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THE STUDY OF STUDENT' DIFFICULTIES IN MASTERING THE CONCEPT OF ARCHIMEDES' PRINCIPLE

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Abstract
The focus of this study is to determine students' difficulties related to mastering the concept of Archimedes Principles topics. The study used descriptive quantitative method with the subject 35 XIth students. The research instrument was 10 multiple choice questions about Archimedes principle. Despite of some improvements, the overall students still do not fully understand the concept of the Archimedes principle. Difficulties among students are failing to understand that the buoyant force is the resultant force by fluid pressure towards the object and still considers the immersed object to have the Archimedes force affected by the depth of the object. When working on the principle application on the given problems, the students managed to answer correctly, but when completing the formulation questions, the students still face difficulties.

Introduction

There are several events in the students' daily life related to the Archimedes Principle, such as diving phenomenons (Thiam, 2017), flying balloons, and boats or submarines (Pisano, 2017). Students generally speculate on the observed events (Saifullah et al., 2017); consequently, the explanations lack scientific evidence (Docktor et al., 2015). The inaccuracy of students' concept due to the limited scientific knowledge is called misconception (NRC), 2001). The stated phenomenon occurs due to inadequate observations and scientific knowledge (Yin et al., 2008). Therefore, it is crucial to study further deeply about the basic understanding of students in various learning topics as what has been performed by following researchers (Lestari et al., 2017; Sutopo, 2016; Taqwa, 2017).

Students' difficulties in understanding the Archimedes principle is indeed a frequent phenomenon (Berek, F.X., 2016; Heron et al., 2003; Wagner et al., 2014). Students think that the fluid quantity in the container affects the buoyancy quantity, meaning that the more water in the container, the higher the buoyancy; thus, the objects with no buoyancy will sink (Berek, F.X., 2016). Some students assume that the higher the floating object's volume, the higher the buoyancy will be (Puspita et al., 2019). Students also did three misconceptions on the topic of the Archimedes principle (Wagner et al., 2014). First, students assume that the effect of Archimedes' force is influenced by the amount of fluid surrounding the object and the surface area of the object. Second, all immersed objects have Archimedes' force, which is influenced by the depth of the object's position in the water. Third,

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Archimedes' force depends on the forces acting on the object. In addition, Loverude et al. (2003) also found some difficulties for students in recognizing factors that influence Archimedes' force (Heron et al., 2003). Those phenomenons are indicated by students' inability in using the formula correctly when they encountered questions that do not involve numbers.

Difficulties of these students will greatly hamper them to achieve the learning objectives (Bouchard & Denoncourt, 2005) and lower student learning interests (Senko & Harackiewicz, 2005) primarily on learning the topic of Archimedes principles. If the mastery of the concepts is lacking, usually students will hardly put interest in learning (Linuwih & Sukwati, 2014), as what can be seen in the comparative studies on Archimedes mastery between students in urban and rural areas (Kusairi et al., 2020). Students' mindset in learning also influences the learning process (Ramadhan & Winaryati, 2016). The referred concept mastery is how students can understand concepts correctly and can apply them in everyday life. If students already possessed a strong understanding of basic concepts, students' errors will also be easily corrected and reflected (Widarti et al., 2016). Therefore, educators need to find out students' misconceptions as a way to design appropriate learning (Resbiantoro & Nugraha, 2017; Yulita, 2018). This research was performed to identify difficulties experienced by students on the topic of Archimedes principles based on previous studies which stated some of the students' difficulties in mastering the concept.

Research Method

This research is a descriptive study using quantitative descriptive methods in explaining research results. The instrument used was ten multiple-choice questions about concept mastery given to 35 students of class XI. Some test questions were adopted from several articles and previous studies. The reliability value of the instrument is 0.471, with the "sufficient" category and the average value of biserial point correlation is 0.412. Reliability was calculated using Cronbach's Alfa (Nieminen et al., 2010). Table 1 below presents a description of the test instrument.

Table1. Description of the Test

The Tested Competences	Test Items Indicators	Question Number
The buoyant force equals to the resultant force force force force by the fluid pressure on the object	Determine the tension of the rope when lifting an object from the liquid	1
	Determine the resultant force on an object in the fluid and its direction	2
The effect of the immersed object volume on the buoyancy force	Determine the ratio of buoyancy by liquid with the different object positions.	3
	Determine the volume of solid objects weighed in air and in water	4
The Effect of fluid density on the buoyant force	Determine the amount of buoyant force when it is on 2 different types of liquid	5
	Explain the effect of fluid density on bouyant force	6
Effect of gravitational acceleration on the buoyant force	Explain the comparison of buoyant forces on earth and on other planets	7
Effect of gravitational acceleration on the part of the immersed object	Determine the effect of gravitational acceleration on the part of the immersed object	8
Force analysis on the state of matter in the fluid.	Explain the phenomenon of steel ships that can float in the sea	9
	Determine the passengers' masses on the water duck boat	10

Results and Discussions

Analysis of students' answers during the multiple-choice test using a scale of 1 to 10. The test was administered after teaching them Archimedes' principle. A total of 22 students (62.8%) scored higher than the class average. The average score is 5.54 (SD = 1.33). The skewness score is -0.65. Based on the skewness value, the students' concept mastery score is in the interval [1.0], so it can be concluded that the data are normally distributed, as described in previous studies by Kim, Rose et al., Doane & Seward (Doane & Seward, 2011; Kim, 2013; Rose et al., 2015).

The number of students who answered correctly did not reach 100%, indicating that there were still students who experienced difficulties on the topic of the Archimedes principle. Furthermore, to find out which concepts are not mastered by students, further qualitative analysis is needed.

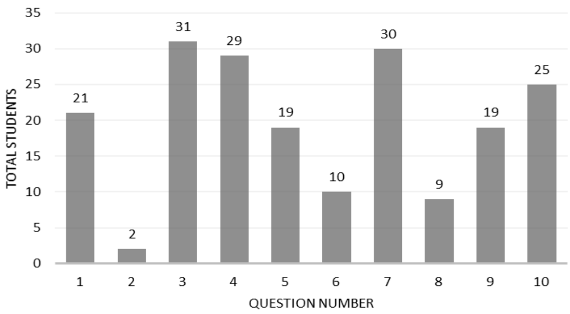


Figure 1. A Diagram Depicting the Number of Students Answering Correctly on Each Question Item

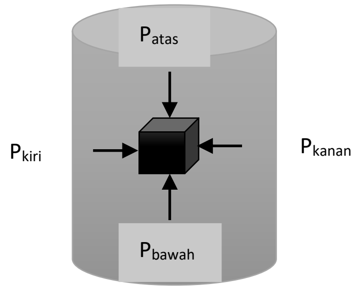
From Figure 1 above it can be seen that there are several questions that most students (more than 50% students) have answered correctly, for example, questions number 1, 3, 4, 5, 7, 9 and 10. However, there are some questions represented by low graphs indicating that less than 50% of overall students could answer it correctly, namely questions number 2, 6 and 8. The most interesting finding from the graph lies in question number 2, in which only 2 students who correctly answer the question, so the question number 2 needs to be studied more deeply along with the students' thoughts when solving the problem.

Question 2

The second problem is intended to figure out the students' comprehension of resultant forces on objects in the fluid. To answer the second question, students must apply the analysis of force that is acting on objects in the fluid so that they can find the result, and understand the law of hydrostatics. See question number 2 below.

A cube is placed in a fluid state as shown in the figure. If the length of the edge is *h*, what is the resultant force on the cube *produced by fluid pressure*? (fluid density = ρ_f)

A. $\rho_f\ g\ h^3$, directed upwards
B. $\rho_f\ g\ h^3$, directed downwards
C. $\rho_f\ g\ h^3$, directed to the side
D. $\rho_f\ g\ h$, directed in all directions
E. Zero



The correct answer to the second question is A. Force due to the fluid pressure on the right and left sides of the cube has the same magnitude and is in the opposite direction, which means that net force is zero. Likewise, on the front and back sides of the cube, the resultant force equals zero because force due to the fluid has the same magnitude and is in the opposite direction. However, the upward pressure applied to the base plane of the cube will be higher than the pressure acting on the plane of the object because of the pressure at each point in the liquid increases with its depth (hydrostatic pressure). The net force acting on the cube due to fluid pressure is called the buoyant force, otherwise known as an upward force which goes in an upward direction. Since the length of the edge is h, the volume and direction go upwards. Two students answered correctly. They have understood the resultant forces on objects in fluid, and also the law of hydrostatic pressure.

Students who answered B and C only understand the resultant forces acting on objects in fluids; however, they lack in understanding the direction of the lift force, which is upward. If students remember that the direction of the lift is always upward, they can quickly eliminate the other answers. However, if they are not careful enough and did not pay attention to the lesson, they might have answered B or C. Nonetheless, there were no students who answered either B or C.

Eleven students answered D, even though it is incorrect. Students whom answer D have understood the theory of fluid pressure (hydrostatic pressure), where the pressure of objects in a fluid depends on its height. However, what is being asked is about the resultant force acting on the object rather than its fluid pressure. So, in this case, D is incorrect. Students who chose D are being tricked because they only pay attention to the word fluid pressure leaving behind the importance of resultant force.

Twenty-two students answered E. It seems that they were fooled by the picture of the direction of pressure on opposite sides of the cube. They assume that because all pressure goes in the opposite direction, which means that the force resultant is zero. The result shows that they did not get a good grasp of this theory. Through interviews conducted with students, it is found that they do not understand the resultant forces acting on objects in the fluid, nor do they apply the knowledge of hydrostatic pressure that has previously been taught. Even though during the discussion, the students were able to figure out the formula, they still had difficulties in answering the questions. The following are the results of the interview with students who chose E.

Teacher: Why did you answer E for the second question?
Student: Because the object is in a stationary position and there are pictures of pressure directions that are all opposite directions which mean that the resultant value is zero, Maam.

From the interview, it appears that students are correct in clarifying how forces act on objects in the fluid. However, they fail to understand that the pressure at the base and the upper side of the object is not related to the hydrostatic law, which says that the higher the depth the greater the pressure. It seems that once again, students were fooled by the picture of the directions, and they thought that the resultant force is zero because they are opposite directions.

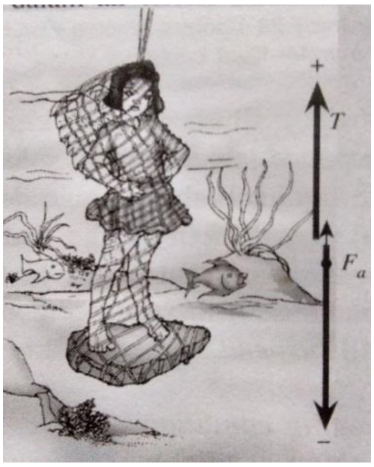
In applying this kind of problem, there are times where students can easily do it. Nevertheless, other times, if let us say that the questions are in the form of formulas, students have difficulty in answering, just like in question number 2. As a reinforcement, on the questions with the ability tested the same as those presented in table 1, "The buoyant force is the same as the resultant of the force by fluid pressure on objects" shown in problem number 1, students are more likely to answer correctly.

Question 1

Problem number 1 is intended to test the students' comprehension of the resultant forces on objects in the fluid. Students are asked to figure out the tension of the rope when lifting an object from the liquid. To answer question number 1, students must apply force analysis that works on objects in the fluid so that they can determine the result and understand the Archimedes principle equation.

A golden statue will be lifted from a sinking ship using a rope slowly at a constant speed. If the mass of gold is 5 kg, what is the tension of the rope if the statue is still in total sea water?
(density of sea water ρa = 1 x 103 kg/m3, density of gold ρb = 10 x 103 kg/m3, g = 10 m/s2)

a. 35 N
b. 40 N
c. 45 N
d. 50 N



The correct answer to question number 1 is C. 21 students answered correctly. To answer this problem, students must be able to find the formula for resultant force, and once they have figured it out, they can find the answer. Additionally, they also need to keep in mind the theory of the lift force.

From the discussion of the two questions above (questions number 2 and 1), it shows that in one indicator of the problem, students found it easy to answer questions involving calculation problems. However, if the questions are in the form of formulas, students had a hard time figuring it out. In several previous findings, it was stated that students 'mathematical abilities do indeed affect students' understanding of abilities in physics (Hudson & McIntire, 1977; Meltzer, 2002).

The difficulty that students encounter was similar to the findings by Wagner et al. (2013), which is that students still consider immersed objects to have an Archimedes style that is influenced by the depth of the objects (Wagner et al., 2014). Moreover, another previous study by Loverude, Kautz & Heron (2003) stated that students found it challenging to recognize factors that influence Archimedes' styles, including the forces acting on objects (Heron et al., 2003). This analysis of students' difficulties in mastering concepts, will help educators design a better approach to teach students and help students in understanding their lessons so that they avoid any confusion. Additionally, this will help in creating a more effective learning strategy so that students will not find it difficult (Thompson et al., 2011), One example of that is by implementing the Conceptual Problem-Solving approach in the 5E Learning Cycle (Diyana et al., 2020). Then, in order to identify the difficulties found by students, there certainly needs to be other aspects of mutual learning in addition to these learning techniques (Elisa et al., 2019).

Conclusion and Recommendation

Conclusion

Based on the studies results of students' difficulties in mastering Archimedes's concept, it can be concluded that students' mastery has increased, but there were still minimal improvements on several numbers. Students still face difficulties in understanding the formulation of the resultant force on immersed objects. While with the same problem indicator, students succeed in working on problems involving calculations. Thus, indicates that there is a relationship between students' mathematical abilities and understanding of physics. Furthermore, students still have difficulties when completing questions requiring formula calculation.

Recommendation

The results of the study of students' difficulties in understanding the Archimedes principle concept can be used as a basis in developing an appropriate Archimedes principle learning strategy by adding reinforcement of concepts for example through problem solving, inquiry and other learning. So students are easier to master the concepts.

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