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STUDENTS' REASONING ABOUT FLOAT, SUSPEND, AND SINK: THE ROLE OF NEWTON'S LAWS

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ABSTRACT

The phenomena of floating, suspending, and sinking have been studied by students from elementary school to university level. However, many students, even at the university level, still misuse their knowledge to solve problems related to these phenomena. This has been revealed by many previous researchers. Student errors are mainly caused by students tending to apply intuition-based spontaneous-reflective thinking patterns triggered by salient features that appear in the problem rather than thinking deeply and reflectively. This research aims to reveal students' understanding and reasoning about floating, suspending, and sinking phenomena in more detail. This research was conducted on first-year students of the Department of Physics Education of Halu Oleo University Kendari, Southeast Sulawesi, with 31 participants. Data was obtained through a series of tests and interviews. The test was given in two stages, and two instruments were developed to reveal students' reasoning skills through the answers they wrote. The first test used the five-block problem. The second test was developed based on the first test's results, which consisted of four test items. Based on descriptive analysis, it is found that students still use incorrect reasoning in solving floating, suspending, and sinking phenomena even though they know various concepts related to these events verbally. In general, the errors shown are caused by students not being able to use the concept of Newton's laws of motion in solving various problems in physics, especially in the phenomena of floating, suspending, and sinking. The data obtained is then used as a reference in designing learning activities, which are expected to help students understand floating, suspending, and sinking phenomena more comprehensively.

Keywords: Newton's laws; student reasoning, floating; suspending, and sinking

INTRODUCTION

The phenomena of floating, suspending (floating under the surface), and sinking are usually used to discuss buoyant force or Archimedes' principle from elementary school to university level through the Introduction to Physics course. At the elementary school level, the discussion is directed at helping students understand the concepts of floating, suspending, and sinking based on the final position of an object when it is immersed in a fluid. Apart from that, it is also to help students find the factors that determine whether an object floats or sinks in a fluid.

At the junior high school level, discussion of this phenomenon is related to the density of objects relative to the density of fluids. High school students generally know that if $\rho_{object} < \rho_{fluid}$, then the object will float; if $\rho_{object} = \rho_{fluid}$, the object will float; and if $\rho_{object} > \rho_{fluid}$, then the object will sink. Students have also been able to discover Archimedes' principle, through observation, that the buoyant force experienced by an object in a fluid is equal to the weight of the displaced fluid, which is mathematically formulated as $F_A = \rho_f V_{fd}\, g$ with ρ_f stating the density of the fluid, V_{fd}

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stating the volume of the displaced fluid, and g stating Earth's gravitational acceleration (Şahin, 2012; Berek et al., 2016; Çepni & Safaah et al., 2017; Shen et al., 2017; Zoupidis et al., 2018, 2021; Ammase et al., 2019). At the high school level, students can explain Archimedes' principle by applying the concept of hydrostatic pressure, namely that the buoyant force is nothing but the resultant force produced by the pressure of the surrounding fluid. Students can also be taught to explain the effect of the density of an object (relative to the density of the fluid) on the floating and sinking of an object by applying Newton's laws, especially for objects in equilibrium (She, 2005; Walker et al., 2011; Hadjiachilleos et al., 2013; Leuchter et al., 2014; Zhou et al., 2015 Jamaludin & Batlolona, 2021; Kusairi et al., 2021). Thus, high school students should already have sufficient knowledge to coherently explain floating, suspending, and sinking phenomena using physical principles. However, research shows that there are still many high school students, even university students, who have difficulty explaining this phenomenon (Unal & Costu, 2005; Loverude et al., 2010; Goszewski et al., 2013; Radovanović & Sliško, 2013; Wagner et al., 2014; Gette et al., 2018; Diyana et al., 2020; Irawati et al., 2022).

Some difficulties in students' reasoning about floating and sinking have been revealed in the physics education research literature. Several studies reveal that students have misconceptions about floating and sinking, such as misunderstanding the relationship between density, object weight, and buoyancy, and inability to analyze the relationship between floating events and fluid pressure (Kim & Paik, 2021; Mellu et al., 2022). In this supported argumentation that pre-service science teachers have many misconceptions, low scientific knowledge level, and low confidence in their knowledge about floating and sinking and Grade R teachers have a partial grasp of floating and sinking concepts, impacting students' science knowledge (Kiray et al., 2015; Maraisane et al., 2024). Therefore, Regarding buoyant force, for example, many students think that the magnitude of the buoyant force depends on the object's position in the fluid. In this context, students generally think that the lower the position of an object in the fluid, the smaller the buoyant force it experiences (Loverude et al., 2003; Unal & Costu, 2005; Chen et al., 2013; Minogue & Borland, 2016) and has a value of zero if the object sinks to the bottom of the container (Wagner et al., 2014; Kiray et al., 2015). The opposite idea is also often found: the lower an object is, the greater the buoyant force it experiences (Zoupidis et al., 2018; Gao et al., 2020). In this context, regarding objects that are fully sinking in water, the buoyant force experienced will increase with depth (Ozkan & Selcuk, 2015; Zhou et al., 2015; Minogue & Borland, 2016; Koes-H et al., 2018; Zoupidis et al., 2021; Bozkurt & Yıldırım 2022). Another commonly found error is that the sinking or floating of an object is determined by the mass or weight of the object without considering its volume (Loverude et al., 2003; Radovanović & Sliško, 2013; Zhou et al., 2015; Buteler & Coleoni, 2016; Taibu et al., 2017; Young & Meredith, 2017).

A commonly used way to uncover student reasoning is by asking students open questions. One problem often used in the literature to reveal students' thinking about floating and sinking is the five-block problem developed by Loverude et al. (2003), as shown in the appendix. The problem stem describes five blocks that are identical in shape but have different masses, first placed in the middle of the vessel and then removed. The final positions of Block 2 and Block 5 have been shown: Block 2 is almost wholly sinking, while Block 5 is sinking at the bottom of the vessel. Students are asked to predict the final positions of the other blocks. Research shows that only a small percentage of students can answer correctly. The most common wrong answer is that the position of the blocks forms a downward sloping line pattern, where the block with the greater mass will be in the lower position: Block 1 is above Block 2, Block 3 is below Block 2, and Block 4 is below Block 3 but above Block 5 (Loverude, 2009; Loverude et al., 2003; Minogue & Borland, 2016; Gette et al., 2018).

Responding to this wrong answer, Loverude (2009) believes that students tend to use the influence of mass or weight to determine the final position of the block without paying attention to its volume. In other words, instead of paying attention to the density of an object, students pay more attention to its weight. Other researchers, for example, Gette et al. (2018) and Mays et al. (2021), suspect that such reasoning errors may not be because students lack conceptual understanding but could also be caused by students not trying to use the formal knowledge obtained from physics classes. In that case, students tend to apply intuition-based spontaneous-reflective thinking patterns triggered by salient features that appear in the problem rather than thinking deeply and reflectively based on the physics knowledge that has been learned. This hypothesis by Gette et al. (2018) aligns with the view of the theory of resources or knowledge in pieces (Docktor et al., 2016; Etkina & Planinšič, 2015; Young & Meredith, 2017; diSessa, 2018), which is now widely used as a theoretical framework in physics education research. The researchers agree with the thinking of Gette and colleagues. The further question that needs to be answered is: What knowledge of physics is needed to answer the five-block problem correctly? Is it true that students failed to solve the problem because they did not activate the prerequisite concepts? If this is true, is it because students do not yet understand these ideas, or do they understand but are not activated because they are lost to the surface features that are more prominent in the problem? So far, such questions have not received attention in physics education research. This research is intended to find empirical answers to these questions.

The five-block problem can be solved using density or force approaches. Students can use one or a combination of the two approaches. The density approach relates the density of the block (relative to the density of water) to the final state of the block after it is released. There are three possibilities: (1) if the density of the block is less than the density of water, then the final position of the block will float on the surface; (2) if the density of the block is exactly the same as the density of water then the block will suspend and remain in its original position, and (3) if the density of the block is greater than the density of water then the final position of the block will sink to the bottom of the aquarium. Furthermore, in the case of floating blocks, students need to apply the physics concept that the volume fraction of the sinking block is the same as the ratio of the density of the block to the density of water. For example, if the density of the block is 75% of the density of water, then the volume fraction of the sinking block is 75% of the total volume. In the context of the five-block problem, the ratio of the densities of the five-block cannot be confirmed quantitatively but can be confirmed qualitatively; that is $\rho_1<\rho_2<\rho_3<\rho_4<\rho_5$.

The qualitative comparison shows that there is, at most, only one block whose density is exactly the same as the density of water. To get there, students need to understand the concept of density as the ratio of an object's mass to its volume and characterize an object based on its mass density. Based on those pieces of knowledge, the final position of the block can be determined as follows. Block 2 is known to be almost floating, so its density is certainly less than the density of water. What about the final position of Block 1? Because the density of Block 1 is less than the density of Block 2, the final position of Block 1 must be above Block 2 because its sinking volume fraction must be less than the sinking volume fraction of Block 2. Block 3 has a greater density than Block 2, which, in this case, is almost the same as the density of water. Two possibilities can happen to Block 3: its density is exactly the same as water so that its final position remains in the middle of the aquarium, or its density is greater than water so that its final position sinks to the bottom of the aquarium. The final position of Block 4 must sink to the bottom of the aquarium because its density is greater than the density of Block 3, so it must be greater than the density of water.

The force approach, on the other hand, involves the process of identifying what forces are acting on each block and predicting where the block will move once it is released. To identify force correctly, students need to refer to Newton's third law, namely, force due to interaction. Right after release, the block interacts contactively with the water and non-contactly with Earth's gravity. Interaction with water produces an upward buoyant force whose magnitude is equal to the weight of the water displaced or proportional to the volume of water displaced ($F_b=\rho_f\, gV_{fd}$). The gravitational interaction with the Earth produces a downward gravitational force whose magnitude is proportional to the mass of the block ($F_{grav}=mg$). Right after being released in the middle of the aquarium, the buoyant force acting on each block is the same because the volume of water displaced is the same. Meanwhile, the gravity of each block is different depending on its mass. To estimate where the block will move, students must determine the resultant force produced by the two forces and then apply it to Newton's second law. If the resultant force is exactly zero, so the buoyant force is exactly equal to the weight of the block, then the block remains in its initial position. On the other hand, if the resultant force is not zero, the block will move up to the water's surface or slide down to the bottom of the aquarium, depending on the direction of the resultant of the two forces, up or down. A good understanding of the concepts of buoyancy force, gravity, and the application of Newton's second law to the initial and final position of the block will determine the student's success in solving the five-block problem. It is known that the final position of Block 2 is floating on the surface. This indicates that the buoyant force experienced when released is greater than its weight. Next, Block 1, which is lighter than Block 2, must move upward because the buoyant force it experiences is much greater than its weight. When it is at rest in its final position, the buoyant force experienced must equal its weight. This can happen if the volume of water displaced is less than that displaced by Block 2. So, the final position of Block 1 is floating in a higher position than Block 2. What about Block 3? Because it is heavier than Block 2, while the buoyancy force experienced is the same as that experienced by Block 2, two possibilities occur. If the weight is exactly the same as the buoyant force, then Block 3 remains stationary in its initial position (in the middle of the aquarium). The second possibility is that the weight exceeds the buoyant force acting. In this case, Block 3 will slide to the bottom of the aquarium. Block 4 must sink to the bottom of the aquarium because it is heavier than Block 3.

We agree with the hypothesis of (Gette et al., 2018) that whatever approach is used, to arrive at the correct answer, students must develop deep-reflective thinking by considering all relevant pieces of knowledge in a coordinative and coherent manner. If students rely only on intuitive and spontaneous-reflexive thinking, they will arrive at the wrong answer, as previous researchers have revealed. Apart from that, we also appreciate the five-block problem developed by Loverude (2009) as a tool with great potential to reveal students' reasoning in explaining floating, suspending, and sinking phenomena (Loverude, 2009; Gette et al., 2018). In this research, we want to reveal students' understanding and reasoning regarding the prerequisite knowledge needed to solve the five-block problem in more detail. The question to be answered is, is it true that students failed to answer the question because they did not activate the prerequisite concepts? If so, why? Is it because students do not understand these ideas yet, or do they understand them but do not activate them because they are lost to the surface features that are more prominent in the problem?

METHODS

The purpose of this study was to identify the reasoning used by students in solving problems about the phenomena of floating, suspending, and sinking. This study was attended by 31 first-year students in the physics education study program at Halu Oleo University in Southeast Sulawesi who had taken the Introduction to Physics course that included static fluid material. Data was obtained through a series of tests and interviews. This research was conducted in two steps. First, we gave the five-block problem developed by Loverude (2009) (Figure 1). Next, we conducted the second research stage by developing additional instruments to identify students' understanding of the required prerequisite knowledge. Data was analyzed using descriptive qualitative methods based on the answers written by students to identify the reasoning they used when solving problems with objects in a fluid.

The second stage instrument was developed based on students' responses to the five-block given in the first stage. A total of 4 (four) free-response questions had been developed through several intensive discussions within the team and involving several experts. Question 1 and Question 2 were identical in revealing students' reasoning relating to density by modifying the position of the block when the block was released. Meanwhile, Question 3 and Question 4 expressed students' reasoning about the lifting force experienced by a block by a fluid, where students had to relate it to Newton's law. The complete instrument is presented in the appendix.

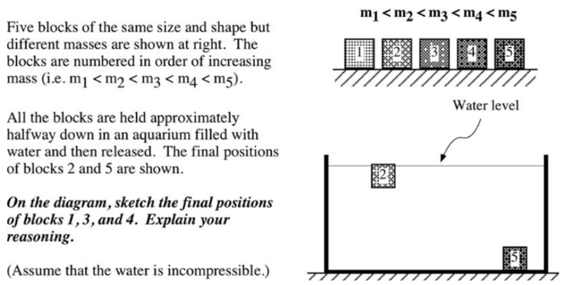


Figure 1. The Five-block Problem of Buoyan (Loverude, 2009)

RESULTS AND DISCUSSION

Stage 1 Results: Student reasoning on the five-block problem. Of the 31 students who were research subjects, not one gave the correct answer. Almost all students' answers are shown in Figure 2; the five blocks form a downward-sloping line formation, with Block 1 in the top position and Block 5 in the bottom.

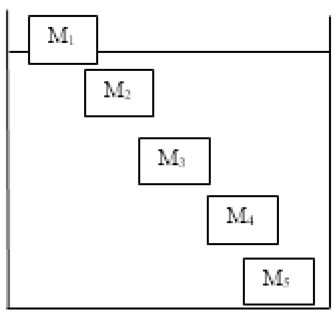


Figure 2. Typical Student Answers Regarding the Five-Block Problem

In general, there are 2 (two) reasons put forward by students in answering the five-block problem, namely (1) The position of an object in a fluid depends on its density; the greater the density, the lower its final position is, and (2) The position of the object in the liquid substance depending on its weight; the heavier it is, the lower its final position. There are two kinds of thinking underlying it. First, fluids have a particular strength limit to support the weight of objects. As a result, the heavier an object, the smaller the lifting force by the fluid compared to its weight, so its position is lower. The second thought is that the object's position reflects the amount of pressure the object exerts on the water. The heavier the object, the stronger it presses on the fluid to lower its position. This thought is confirmed by the interviews conducted with the following students.

"*Students are asked to observe the picture presented in the problem. It is known that the position of Object 2 is floating, and Object 5 is sinking. Considering it is known that Object 1 is smaller than Object 2, Object 3 is larger than Object 2 is smaller than Object 5, and Object 4 is larger than Object 3 is smaller than Object 2. The first student describes that the position of Object 3 is slightly below Object 2 because Object 3 is bigger than Object 2. Another student says it is because the immersion power is smaller. Likewise, for Object 1, because it is lighter than Object 2, it will be located slightly higher than Object 2, and likewise for Object 4 and Object 5.*"

These results are in line with findings in previous research, which states that students tend to equate buoyancy and weight regardless of whether the object sinks, suspends, or floats. Additionally, students fail to differentiate buoyancy force from buoyancy, saying that greater buoyancy force results in a "more buoyant" object so that the buoyant force on a floating object will be greater than on a sinking object of the same size. Students often predict whether an object sinks or floats based on the weight of the object without considering the volume. Students often still hold specific ideas and concepts about floating, suspending, and sinking, which are obtained through limited daily experience, for example, that large or heavy objects will sink while small or light objects will definitely float, that the lifting force experienced by objects completely sinking in fluid increases according to depth in the fluid (Heron et al., 2003; Loverude et al., 2010; Radovanović & Sliško, 2013; Wagner et al., 2014; Gette et al., 2018; Bozkurt, 2022). These results indicate that students' thinking about buoyancy often focuses on only one dimension of the sinking and floating phenomena, which can hinder their ability to appreciate the reasons underlying the observed sinking/floating phenomena (She, 2005; Yin et al., 2008; Çepni & Şahin, 2012; Wagner et al., 2014; Minogue & Borland, 2016; Schwichow & Zoupidis, 2023).

Stage II. Apart from the reasons explained above, several findings reveal the causes of students' errors in solving buoyancy problems based on the results obtained through additional instruments compiled by the researchers. The following is an explanation of students' misconceptions about buoyancy.

Most students already know that there is a relationship between the density of an object and the floating or sinking of the object. Students already know that if $\rho o<\rho f$, the object floats on the surface of the water; if $\rho o=\rho f$ the object is suspended underwater (floats below the surface); and if $\rho o>\rho f$, the object will sink to the bottom of the vessel.

However, this knowledge seems only verbatim and based solely on rote memorization. Students do not understand correctly what the similarities and dissimilarities mean. This is supported by students' responses to the question about three objects floating in water (Figure 3) and the question about the motion of an object whose density is the same as the density of water if it is released from a position above or below the middle of the fluid (Figure 4).

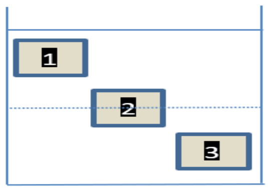
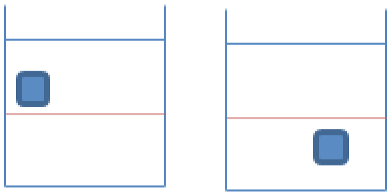


Figure 3. Three Identical Objects are Placed In a Water-Filled Vessel in Three Different Positions. Students are asked to determine (a) which objects are suspended, (b) the ratio of the densities of the three objects, and (3) the ratio of the magnitude of the buoyant force experienced by these objects

Regarding the questions in Figure 3, questions (a) and (b), the majority of students (77%) state that only object number 2 suspends and fulfills the condition $\rho o=\rho f$. Apart from that, all students thought that $\rho o<\rho f$ and $\rho o>\rho f$. This shows that most students do not understand the concept of density. Their thinking is still very easily disturbed by the surface features of the problem, in this case, the object's position in the fluid. It should be noted that the question clearly states that the three objects are identical, implicitly meaning that they have the same density.



(a) (b)

Figure 4. An object with the same density as the density of water is initially held above the center of the water (Figure A) and below the center of the water (Figure B). Students are asked to explain how the object moves after being released.

This is in line with the findings when conducting interviews with students. Given a picture of 3 blocks suspended in a fluid in different positions, students are asked to determine which block is suspended from the three blocks, and almost simultaneously, they answer that the suspended block is the block that is located right in the middle of the fluid in this case Block 2 because Block 2 which has exactly the same density as the density of the fluid. Meanwhile, the density of Block 1 is slightly smaller than the fluid, and the density of Block 3 is slightly greater than the density of the fluid.

Regarding the question in Figure 4a, which describes an object with exactly the same density as water and is released from a position above the middle of the water, 74% of students state that the object will move downwards and stop in the middle of the vessel. Regarding the question in Figure 4b, which describes an object with exactly the same density as water and is released below the middle of the water, 90% of students state that the object will move up and stop in the middle of the vessel. The findings show that most students think the relationship only applies if the object is in the middle of the water depth.

Students' lack of understanding is also revealed when asked how the object will move after being released from the position, as in Figure 4(a) or 4(b), if the object's density is slightly greater or smaller than the fluid's density. For the initial position, as in Figure 4(a), and the object's density is slightly greater than the density of the fluid, around 35% of students state that the object will fall slightly and not reach the bottom of the vessel. Other students (65%) answered correctly that the object would move down to the bottom of the vessel. On the other hand, if the density of the object is slightly less than the density of the fluid, around 32% of students state that the object will remain there (16%) or that the object will move slightly upwards and not reach the surface of the water (16%). The rest (68% of students) answered correctly that the object will move upward until it reaches the water's surface. For the initial position, as in Figure 4(b), and the object's density is slightly greater than the density of the fluid, 13% of students answer that the band will move slightly downwards, and 26% of students answer that it will not move. The remaining 3% say it will move upwards slightly. About 58% of students answered that the object moves downwards to the bottom of the vessel. For the object's density slightly smaller than the density of the fluid, around 36% of students answered that the object would move slightly upwards but not reach the surface, and 9% of students answered that it would move downwards. About 55% of students answered correctly that the object moves to the water's surface. Students are still consistent with the assumption that an object will be suitable in the middle of the fluid if it has the same density as the density of the fluid so that wherever the object is placed, the object will always go towards the middle.

Based on the data found above, it can be concluded that there are several reasons underlying the students' answers, namely (1) students do not understand the concept of density that an object has when it is fluid. Factually, students know that the density (ρ) of an object is the ratio between the mass of an object and its volume, but when applied in the context of an object in a fluid, they are confused; (2) students' mistakes regarding objects floating in fluid ($\rho_b = \rho_f$). Students assume that if $\rho_b = \rho_f$, then Fa = W, and the object will float right in the middle of the fluid, wherever the object is placed; (3) the student's assumption that the density of an object is slightly greater and slightly smaller than the density of a fluid which has implications for the position of the object being slightly upwards or slightly downwards. These results are in line with those stated by Heron et al. (2003), Loverude et al. (2003), and Yin et al. (2008) that students still fail to differentiate the concepts of mass, volume, and density, so students assume that the volume of water displaced by a sinking object depends on the mass of the object. These errors can also be caused by students still using intuition triggered by specific question features or their perception of how objects float and sink (Gette et al., 2018).

Most students (around 81%) think that the object's position influences the magnitude of the buoyant force in the fluid. The closer an object is to the surface of the water, the greater the buoyant force it experiences. Conversely, the closer an object is to the bottom of the vessel, the smaller the buoyant force it experiences. This is revealed from the students' responses to question (c) in the problem in Figure 3. They (around 81% of students) answered that Object 1 (the one in the top position) experiences the greatest buoyant force, and Object 3 (the bottom position) experiences the smallest buoyancy force, $F_{f1}>F_{f2}>F_{f3}$. Furthermore, even though students have been given clues to relate the magnitude of the buoyant force to the weight of objects, not a single student can use these clues to improve their reasoning. In this context, most students still think that the buoyant force on the three objects is different, not necessarily the same as the object's weight. Some students state that the magnitude of the buoyant force is equal to the object's weight only when the object's position is correct in the middle of the fluid. When the object's position is above the center line, the buoyant force is greater than the object's weight, and when the object is below the center line, the buoyant force is smaller than the object's weight.

Students' understanding of the relationship between a fluid's buoyant force and an object's weight in the floating, suspending, and sinking positions seems wrong in certain situations. Although most students know the definition of a floating object if $F_f > W$, suspend if $F_f = W$, and sink if $F_f < W$. Like the answer given to the question in Figure 1, where students are given the situation of 3 identical suspended objects in different positions in a fluid as in Figure 1 above. Then, students are asked to rank the amount of buoyancy force experienced by the fluid on the block; around 81% (or 25 people) say that $F_1 > F_2 > F_3$. This is consistent with the answer that the greater the density of an object, the lower the object's position in the fluid.

Students' errors in solving problems related to the buoyant force experienced by objects by fluids result from students' failure to differentiate buoyancy force from buoyancy by saying that a greater buoyant force produces a "more buoyant" object so that the buoyant force on a floating object will be greater than on a sinking object of the same size. This is in line with the findings expressed by Wagner et al. (2014) and Minogue and Borland (2016) that students have an understanding that the buoyant force (on fully sinking objects) is greater for objects with greater mass but the same volume (equating buoyant force and weight regardless of whether the object sinks or floats). In addition, students also assume that the buoyancy force (on fully sinking objects) increases with fluid depth (students misinterpret VFD as the volume of the fluid column above the sinking object (column above)) (Hadjiachilleos et al., 2013; Wagner et al., 2014; Minogue & Borland, 2016; Low & Wilson, 2017; Radovanović et al., 2019; Irawati et al., 2022).

It is believed that students' failure to analyze the buoyant force on sinking and floating objects stems from their failure to apply Newton's laws to objects at rest in a fluid. Regarding the question in Figure 3, to help students determine the ratio of buoyant forces experienced by the three objects, students are asked to determine what forces act on each object through a guiding question: "What forces act on each object? Is it just buoyancy, or just gravity, or both? Draw it." Most students (80%) answer buoyant force and gravity, but none of them can describe the direction of each of these forces. As a result, none of the students argued that the magnitude of the buoyant force is the same as the object's weight. This shows that only some students think Newton's laws, especially regarding force balance, are essential in analyzing the magnitude of the buoyant force acting on objects in a fluid. Others (20%) answer only buoyancy, gravity, or a combination of buoyancy, suspending, and sinking. This shows that the student can also not apply Newton's third law to identify the forces acting on an object in a fluid.

In general, students' difficulties in solving floating, suspending, and sinking problems are caused by a lack of students' understanding of the causal structure of floating, suspending, and sinking phenomena. Students have not been able to integrate domain-specific knowledge regarding the relationship between buoyancy forces (F_b), gravitational force/weight (W), density (ρ), conservation of volume, and Newton's law (Cepni et al., 2010; Radovanović & Sliško, 2013; Kiray et al., 2015; Minogue & Borland, 2016; Low & Wilson, 2017; Hidayat et al., 2020). Lack of appreciation of Newtonian dynamics when solving buoyancy-related problems is the main reason for the observed difficulties (Heron et al., 2003; Chen et al., 2013;Wagner et al., 2014; Taher et al., 2017; Gette et al., 2018).

It appears that students still have difficulty solving problems related to the magnitude of the lifting force experienced by objects by fluids, even though students appear fluent in the formula that V is the volume of fluid that is pushed/moved if water is not spilled from inside the container when the object is immersed. Students also cannot differentiate between the weight of the spilled fluid and the volume of the fluid spilled/moved.

Figure 5. Students are asked to determine the magnitude of the buoyant force experienced by the block when it is immersed in a fluid: (a) the initial volume of the fluid, (b) the volume of the fluid when the block is immersed

Many students still determine the magnitude of the lifting force by using the final volume shown by the container when solving cases such as Figure 5. Based on the data, the findings show that all students fail to express the magnitude of the buoyancy force experienced by an object in a fluid concerning the volume of the fluid displaced. This is thought to be because students do not understand correctly that the magnitude of the buoyant force experienced by an object is proportional to the volume of fluid that is moved (or spilled) and because students are not yet accustomed to solving problems regarding objects in fluids by applying the concept of Newton's laws.

CONCLUSION

There are several incorrect reasoning skills experienced by students when applying their knowledge to solve floating, suspending, and sinking problems. Among them are students' understanding of the mass and density of objects, which influence the position of objects in fluids, and understanding of the magnitude of the lifting force experienced by objects, which also varies depending on the position of the object in the fluid. In addition, students still fail to differentiate between buoyant force and buoyancy. Students also do not understand well that the density of an object will have consequences for the object's weight and affect the magnitude of the total force acting on the object. In verbatim, students already know the density, weight, buoyancy, and when floating, suspending, and sinking events occur. However, students must be more consistent in using and applying this knowledge if the context changes. In general, the errors shown are caused by students not being able to activate their prerequisite knowledge because they are inferior to surface features that are more prominent in the problem; for example, students use knowledge about the mass of objects and not the density of objects. Apart from that, students are still unable to use Newton's laws of motion to solve various problems in physics, especially in the phenomena of floating, suspending, and sinking. Students' answers are still influenced by their intuition, which impacts reasoning errors in solving problems related to the buoyant force. Based on these results, the researchers designed learning activities to help students understand floating, suspending, and sinking phenomena more comprehensively.

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