using a CPS approach. The learning process is adapted to the learning objectives, starting with the Engagement, Exploration, Explanation, Elaboration, and Evaluation. This article is intended to describe the research results on increasing student's mastery of the Archimedes principle concept with the CPS learning approach. The result of this research is expected to be a significant finding in the learning solutions to improve the understanding of XI grade students' concepts on the topic of Archimedes Principles.

METHOD

The combination of the 5E learning cycle with a Conceptual Problem-Solving (CPS) approach is used to train problem-solving skills conceptually. The combination of CPS with the 5E learning cycle is used because both have the same characteristics, such as requiring the students to learn particular concepts while solving the problems contextually. 5E learning cycle consists of 5 phases, namely engagement, exploration, explanation, elaboration, and evaluation. In this case, the teaching and learning procedure of the 5E learning cycle model is consistent with the inquiry method to enable the students' independent in learning [15].

The research participants were XI natural science-2 students, with a total of 35 students. The research method used was a mixed-method with embedded experimental design [16]. The research design is explained in Figure 1.

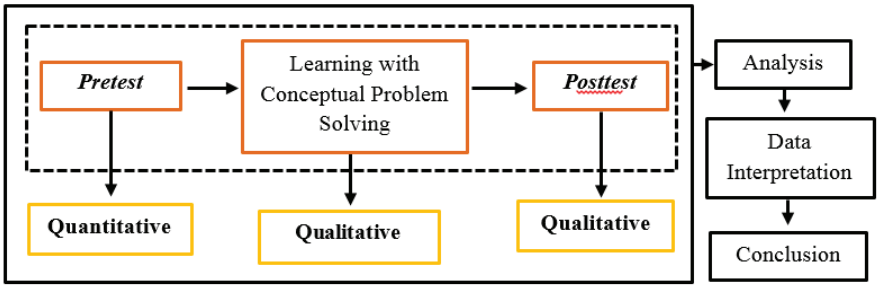

FIGURE 1. Mixed-Method research design with Embedded Experimental Design

The test instrument in the form of multiple-choice questions as much as 10 grains developed with reference to the "Application of the fluid static laws in everyday life" curricula core competence. Pretest and posttest use the same question instrument. Here are the indicators of achievement for each question (Table 1).

TABLE 1. Indicators of Achievement for Each Question

Indicator of Achievement	Question Number
Explain the Archimedes force/upward force/buoyancy force such as the resultant force by fluid pressure on the object.	1, 2
Apply the principle that the magnitude of the buoyancy force is influenced by the volume of objects dipped in the fluid	3, 4
Explain the effect of fluid density on buoyancy	5, 6
Explain the effect of gravitational acceleration on buoyancy	7
Explain the effect of gravitational acceleration on the part of a dipped object in a fluid	8
Apply force analysis to several states of matter in the fluid	9, 10

The instrument was reviewed by an expert to see the validity and legibility. Referring to the statement of Ding et al. that asking for an expert opinion is one of the standard methods in assessing test validity [17]. The instrument was also tested on 84 students and obtained the statistical quantities shown in Table 2. The statistical analysis of the instrument was based on posttest scores, as conducted by Nieminen in his research [18]. Instrument reliability was calculated by Cronbach's Alfa [19]. The result of Cronbach's Alfa value is 0.471 which is categorized "sufficient".

TABLE 2. Results of Instruments Analysis

Different Power			Difficulty Level			Correlation	
Range	Average	Category	Range	Average	Category	Range	Average
0.1 – 0.8	0.42	Good	0.0 – 0.7	0.37	Medium	0.19 – 0.61	0.41

The field research was conducted in several class meetings, the first meeting was a pretest, the next meeting was learning with the combination of CPS and 5E learning cycle stage. At the last meeting, students work on posttest questions. After obtaining the research data, statistical tests are conducted for quantitative data and interviews for qualitative data. Data normality is analyzed from the skewness value in descriptive analysis. After knowing the data normality, a different test was conducted using a paired sample t-test to find out how significant the difference in the pretest and posttest scores. The degree of increase in the pretest and posttest scores was calculated using the d-effect size value. The value category in Table 3 [19]. And then, to strengthen quantitative data, qualitative data analysis is carried out.

TABLE 3. *d-effect Size* Value Category

d-effect size	Category
d >1,00	Greater than the standard
0,51 ≤ d ≤ 1,00	Greater than standard
0,21 ≤ d ≤ 0,50	Standard
d ≤ 0,20	Smaller than the standard

Then the average gain of normalized (N-gain) is used to describe how strong the improvement of students' conceptual understanding by calculating the pretest and posttest scores. The value category in Table 4 is used as a reference. Finally, to see which concepts need to be improved and which concepts have been understood by students, it is necessary to carry out further qualitative analysis to get a better understanding of the learning method.

TABLE 4. N-gain Value Category

N-gain	Category
(g) <0,25	Low
0,25 ≤ (g) < 0,45	Medium low
0,45 ≥ (g) < 0,65	Medium high
(g) ≥ 0,65	High

RESULT AND DISCUSSION

The students' pretest and posttest scores indicated that 21 students (60%) scored above the average on the pretest. The average score of the class for both pretest and posttest are shown by the dotted line. A total of 22 students (62.8%) obtained posttest scores higher than the class average. The average posttest score was 5.54 (SD = 1.33).

TABLE 5. Descriptive Statistics

Statistics	Pretest	Posttest
Mean	2.66	5.54
Standart Deviation	0.97	1.33
Minimum	1.00	2.00
Maximum	4.00	8.00
Skewness	-0.27	-0.65

Test scores on a scale of 1-10

The skewness value at pretest is -0.27 and the posttest is -0.65. Based on the skewness value, the students' concept mastery score at pretest and posttest is in the interval [1.0] so it can be concluded that the data is normally distributed, as described in previous studies [20]–[22]. Furthermore, the data can be examined difference using paired sample t-test and *p-value*=0.00 (p-value < 0.05), therefore it can be concluded that the difference between the pretest and posttest scores is statistically significant [23]. This means that the posttest score is higher than the pretest score so learning with the CPS approach can improve students' understanding of concepts in the Archimedes principle topic.

Then to know the increased score between the pretest to posttest, the d-effect size is used and the result obtained the value of 2.51. The results of these calculations are included in the category "greater than the standard" or “high” based on the categorization [19]. The increase is also found in the average normalized gain (N-gain) with a value of 0.39. The results of the said N-gain value are categorized as “medium” based on the previous studies calculation [24]. There is one student who obtained a “high” gain-value (2.9%), while there are 6 students in “low” category (17.1%), 13 students in “upper-medium” category (37.1%), and 15 students (42.9%) obtained “lower medium” gain-value.

To see which concept needs to be further improved, further qualitative analysis needs to be carried out to get a better understanding of the applied learning method. Diagram pictures presented are intended to find out students' responses during the pretest and posttest, so that the amount of improvement can be directly identified. Student responses to the results of the pretest and posttest can be described in Figure 2.

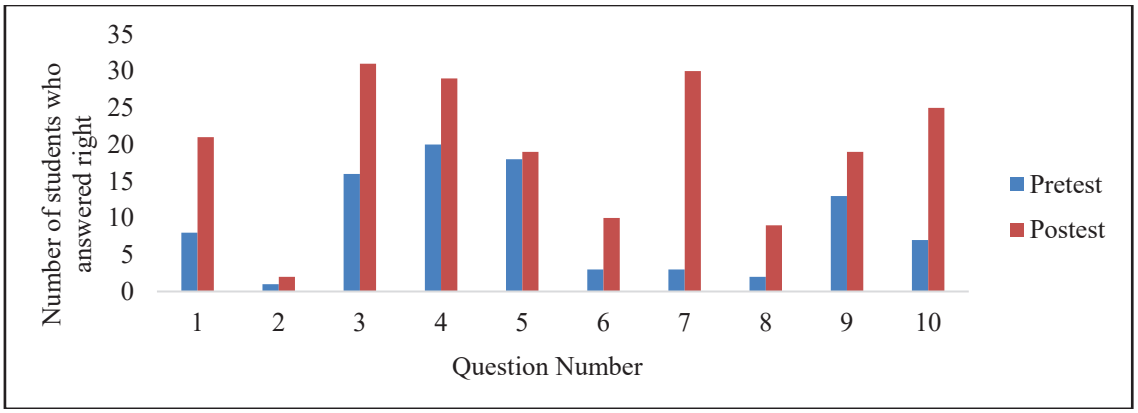

FIGURE 2. Diagram of Number of Students Answering Correctly on Each Problem Item

Based on the diagram above, it is known that there are multiple questions that the students answer correctly in the post-test in comparison to the pre-test by analyzing the scores in between. One of the correct answers is in question number 7. The Problem in number 7 is intended to check students' understanding of the gravitational acceleration effect on buoyancy and explain the comparison of buoyancy on earth and other planets. To be able to explain the comparison, students must first understand the formula of the buoyancy style. Here is question number 7:

A bar is tested on earth and it hovers inside the fluid. What is the buoyant force acting on the bar if the experiment is brought to a planet with a ½ times the gravitational acceleration of Earth's gravity acceleration? (the bar is still hovering in the water)

A. Becomes 1/2 times
B. Becomes 2 times
C. Becomes ¼ times
D. No change

In question number 7, the correct choice of answers is A. At the time of the pretest, the number of students who answered correctly was only 3 students while at the posttest, it increased to 30 students answered correctly. The said result can be seen in Table 6 below.

TABLE 6. Crosstabulation of Students' Answers in Pretest and Posttest Problem no. 7

		POSTTEST			
		A*	**B**	**C**	**Total *Pretest***
PRETEST	**A***	3	0	0	3
	B	14	1	1	16
	C	10	2	0	12
	D	3	0	1	4
Total *Posttest*		30	3	2	35

From the increase in the number of correct answers in question number 7, it can be concluded that students have been able to understand the relationship between lifting force and gravity. In addition to those who answered correctly, five students still answered the wrong options. The teacher tried to confirm the reason why the student was still wrong in answering the question. The following are excerpts of dialogue between the teacher and students who answered incorrectly during the pretest and posttest in question number 7.

T : Son, what do you understand about the effect of gravity on the amount of lift force acting on objects in fluid?
S : Lift force depends on gravity, ma'am. If the force of gravity is in a different place then the lift force is also different, with the same object conditions.
T : Then why did you answer B to question number 7 during the pretest or posttest? Give your reason!

S : I miscalculated, mam. I have compared the F_a on Earth and the F_a on the Moon, apparently I overly focused on number 2 so I answered 2 times. Apparently that is a comparison when on Earth.

T : Fine, so evaluation and reflection after working on the problem are important, son, so there will be no miscalculations.

S : Fine, ma'am. Henceforth, I will be more thorough again. Thank you, mam.

From students' responses to question number 7, it is known that learning about the factors that influence the buoyancy force is successfully understood by students. The teacher presented the problem by giving examples of problems and solving them together with students.

CONCLUSION

Based on the analysis and discussion described in the previous chapter, it is concluded that learning with CPS in the 5E learning cycle can improve the concept mastery among XI Natural Science students in dealing with the Archimedes principle topic. The improvement is indicated by the results of the pretest and posttest. *T-test* results obtained a significance value of 0,00, therefore, the difference in the pretest and posttest scores is significant. The degree of the increase in the pretest and posttest scores was calculated using d-effect size and the results obtained were 2.51 which were included in the category that was greater than the standard limit. The increase through the calculation of the average normalized gain (N-gain) results obtained 0.39, which is categorized as "lower medium". The significant students' improvement is related to their understanding of the effect of gravity on buoyancy and how to determine the buoyancy. While the least improvement is on students' ability to formulate the buoyancy force related to the forces acting on objects in the fluid.

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