Jurnal Pendidikan Sains
Volume 7, Number 1, March 2019, pp. 29–34

Students' Conceptual Errors on Hydrostatics Pressure and Bouyancy Theory

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Abstract: The purpose of this study is to describe the conceptual error of high school students about the hydrostatic pressure and buoyancy. The design of this research was descriptive. Data were collected through multiple choice tests of four questions. The test was given to 64 high school students who had taken static fluid material. The test results were analyzed using percentage techniques. The results showed that the highest error experienced by students was in applying the concept of hydrostatic pressure (as much as 90.63% of students) followed by errors in analyzing the relationship between buoyancy force and the volume of objects immersed (as much as 87.50%). To sum up, two major misconceptions of students are about the notion that the hydrostatic pressure is influenced by the closed container and the volume of water and the buoyancy is proportional to depth and inversely proportional to the volume of the immersed object.

Key Words: buoyancy, error, hydrostatic pressure

Abstrak: Tujuan penelitian ini untuk mendeskripsikan kesalahan siswa SMA tentang konsep tekanan hidrostatik dan gaya apung. Desain penelitian ini adalah deskriptif. Data dikumpulkan melalui tes pilihan ganda sebanyak empat soal. Tes diberikan pada 64 siswa SMA yang telah menempuh materi fluida statik. Hasil tes tersebut dianalisis menggunakan teknik persentase. Hasil penelitian menunjukkan bahwa kesalahan tertinggi siswa adalah dalam menerapkan konsep tekanan hidrostatik (sebanyak 90,63% siswa) diikuti dengan kesalahan dalam menganalisis hubungan antara gaya apung dan volume benda tercelup (sebanyak 87,50%). Simpulan penelitian adalah kesalahan konsep tekanan hidrostatik yang dialami siswa, yaitu tekanan hidrostatik dipengaruhi oleh wadah tertutup dan volume air. Kesalahan konsep gaya apung yang dialami siswa, yaitu gaya apung sebanding kedalaman dan berbanding terbalik dengan volume benda yang tercelup.

Kata kunci: gaya apung, kesalahan, tekanan hidrostatik

In learning in schools, teachers are commonly dealt with a number of diverse student characteristics. Some students are able to perform learning activities without a hitch and do not encounter significant and major problems in acquiring a concept. Generally students consider that Physics is classified as a lesson that is difficult to understand (Sari, et al., 2013). Because in Physics lesson, it is insufficient to just memorize the formulas, in fact it takes perseverance and tenacity in doing exercises and must be able to correlate the formulas with the problems faced (when answering questions). If students have dealt with some errors in learning the previous concepts, students will also find it difficult to acquire the next concepts.

Frequent conceptual errors encountered by students are the concept of hydrostatic pressure (Goszewski, et al., 2012 & Loverude, et al., 2010) and buoyancy (Wagner, et al., 2013 & Yin, et al., 2008). Mostly, conceptual errors occured in students was due to students' interaction and experience in real-life context. Before taking Physics lesson, all students had acquired Physical phenomena experience, for instance: object immerses when the object volume is large, object floats when the water volume is large. When students acquired such experience, it automatically constructed certain intuition within student's mind regarding particular Physics event; in which the intuition constructed by students is not necessarily true. When students

Article received 22/11/2018; Approved 28/02/2019

constructed incorrect concept, it is relatively difficult to be addressed and resolved; in fact the incorrect conceptual understanding has become the main reference of student.

Hydrostatic pressure in at h depth, as illustrated in Figure 1, is an atmospheric pressure with $\rho g h$ where P_0 is an atmospheric pressure, ρ is the density of the fluid, g is the acceleration due to gravity, and h is the depth of the surface of the fluid (Knight, 2008). Mathematically the hydrostatic pressure can be written as follows.

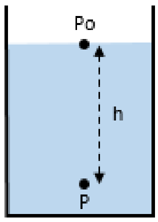

Figure 1. Hydrostatic Pressure at *h* Depth

$$P = P_0 + \rho g h \text{..........(1)}$$

Equation 1 states that the pressure at all points with the same depth is similar, does not rely on the shape of the container. Hydrostatic pressure is influenced by atmospheric pressure, fluid density, acceleration of gravity, and depth of the fluid surface.

Errors in students' understanding about hydrostatic pressure are errors in interpreting *h*, the volume of water that affects pressure, closed spaces that increase pressure, the distance of the wall that affects pressure, assuming that the direction pressure is only vertical, the farther from the hole the greater the pressure, assuming that pressure at all points is similar (Goszewski et al., 2012 & Loverude et al., 2010).

The magnitude of the buoyancy force is always similar as the weight of the fluid displaced by the object (Serway & Jewett, 2004; OpenStax, 2016). Mathematically the buoyancy force can be written as follows.

$$F_a = \rho g V_f \text{..........(2)}$$

Comparison of the magnitude of buoyancy and weight of objects in the fluid causes the object to float, static equilibrium, or sink (Knight, 2008).

The object sinks if the weight of the object is greater than the weight of the displaced fluid or the density of the object is greater than the density of the fluid. Objects float if the weight of the object is smaller than the weight of the displaced fluid or the density of the object is smaller than the density of the fluid. Objects in static equilibrium if the weight of the object

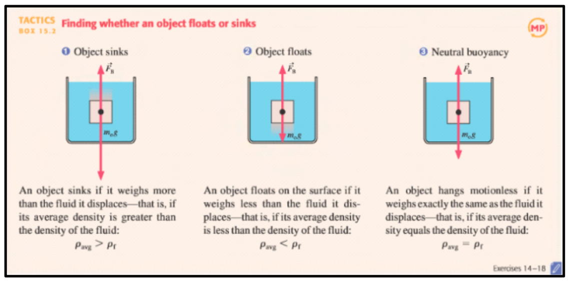

Figure 2. Comparison of the Magnitude of Buoyancy and Weight of Object in Fluid

equals the weight of the displaced fluid or the density of the object equals the density of the fluid.

There are ten conceptual errors related to floating and sinking objects, namely large sinking objects, small floating objects, floating hollow objects, sinking hollow objects, floating thin objects, sharp objects sinking, vertical position objects sinking, objects made of hard sinking material and floating soft material, a filler that floats makes things float, more volume of water makes things float, sticky liquid makes objects float (Yin et al., 2008).

METHOD

This paper employed descriptive approach research which intends to depict and describe certain phenomena. This research took the data of test results of students' conceptual understanding about hydrostatic and buoyancy force. Test items were taken from several articles (Goszewski et al., 2012; Loverude et al., 2010; Wagner et al., 2013) regarding hydrostatic and buoyancy force. This research was conducted in two class with the total number of students was 64.

Tests were given to students who had taken hydrostatic and buoyancy force topics in Physics lesson. Students completed four conceptual test which consisted of two items of hydrostatic pressure and two items of buoyancy force. The tests were given in the form of multiple choice; it intended to explore students' error in understanding hydrostatic pressure and buoyancy force concepts. Students were given 15 minutes to complete the test.

Then, after obtaining students' answer, it was proceeded to the analysis to discover misunderstanding aboyt hydrostatic pressure and buoyancy force concepts. It employed percentage calculation to identify students' error in each item of test and students' error in the whole conceptual understanding about hydrostatic pressure and buoyancy force.

RESULTS

The answers given by students during the test reflect students' error in both hydrostatic pressure and buoyancy force concepts. Each item given to students intended to observe conceptual misunderstanding about hydrostatic pressure and buoyancy force concepts. The first and second items tested students' understanding about hydrostatic pressure and the third and fourth items tested students' understanding about buoyancy force.

The first test item instructed student to solve hydrostatic pressure on communicating vessels as illustrated in Figure 3. It was found that six students (9.38%) answered correctly and 58 students answeres incorrectly (90.63%).

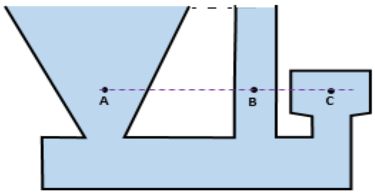

Figure 3. Communicating Vessels

Students' errors in understanding hydrostatic pressure on the communicating vessels are presented in Table 1.

The second problem instructed students to analyze the relationship between density and hydrostatic pressure as illustrated in Figure 4. Students who answered correctly were 31 students (48.44%) and 33 students (51.56%) answered incorrectly.

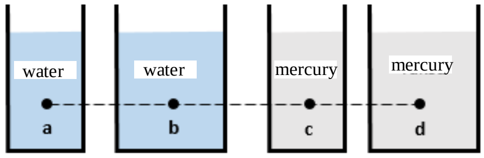

Figure 4. The Relationship between Density and Hydrostatic Pressure

In the second problem, the density varied was the fluid density and fluid volume while the point depth was similar. The student's error was when analyzing the relationship between density and hydrostatic pressure. Student answers are available in Table 2.

Overall, the percentage of concept errors of hydrostatic pressure experienced by students can be seen in Figure 5.

The third question instructed students to analyze the buoyancy force on objects tied to a rope in the water as presented in Figure 6. Students who answered correctly were 18 students (28.13%) and 46 students (71.88%) answered incorrectly.

In the third problem, there is a block tied to a rope in the water as illustrated in Figure 6. Then, students were asked to choose the correct answer to increase the buoyancy of the block. Student errors in analyzing buoyancy on the tied objects in water can be seen in Table 3.

Table 1. Students' Errors in Understanding Hydrostatic Pressure on The Communicating Vessels

No.	Answer	Total (%)
1	Hydrostatic pressure is influenced by distance from vessels wall	3,13%
2	Hydrostatic pressure is influenced by the volume of the water above the vessels	17,19%
3	Hydrostatic pressure will be greater if the above part of the vessels is closed	46,88%
4	the closer the part of the open container is, the greater the hydrostatic pressure	7,81%
5	and the farther away from the open container section the greater the hydrostatic pressure	15,63%

Table 2. Students' Error in Analyzing The Density and Hydrostatic Pressure

No.	Answer	Total (%)
6	the smaller the density of the fluid the greater the hydrostatic pressure	12,50%
7	the smaller the volume of water the smaller the hydrostatic pressure	17,19%
8	the smaller the volume of water the greater the hydrostatic pressure	18,75%
9	hydrostatic pressure is only influenced by depth	3,13%

Table 3. Student Errors in Analyzing Buoyancy on String-Bound Objects in Water

No.	Answer	Total (%)
1	buoyant force is proportional to the mass of the object	20,31%
2	buoyant force is inversely proportional to depth	20,31%
3	buoyant force is inversely proportional to the density of the fluid	18,75%
4	buoyant force is proportional to depth	12,50%

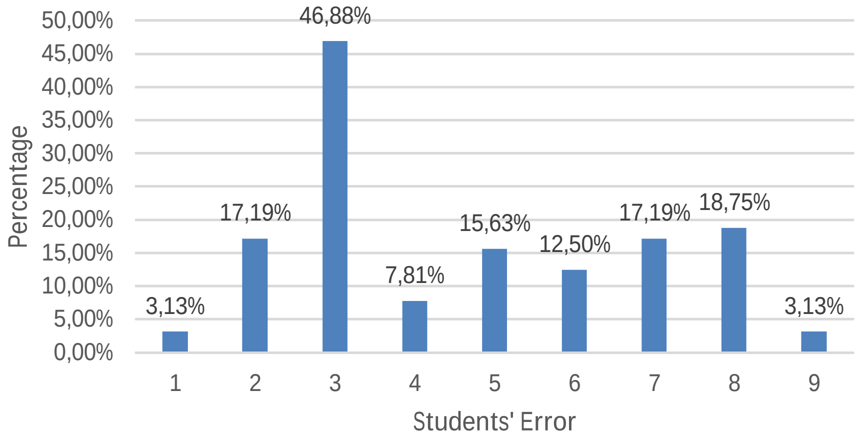

Figure 5. The Percentage of Students' Error in Hydrostatic Pressure

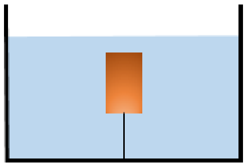

Figure 6. Tied Object in The Water

The fourth problem instructed students to analyze the relationship between the volume of fluid transferred by objects and buoyancy as shown in Figure 7. The students who answered correctly were five students (12.50%) and 56 students (87.50%) answered incorrectly.

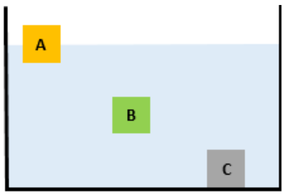

Figure 7. Relationship between Fluid Volume and Buoyancy

In this problem, the three blocks have different mass, but have the same shape and size, were dipped in a container filled with water in different positions: floating, equilibrium, and sinking. Student errors in analyzing the relationship between the volume of fluid displaced by objects and buoyancy can be seen in Table 4.

Overall the percentage of floating force concept errors experienced by students can be seen in Figure 8.

DISCUSSION

The first problem intended to identify students' error related to the application of the concept of hydrostatic pressure in a communicating vessel with three different shapes. In this problem, students considered the hydrostatic pressure to be influenced by the distance from the vessel wall where the closer the vessel wall, the smaller the hydrostatic pressure. It means that the hydrostatic pressure is inversely proportional to the distance to the vessel wall. The second error, students assumed that the hydrostatic pressure is influenced by the volume of water above. It means that the hydrostatic pressure is influenced by the volume of water above; where the greater water volume, the greater the pressure would be. The third error, students assumed that a closed space increase hydrostatic pressure. The fourth error, students assumed that the hydrostatic pressure is influenced by the distance from the open container section where the closer from the open container part the greater the hydrostatic

Table 4. Student Errors in Analyzing The Relationship between The Volume of Fluid Displaced by Objects and Buoyancy

No.	Answer	Total (%)
5	the deeper the position of the object the smaller the volume of water moved	17,19%
6	the deeper the object's position the greater the volume of water moved	48,44%
7	the volume of water displaced by the floating object is greater than the object that is floating or floating	14,06%
8	the volume of water transferred depends only on the volume of the object	7,81%

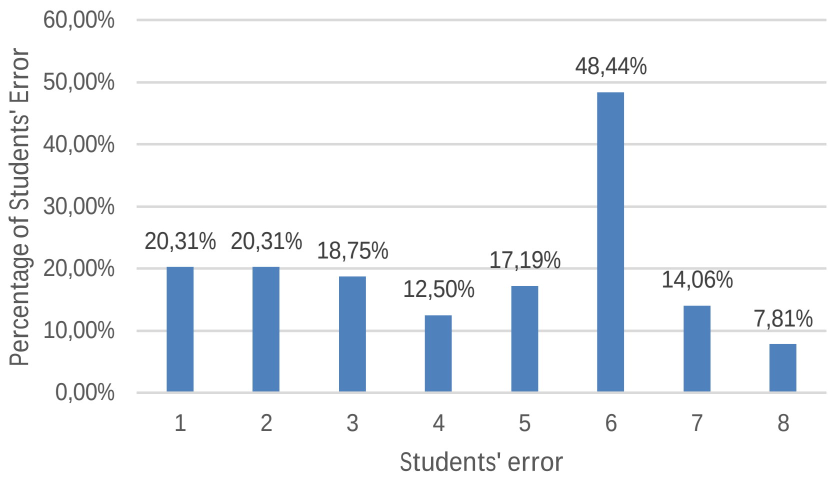

Figure 8. Percentage of Student Errors in the Buoyancy Concept

pressure means that the hydrostatic pressure is inversely proportional to the distance from the open container section. Fifth error, students assumed that the greater distance from the part of the open container, the greater the hydrostatic pressure means that the hydrostatic pressure is proportional to the distance from the part of the open container.

The second problem shows students' errors in analyzing the relationship between density and hydrostatic pressure. In this problem, the density is varied, namely the density of the fluid and the volume of the fluid while the depth of the object is the same. The first error students experience is that the hydrostatic pressure is directly proportional to the density of the fluid but not inversely proportional (the smaller the density of the fluid the greater the hydrostatic pressure). The two hydrostatic pressures are not affected by the amount or volume of water (the smaller the volume of water the smaller the hydrostatic pressure). The three hydrostatic pressures are not affected by the amount or volume of water (the smaller the volume of water the greater the hydrostatic pressure). The four hydrostatic pressures are influenced by the density of the fluid not only by depth by assuming all the pressure points are the same when the fluid types are different.

The third problem error analyzes the buoyant force on objects tied to a rope inside. In this question, how do students improve the buoyancy of the beam which is tied to a rope and submerged in water. The first error experienced by students is to replace with a beam whose mass is greater and the volume is the same meaning that the greater the mass of an object, the buoyancy force is also greater. Both students consider by reducing the water from the container but the beam is still immersed which results in the depth of the object from the surface getting smaller meaning that the buoyant force is inversely proportional to the depth. The three students assumed that by replacing water with alcohol whose density is smaller than water it means that the buoyancy force is inversely proportional to the density of the fluid. The four students assume that by shortening the rope that results in greater depth the object means that the buoyant force is proportional to the depth of the object.

The fourth problem is about analyzing the relationship between the volume of fluid displaced by objects and buoyancy. In this problem the three mass blocks are different but the same shape and size are dipped in a container filled with water in different positions namely floating, floating and sinking. The students' first concept error was that block A moved the largest volume of water and the smallest block C meant that buoyancy was inversely proportional to depth. The second block C moves the largest volume of water and the smallest block A means that buoyancy is proportional to depth. the third volume of water displaced is the largest in beam A and equally small in beam B and C means that the buoyant force is inversely proportional to the volume of the immersed object. The four volumes of water displaced are equal to the three beams meaning the buoyant force is proportional to the volume of the object regardless of the volume of the immersed object.

CONCLUSION

This study concludes that the majority of students' misconceptions about hydrostatic pressure are about hydrostatic pressure influenced by the the upper closed container, the volume of water above it, the distance from the open part of the container, inversely proportional to the fluid density, distance to the wall of the container, and only influenced by depth. Whereas, the majority of students' errors regarding buoyant concept are buoyancy proportional to depth, proportional to object mass, inversely proportional to depth, inversely proportional to fluid density, inversely proportional to depth, and inversely proportional to volume of immersed object.

Students are expected, during the learning process, not only to memorize the hydrostatic pressure formula and the buoyancy force formula , but must understand the concept as a whole both quantitatively and qualitatively.

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