JTET

http://penerbit.uthm.edu.my/ojs/index.php/jtet
ISSN 2229-8932 e-ISSN 2600-7932

Journal of Technical Education and Training

Understanding Archimedes Law: What the Best Teaching Strategies for Vocational High School Students with Hearing Impairment

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DOI: https://doi.org/10.30880/jtet.2020.12.01.024
Received 26th December 2019; Accepted 03rd February 2020; Available online 31st March 2020

Abstract: The purpose of this study was to demonstrate strategies in teaching the Archimedes law in the concept of floating, hovering, and sinking using egg as a model to students with hearing impairment (SHI). This study used a single-subject design with pre-test and post-test. The subjects of this study were three students with SHI at the Bandung Vocational School, Indonesia. Teaching was delivered using several methods, in which we used and compared "conventional teaching method" and "combination of conventional method and experimental demonstration". The conventional method was done by giving lectures, question and answer, and assignments. The experimental demonstration was carried out by doing experiment and observing the eggs that were sinking, hovering, and floating. The results showed that the conventional teaching method was ineffective. Students with SHI found it difficult to understand an abstract concept because they have problems in auditory perception. However, when combining experimental demonstration supported with media, the difficult subjects could be taught to students with SHI. The reason for achieving successful teaching was because the experimental demonstration method improved students' focus, helping students with SHI to easily understand the subject matter. This study also gives idea that the teacher must choose visual learning methods and media to make them as attractive as possible. Indeed, understanding the Archimedes law is important for students to understand advanced subjects related to the Archimedes law in vocational school.

Keywords: Students with Hearing Impairment (SHI), The Archimedes Law, Vocational School, Teaching Methods, Experimental Demonstation

1. Introduction

Learning science is very important to do in vocational school because it has the aim to develop students' information and competencies (Lytvyn et.al, 2020). To support science learning, some laws are taught, such as Newton's law, mechanics,

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density, fluid dynamics, etc (Hudallah & Suryanto, 2017). One of the important laws is the Archimedes law. The Newton law was taught in vocational school before studying the Archimedes law (Nurahman et.al, 2019).

The Archimedes law is one of the subjects studied at the vocational school. The Archimedes law discusses the concepts of floating, hovering, and sinking (Soeharto et.al, 2019). The Archimedes law involves a basic science material, which is necessary for more complex science material (Adam & Suprapto, 2019). We often apply the concept of the Archimedes law to various purposes. For example, when we create a toy boat, the Archimedes' concept supports in making the boat floating on water.

Currently in Indonesia, the Archimedes law was found in the high school and vocational school curriculum. Vocational students required to have creativity, innovative, and productive (Harth & Panke, 2019). Vocational school graduates must have expertise to produce products. The products must be marketable and have high economic value opportunities. Thus, we must pay attention to the learning methods for teaching the Archimedes law. Learning method affects the level of student understanding. Taqwa & Rivaldo, (2019) explained about the multi-representation method used in learning the Archimedes Law for improving students' mental model. McKee & Czarnecki (2019) explained the methods for discussing, questioning and answering, and doing experiments to teach the concept of buoyancy in the Archimedes law. Adam et.al (2019) described a method with virtual laboratory features for delivering the Archimedes law. But, the above methods were used only for normal students. Almost no research discusses how to teach the Archimedes law to students with special needs. One of them is students with hearing impairment (SHI).

When teaching students with SHI in vocational school, many problems are encountered. Many factors affect student learning processes both external and internal factors (Gray et.al, 2019). Students with SHI find it difficult to understand abstract concepts. They have difficulties in communication for understanding the information conveyed. Thus, it gives an impact on the students' academic aspects. They gain new knowledge through the visual senses. The other factor is the teacher's knowledge that is still limited, lack of creativity, and less innovation in the teaching process. Most teachers do not believe for the ability of students with SHI to receive high order subjects (Werfel & Reynolds, 2019). Indeed, this gives an impact for teaching science since science is quite complicated. That is why reports on teaching science for students with SHI are rarely found because researchers have difficulties in dealing with the characteristics of students with SHI. Thus, special method and media that are simple, concrete, and interesting in the teaching process must be added.

Therefore, the aim of this research was to find out the appropriate method used in teaching the Archimedes law in the concept of drowning, hovering, and floating using eggs as models for students with SHI. We compared the effectiveness of teaching using conventional methods and experimental demonstrations. We believe that this study can create more advanced techniques to improve the strategies for teaching students with some disabilities.

2. Theoretical Explanation

2.1 Theoretical of the Archimedes law

Figure 1 shows an illustration of objects inside the medium allowing the Archimedes law. The Archimedes law is the law stating that for every object immersed in whole or in part in a fluid, the object receives an upward force (or buoyancy force). The amount of buoyancy force is equal to the weight of the water displaced by the object ($W = m \, x \, g$; where W is the weight of the object, m are the mass of the object, and g are the Earth's gravity (9.807 m/s^2)). This force has the opposite direction with the weight force (direction of W is downward whereas direction of buoyancy (Fa) is upward).

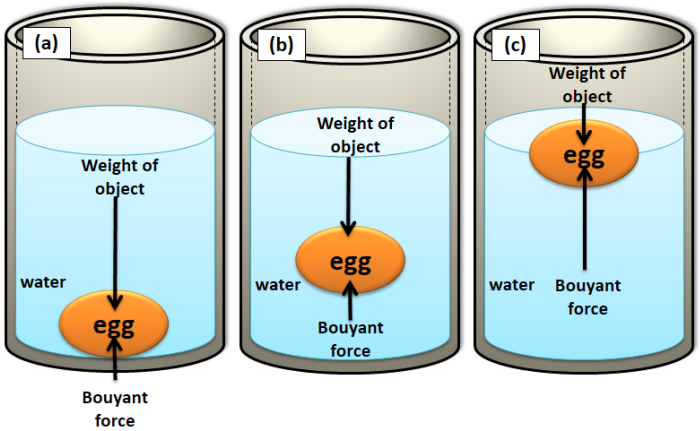

Fig. 1 - Illustration of Archimedes law; (a) sinking objects, (b) floating objects, (c) floating objects

Figure 1 (a) illustrates an object submerged in water because *W* is greater than *Fa*. The formula equation can be written as follows:

$$W > Fa \quad (1)$$

Figure 1 (b) illustrates an object floating in water because *W* is as large as the *Fa*. The formula equation can be written as follows:

$$W = Fa \quad (2)$$

Figure 1 (c) illustrates an object floating in water because *W* is smaller than *Fa*. The formula equation can be written as follows:

$$W < Fa \quad (3)$$

The difference between *Fa* and *W* is the net force on the object. The net force could be neutral (zero), negative, or positive. The object floats if the net force is positive. The object sinks if the value is negative. Then, the neutral buoyant can bring the object to be either floating or sinking.

Explanation of the Archimedes law is important in vocational systems. The learning process for vocational students is always associated with innovation in a tool-making technique. One of the applications from the Archimedes law is shipbuilding (Dang, Phan, & Ahn, 2019). The weight of a floating object (static) must be equal to the weight of the volume of water that is displaced by the object. This law of buoyancy explains the object to be able to move on water or not. When an object is heavier than the amount of the fluid, it releases in water and the object sinks.

For regular students, it is generally very easy to understand the Archimedes law. They understand that there are 3 concepts of the position of objects in water that are influenced by forces namely, sinking, hovering, and floating (Leble, & Barakos, (2016). However, this cannot be explained to students with SHI. They need a long time to digest the explanation from the teacher. They need simple media and special methods to understand every matter.

2.2 The phenomenon of learning the Archimedes law

The curriculum in vocational schools required vocational learning for students. Students have to get special expertise and provision after students graduate from school. Vocational students must learn how to design a boat, and in the advanced course, they combined with a motor to create a dynamo boat. In order for the toy boat to float on water, the concept of Archimedes' law must be applied. In calm water settlements, there are always many practical styles working on the boat or ship.

To simplify the process for explaining the Archimedes law, we used eggs as the model of floating object. We put eggs the glass filled with water. The students have new experiences with experimental demonstrations to learn the Archimedes law. Students observe the eggs inserted into a measuring cup containing 500 mL of water. We added some salt in some glasses to assume the realistic condition for water. Students observe what the position of the egg in the glass. The positions of eggs were then compared with the Archimedes law where every object that enters the water receives buoyancy force (*B*). The equation of the magnitude of the buoyancy force with the formula of the Archimedes law is

$$B = P_{water} \times g \times V_{transferred\ water} \quad (4)$$

where *B* is the buoyancy force and P_{water} is the water density. $V_{transferred\ water}$ is the volume of water moved by the immersed object.

The eggs in the glass sink because the mass of the object is greater than the mass of water. In addition, we gave the lesson for students that the buoyancy and gravity also affected the position of objects. Then, we also compared to the mass of objects, and condition of water (density and number of salt).

3. Methodology

3.1 Research subjects

This study used a single-subject design with pretest-posttest. We delivered the Archimedes law for giving understanding the concepts of sinking, hovering, and floating objects. The study participants were three students with SHI in Vocational School in Bandung, Indonesia. This school was a public school where there were students with special needs. In other words, students with SHI were in the same place as students in general during the teaching and learning process. Teaching was delivered using a conventional method. Then, to improve student understanding, we conducted teaching with simple experimental demonstrations.

In addition, to get basic information from students (such as IQ levels, demographic information, and their basic knowledge abilities (i.e., mathematics, social science, natural sciences, Indonesian, and Islamic religion)), interviews with school teachers were conducted. The data collected were then used to develop research instruments. To simplify the analysis of student ability levels, all information were assessed using a score of 5 on a scale of 0 (do not know anything), 1 (not good), 2 (not good) 3 (good enough), 4 (good), 5 (very good).

3.2 Teaching method

For the teaching process, we used conventional method in the first session. Then, it is followed by experimental demonstration. Each session was done and completed with pretest and posttest. Detailed information for the teaching process and its duration is shown in Table 1.

Table 1 - The process of collecting data

Method	Session	Duration	Pretest	Posttest
Conventional Method	1	60	10 minutes early in the learning process	Last 10 minutes in the learning process
Experimental Demonstration	2	60	10 minutes early in the learning process	Last 10 minutes in the learning process

3.2.1 Conventional teaching method

During this method, we explained the Archimedes law through lecture, question and answer, and assignment. Learning was carried out for 60 minutes only using chalk and talk method.

3.2.2 Experimental demonstration

We applied the experimental method in learning the Archimedes law for students with SHI. The learning was carried out for 60 minutes. Previously, the teacher explained the Archimedes law, of benefits, and materials used to carry out experiments. In the experimental demonstration, we used several tools and materials as a concrete media. Students with SHI participated actively in preparing the tools and the materials for the experiments.

We used eggs, salt, measuring cups, water, and spoons. First, we poured 500 mL of water into each measuring cup. We prepared 3 types of cups. The first cup was only water (Glass X), the second was water with some salt (Glass Y), and the third was water with large amount of salt (Glass Z). After that, we put 2.5 spoons of salt into a measuring cup, filled with water into Glass Y. We also prepared 5 spoons of salt (added with water) into Glass Z. We stirred the solution and put the eggs in each glass. Students were asked to observe and compare the different position of the eggs in each glass.

To get information about students' understanding during the experimental demonstration, the teaching process was completed with a pretest and posttest (through interviews). We gave nine questions about the Archimedes law and the concept of sinking, hovering, and floating with three repetitions. Similar to the conventional teaching method, each question gave to students after the experimental demonstration has a maximum score of 5. Thus, student who can answer nine questions perfectly gets a maximum score of 45.

3.2.3 Teaching assessment

To ensure students' level of understanding during the teaching process, tests on the Archimedes law in the concept of sinking, hovering, and floating were given to students with SHI. Table 2 shows some questions related to the Archimedes law given to students. As a model, we asked nine questions. We compared the results of the teaching process with additional experimental demonstrations (W) and without (W0) experimental demonstrations or with conventional method.

For evaluating the effect of teaching method, we did a pretest to students by giving nine questions in the first 10 minutes of teaching (both conventional method and experimental demonstration). Then, after teaching process, we did a posttest by giving the same nine questions in the last 10 minutes. Each question was repeated three times. Each question

has a maximum score of 5. When students answer 9 questions perfectly, the maximum score obtained is 45. The correct answers were then calculated using

$$\text{Score \%} = \frac{\text{score obtained by student}}{\text{maximum score}} / \text{x100\%}$$

For example, when students have 6 correct answers, students get a score of 30. Then, this value was then divided by the maximum score. Thus, we get the percentage score = $\frac{30}{45}$ / x100%= 67%.

Table 2 - Scores obtained from learning with conventional methods and experimental demonstration

No	Question	Student A		Student B		Student C	
		W0	W	W0	W	W0	W
1	What is the Archimedes law?	0	3	0	3	0	2
2	What happens if the weight of the object is lighter than the specific gravity of the water?	0	3	0	3	0	2
3	What happens if the specific gravity of the object is heavier than the specific gravity of water?	0	3	0	3	0	2
4	What happens if the specific gravity of the object is balanced with the specific gravity of water?	0	3	0	3	0	2
5	What makes the density of water increases?	0	3	0	3	0	2
6	Why does the egg sink?	0	4	0	4	0	3
7	Why do eggs float?	0	4	0	4	0	3
8	Why are the eggs floating?	0	4	0	4	0	3
9	What is the formula for looking for buoyancy and gravity of matter?	0	3	0	4	0	3
	Score	0	30	0	31	0	22

*Note: W0 = without experimental or conventional method, and W = Experimental demonstration

4. Results and Discussion

4.1 Student demographics

Demographic data of students with SHI is shown in Figure 2. There are five information displayed from students aged 16 to 17 regarding the diagnosis of students with SHI such as the diagnosis of hearing loss, the ability of students to use sign language, the ability to speak to convey information, the ability to understand information, and motor skills. This information is needed to understand the level of intelligence of students with SHI, which have an impact on student understanding.

Students A, B, and C have level 1 for hearing loss, meaning that the level of hearing is not good. In the aspect of the ability to use sign language students A and C are at level 2 or not good. Meanwhile, student B is at level 3, which is the use of sign language B good enough. Students A, B, and C on the aspect of speaking ability convey information at level 2, which means it is not good. This is because interference with the hearing aspect affects the acquisition of the language used (Ellis, 1996). In the aspect of the ability to understand information, students A and B are at level 3, which means that A and B students are good enough to understand the information conveyed by others. Student C is at level 2, informing that student C has inadequate abilities in aspects of understanding information conveyed by others. In the motor skills aspect, student B is at level 4. Students have good gross motor skills and fine motor skills. This is one of the factors that cause the ability of sign language B quite good because it is related to kinesthetic visual coordination. Meanwhile, students A and C have gross motor skills and fine motor skills at level 3 or good enough.

From previous observations, the level of student ability has been explained. If the classification from high level to lowest level is done, we concluded the sequence is Student B, A, and C.

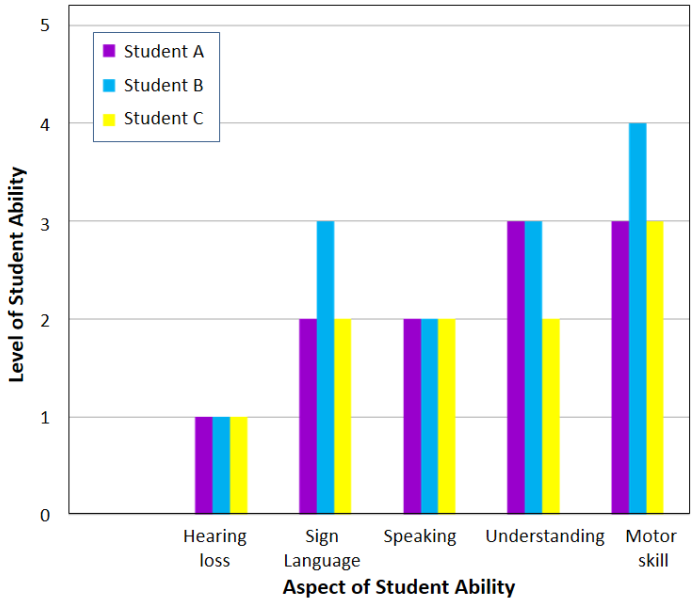

Fig. 2 - Student of Conditions

Figure 3 shows the level of knowledge students in understands the subject learning in the vocational school. There were five subjects observed, namely Indonesian language, social science, science, Islamic religion, and mathematics. This information is very important in knowing students' readiness to participate in learning.

Each student has different characteristics. Student A and B have more interests in social science and natural science subjects than other subjects. Student C who has less understanding than others shows interests in mathematics and religion. However, student A, B, and C do not like learning Indonesian. The results confirmed that interests from one subject to another seem to stem from curiosity and student satisfaction. Data from Figure 3 can be used as a basis to determine the level of intelligence and evaluate the best teaching method.

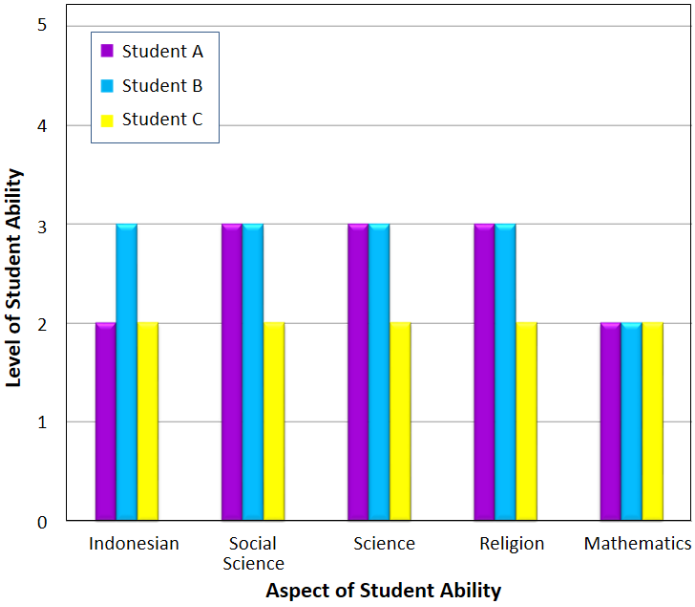

Fig. 3 - Levels of Student Understanding of Aspect Knowledge

4.2 Teaching process

Based on the demographic data above as well as the communication skills and the basic knowledge of students, we found the complexity in teaching students with SHI to get good academic achievement.

Comparison of teaching strategies can be explained in Table 2. The results showed that the first 60 minutes in the learning process was carried out using the conventional method. In the initial teaching step, we gave students' knowledge of the basic concepts what object is sinking, hovering, and floating. We also demonstrated why this concept is important, which can be found when making boat. We explained the need for selecting good material as well as designing object properly when making boat. However, students still confused when we asked questions. Almost all questions cannot be answered by students. Students just kept quiet and looked at their peers. Although the questions were repeated three times, students were still confusing.

In the next session, we did the teaching with the experimental demonstration. When we started doing simple experiments, students begun to be interested, giving their attention with enthusiasms. Specifically, when students tried to put salt in a glass and stirred it. Students observed eggs that were sinking, hovering, and floating. In short, each student was asked to pour 500 mL of water into a measuring cup. After that, students were asked to put two spoons of salt into glass Y and five spoons in glass Z. Then, students were asked to stir and put eggs in each glass. Students A and C did the instructions quite well even though the teacher had to repeat the instruction three or two times. This is where an interactive learning process occurred and students understood the concept of the Archimedes law. A simple additional experimental demonstration increased the level of student understanding, compared to conventional teaching with the lecture method only. The results showed that the way of teaching suits students' needs and are very effective for increasing students' understanding.

In the posttest after experimental demonstration, we found that almost all students can answered every question correctly. Students seemed enthusiasm in the learning process, and students' understanding of the Archimedes concept increased. This was because the experimental demonstration method is equipped with concrete media to help students with SHI and to get more easily understand the subject matter.

Student A received a score of 30 or approximately 67% of the maximum score. Most of the questions were answered correctly by student A. Student B received a higher score than student A. Student B received a score of 31 or approximately 69% of the maximum score. Meanwhile, students C initially did not understand about the Archimedes law and its applications. The level of understanding of students C is still less than 50%. However, we found that learning with the experimental demonstration improve students' understanding. This can be seen from the acquisition of a score that was initially 0 (pretest) increased to 22 (posttest) or approximately 49% of the maximum score. Although the score obtained by student C is not as high as students A and B, there is an increase in understanding. This might be due to the lack of ability of C students to receive and convey information during teaching process. This is confirmed by the fact that student C has difficulties in conveying and receiving information communicated by the teacher and has poor academic ability compared to student A and B (see Figures 2 and 3).

The results showed that with learning using experimental demonstration the level of understanding of students with SHI can increase. This is the same results with other reports (Nandiyanto et.al, 2018).

4.3 Qualitative analysis

In the conventional method, we gave the nine questions on pretest for students with SHI. When we asked "who knows about the Archimedes law?" students A, B, and C confused and they did not answered the questions. We repeated the question three times, but they answered only "Aaaa...iii .... archi, miss" and they used sign language. The conventional methods made students with SHI to be passive. In the last 10 minutes, we did a posttest by giving the same nine questions, but students still not answered the questions.

In the first 10 minutes of the experimental demonstration, we conducted a pretest. Students still not answered the pretest questions. After that, we did a teaching demonstration experiment. Students A, B, and C seemed enthusiastic in the learning. We asked students with SHI to prepared tools and materials. They answered "Ok Miss" with enthusiasm and cheerfulness. After the experimental demonstration, we gave posttest. Students answered all questions correctly. Although, the level of students' comprehension C is lower than students A and B. When we asked the question "Why do eggs sink?", Student A answered "eggs sink because the mass of the egg is greater than the mass of the water". Student B answered "the mass of the water is smaller than the mass of the egg, it was resulting in the egg sinking, Miss", while student C answered "Yes Miss, the egg sink due to different mass" with hesitation. All questions answered using sign language. The enthusiasm of students C was not as high as students A and B. The main reason is the level of intelligence and student's interest to science subjects (See Figure 3).

4.4 The contribution of study the Archimedes law

The Archimedes law is very important since it is contained in the curriculum in vocational school. The Archimedes law has various benefits and this law is classified as the main basic science which will be applied for more complex subject. Indeed, increasing students' knowledge about the Archimedes law can bring benefit for advanced science in the next course.

5. Conclusion

Experimental demonstration is a normal practice in teaching learning. This study demonstrated experimental demonstration, in which this is different from other studies. We conducted experimental demonstrations to students with SHI with the aim to find out the best teaching strategies for making them more comprehension. As we expected, the experimental demonstration improves student comprehension. We believe that this study can bear more researches for gaining better teaching strategies to students with disabilities.

Acknowledgements

We thank to Sekolah Pasca Sarjana, Universitas Pendidikan Indonesia, for supporting this research. We also thanked to teachers of vocational school in Bandung, Indonesia for assisting this experiment. ABDN acknowledged RISTEK BRIN for grant Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT).

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