

Developing students' learning achievement and experimental skills on buoyancy and the involvement of Newton's third law through an experimental set

Jaewijarn Chokchai^{1,2,3}, Toedtanya Khanti¹ and Wuttiprom Sura^{1,3}

¹ Department of Physics, Faculty of Science, Ubon Ratchathani University, Thailand

² Hatyaiwittayalai school, Hatyai, Songkhla 90110, Thailand

³ Thailand Center of Excellence in Physics, Thailand

E-mail : sura.w@ubu.ac.th

Abstract. The purposes of this research were: to construct packages of operations on buoyancy and the involvement of Newton's third law, to enhance achievement score of students on buoyancy and the involvement of Newton's third law, to enhance experimental skills on buoyancy and the involvement of Newton's third law and to evaluate students' attitude towards the packages of operations on buoyancy and the involvement of Newton's third law using inquiry method. The samples were 42 grade 11 students in academic year 2016 at Hatyaiwittayalai School, Hatyai, Songkhla. The research method was one group pretest-posttest design. The research tools consisted of an experimental set on buoyancy and the involvement of Newton's third law, the learning achievement test on buoyancy and the involvement of Newton's third law and the students' attitude questionnaires. The experimental skills of most students was in a good level. The satisfaction of most students was in a good level. The research showed the learning achievement after instruction higher than that before instruction using experimental set at the significant level of 0.05 and the class average normalized gain is in the medium gain.

1. Introduction

Over 2200 years ago, in order to determine the purity of a golden crown of the king of Syracuse, Archimedes submerged the crown in water and determined its volume by measuring the volume of the displaced water. This simple experiment became the foundation of what eventually became known as Archimedes' principle [4]. The buoyant force is equal to the weight of the displaced water. Some acquaintances have always thought that buoyancy force only acts upwards but in reality, the action force which directed upwards is always equals to the reaction force directed downwards, relating to Newton's third law of motion [2]. An excellent demonstration of buoyancy and Newton's third law can be done with a balance and a beaker of water. By placing the beaker on a balance, leveling the balance, and asking students to predict what will happen if a finger is placed in the water [1]. The experiment of J Agostinho Moreira and his team resulted in the setting up of experimental demonstration set, which consists of 2 scales, in the interest of finding the buoyancy force, accordance to Newton's third law [5]. Published literature in physics education has covered the topics of buoyant force and the readings on the balance quite extensively [3]. In order to convey the process of studying buoyancy and the involvement of Newton's third law to have a variety of approaches and engenders pertinent values, researchers have designed this experimental setup.

2. Methodology

The purposes of this research were: to construct packages of operations on buoyancy and the involvement of Newton's third law, to enhance achievement score of students on buoyancy and the involvement of Newton's third law, to enhance experimental skills on buoyancy and the involvement of Newton's third law and to evaluate students' attitude towards the packages of operations on buoyancy and the involvement of Newton's third law using inquiry method. The samples were 42 grade 11 students in academic year 2016. The research method was one group pretest-posttest design. The research tools consisted of experimental set on buoyancy and the involvement of Newton's third law. In grade 11 student's curricular activity, which aims to enhance the knowledge of buoyancy force and Newton's third law, the researchers initiated by asking questions to test the understanding and stimulated the interest in learning. According to figure 1. by Paul Hewitt, shows a teabag being dropped into a cup. Then let the students queried for if the weight of the cup changes, and why. Conforming to the investigation, a majority of students acknowledged that the weight of the cup increased coherent to the weight of the teabag. The researcher now perceive that students still misunderstood the mechanic of buoyancy force. Thenceforth, the researcher demonstrates that the weight increased was not associated with the object dropped into the cup. This experiment was adapted from the experiment by J Agostinho Moreira and his team, figure 2.

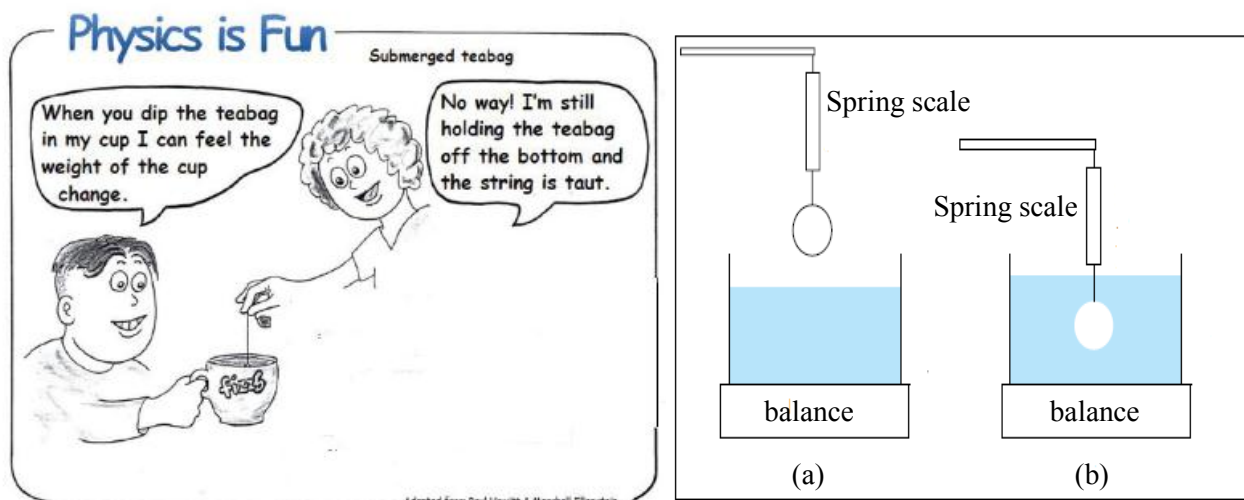


Figure 1. Paul Hewitt's "Figuring Physics" challenges. Figure 2. J Agostinho Moreira's Experimental.

The experiment features an object tied to the spring balance, the students then first observe the weight of the object in air. Next, the object is dropped into a beaker containing water which is situated on a digital scale. The students then inspect the increased weight, which is not analogous to the weight of the object. However, the interpretation is the difference between the weight of the object in air and the object submerged in liquid, this is the buoyancy force (F_B).

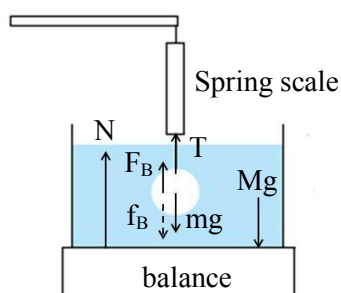


Figure 3. free body diagram



Figure 4. Experimental setup

Afterwards, the students were asked to draw the free body diagram of this experiment, highlighting the submerged object and the digital scale. Then, take note of the students drawing, the key is relevant to figure 3. The letter “m” represents the mass of the object, M is the weight of the liquid and container, N is the reaction force from the balance, f_B is the reaction force of the buoyancy force.

Trailing the student basic understanding of buoyancy force and free body diagram, the students then advance to the researcher’s experimental set up. The instruments are made from the application of common objects, including a plastic bottle with the diameter of 13.5 centimetres, a plastic ruler of 30 centimetres, an analogue scale with the maximum of 30 newton, a spring balance, a pulley, dishwashing soap and a cylindered buoyant object with unknown density. To begin, set the equipment according to figure 4. After that, the student then draw a free body diagram of this experiment. Subsequently, the student will have to applicate this set up to discover the density of the liquid and the cylindered object, also to discern the relation between the acquired weight measurement of the scale and the tension force of the string. The data is collected from the spring balance (T) and the difference in the height of the liquid (Δh), to be analysed as a graph for further calculations of unknown variables.

3. Results

After using the experimental set, the experimental skills of most students was in a good level. The satisfaction of most students was in a good level. The research showed the learning achievement after instruction higher than that before instruction using experimental set at the significant level of 0.05 and the class average normalized gain is in the medium gain.

4. Discussion

Students’ free body diagram matched with experiment that adapted from J.Agostinho Moreira and team. The force is differentiated into sub-force that acts on the submerged object and others acts on the bottom of the container and scale. As a result, many students drew the diagram incorrectly. Mostly their mistakes were positioning wrong direction the buoyancy force on the bottom of the container. This led to the miscalculations of the total force. After showing the correct free body diagram, a majority of students were surprised by the fact that there was a force that acts on the submerged object in upwards direction and also the force was equivalent to the buoyancy force. It could be explained that the force was the reaction to the action force with Newton’s third law. The forces can be displayed by separating and analyzing the force for each mass, as follows.

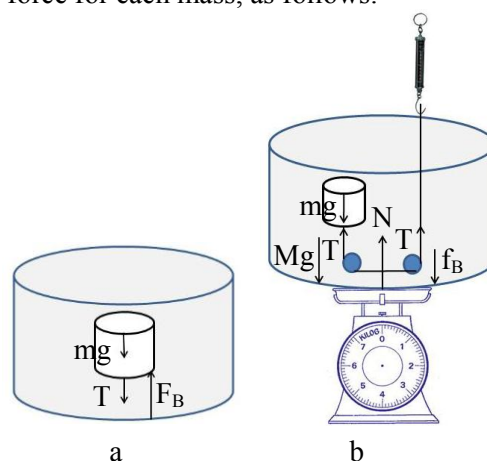


Figure 5. Free body diagrams of the force

The buoyancy force in figure 5(a) can be written by considering the direction of forces.

$$F_B = mg + T \tag{1}$$

Considering the force acts on the bottom the container concordance to the scale as figure 5(b)

$$N + T + T = f_B + Mg \quad (2)$$

From the relevance, we substitute the equation (1) in equation (2).

Then we know that f_B equals to F_B . The normal force can be expressed as follow.

$$N = F_B + Mg - 2T$$

$$N = mg + T + Mg - 2T$$

$$N = (m+M)g - T \quad (3)$$

From equation (3) it can be observed that the relevance between the weight measured from the scale (N) and the rope tension (T) is inversely proportional. If the rope tension force is high, the measured weight from the scale is relatively low. The equation corresponds to the experiment which was completed by the students. This proves that applying Newton's third law on drawing free body diagram, can maximize the accuracy of experimental results. To attain the value of density by analysing the graph between the difference in the height of the liquid and the rope tension force, is through this equation.

$$T = F_B - mg$$

And from the relation of buoyancy force in agreement with Archimedes' principle, we get the following equation.

$$T = \rho_L V_s g - mg$$

Note that ρ_L is the density of the liquid and V_s is the volume of the submerged part of the object. From the relation between the submerged part and the increased height of the liquid, both are equivalent, which brings about this equation.

$$V_s = (A-a)\Delta h$$

A is the surface area of the cross-sectional area of the liquid container.

a is the cross-sectional area of the cylindered object submerged in the liquid.

Δh is the difference in the height of the liquid, which led to this equation.

$$T = \rho_L (A-a)g\Delta h - mg \quad (4)$$

Consecutively, the graph is plotted between Δh and T. The inclination value is $\rho_L (A-a)g$. The inclination is used to calculate ρ_L with the Y-axis intersection as mg, the result is this relation. V_o is the volume of the object.

$$m = \rho_o V_o$$

ρ_o could be obtained.

5. Conclusion

By questioning and setting experiment for students, the result shown that the students had got more understanding about free body diagram, buoyancy force and Newton's third law.

Acknowledgments

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