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Profile of Student Misconceptions on Static Fluids: A Meta-Analysis Study

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Abstract: Misconceptions in physics learning, especially regarding static fluids, are one of the main challenges in learning which can hinder students' understanding of basic concepts and the development of high-level thinking skills. This research aims to identify and analyze misconceptions that occur among students regarding static fluid material. This research is a meta-analysis study. This research examines the results of previous research that discusses misconceptions on the topic of static fluids with a focus on the types of misconceptions that often arise and the factors that influence them. The data analyzed were obtained from a number of studies involving various methods, such as diagnostic tests, interviews, and experimental research. The meta-analysis results show that the most common misconceptions occur in the understanding of hydrostatic pressure, Archimedes' principle, and Pascal's law, where students often associate these concepts with inaccurate everyday intuitions. Apart from that, factors such as less contextual teaching, limited learning experience, and difficulties in visualizing abstract concepts are the main causes of misconceptions. This research suggests the importance of a more explicit and concept-based teaching approach, as well as the use of visual aids or simulations to help students build a more precise understanding of static fluids.

Keywords: Misconceptions; Physics; Static Fluids; Meta-analysis

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Introduction

Physics is a branch of science that studies natural phenomena and their causes. Physics plays an important role in forming students' scientific understanding of natural phenomena. Apart from that, studying physics also trains thinking skills that are essential in everyday life. Physics teaches how to observe, analyze, and understand the relationships between various factors in the physical world, which helps students develop critical and logical thinking patterns (Liliasari, 2011). By studying physics, students also learn how scientific theories are applied to technology and innovation, which is very relevant to the development of the modern world (Pratama & Istiyono, 2015).

One of the problems that is often found in studying physics is the occurrence of misconceptions among students. Misconceptions are incorrect understandings or are not in accordance with actual physics concepts (Nugraeni et. al., 2013; Gurel et al., 2015; Hidayatullah et al., 2020). According to Nurulwati et al., (2014), misconceptions are beliefs or ideas that are not in accordance with generally accepted scientific understanding, and often arise as a result of personal experience or intuitive understanding that is formed before gaining a deeper understanding. Meanwhile, Makhrus & Busyairi (2022) stated that misconceptions can occur when students combine new knowledge with old, incorrect knowledge, thus forming inaccurate interpretations. Misconceptions have several synonyms such as misunderstanding of concepts, alternative conceptions, naive concepts, intuition, and so on (Leonard et.al., 2014).

Misconceptions in learning physics can be a serious obstacle in developing students' higher-order thinking skills. When students have a wrong or incomplete understanding of basic physics concepts, they tend to have difficulty relating these concepts to more complex problems (Busyairi & Zuhdi, 2021). This misconception can interfere with the analysis and problem-solving process which requires deep and systematic understanding. For example, if students misunderstand the concept of force or Newton's laws, they may not be able to apply these principles correctly in solving more complex problems. As a result, students are trapped in the wrong mindset, which prevents them from thinking at a higher level, exploring new ideas, and developing appropriate solutions (Aulia et.al., 2018; Shobayar et. al., 2017). Therefore, overcoming misconceptions is very important in learning physics, so that students can develop the higher-order thinking skills needed to understand, analyze, and solve physics problems effectively.

One of the reasons why misconceptions are difficult to overcome is because students often do not realize that they have a wrong understanding. These misconceptions often seem logical to students based on their experiences and observations, so they feel there is no need to change these understandings (Rohmah et al., 2023). For example, many students believe that the pressure at the bottom of a wide dam is greater than the pressure at the bottom of a well even though both have the same water depth. In fact, if you use the hydrostatic pressure equation, the pressure at two points that have the same depth is the same. Misconceptions like this can be rooted in students' seemingly logical logic. Therefore, the process of identifying misconceptions needs to be carried out carefully to find the points where students begin to experience confusion.

Apart from that, the importance of identifying misconceptions can also be seen from its impact on learning outcomes. Research shows that students who have misconceptions about physics tend to have difficulty solving problems related to the same concepts in the future. They may be able to remember formulas or procedures, but cannot relate those formulas to relevant physical phenomena. By identifying and correcting these misconceptions, it is hoped that students can gain a deeper and lasting understanding of physics concepts (Alawiyah et al., 2017).

Furthermore, identifying misconceptions in physics learning also has implications for selecting or developing learning designs (Ramadhani et al., 2022). By understanding the difficulties faced by students, the choice of design and other learning tools can be adjusted to the student's needs. Using activity-oriented learning strategies that can reduce students' misconceptions (Busyairi et al, 2021). Learning activities such as observing physical phenomena that students often experience misconceptions about, using learning media that can visualize abstract phenomena, and using learning resources whose truth has been validated by experts are the right choices to reduce misconceptions. This will not only improve students' understanding of physics but will also increase their interest and motivation in learning.

In the educational context, teachers have a very important role in detecting and overcoming these misconceptions. They must be able to understand how students think and recognize mistakes that often occur. This is not only useful for improving student understanding but also for adjusting the teaching methods used. By knowing where misconceptions lie, teachers can design more effective and targeted teaching strategies. For example, if it is found that students often misunderstand the concepts of hydrostatic pressure and buoyancy, teachers can design activities or experiments that are considered more effective in explaining these principles in a way that is easier to understand.

Research on misconceptions in physics can also contribute to the development of learning theories. Misconceptions are often related to the way students build new knowledge based on previous knowledge (Makhrus & Busyairi 2022). By understanding how misconceptions form and persist, we can better understand the learning process as a whole. This is important to develop teaching strategies that not only emphasize mastery of facts but also a deep understanding of concepts (Busyairi et al, 2021).

This research aims to identify the locations of misconceptions in a static fluid material. By understanding and correcting existing misconceptions, we can improve students' understanding of physics, design more effective teaching strategies, and contribute to the development of better curricula. Through this research, it is hoped that innovative ways can be found to overcome misconceptions so that physics education can be more beneficial for students and prepare them to become critical thinkers in the future. Identifying misconceptions is not just an academic activity, but is a fundamental step in improving the overall quality of physics education.

Method

This research is a meta-analysis study. This research aims to synthesize and analyze findings from various previous studies that discuss misconceptions in understanding static fluid materials. The meta-analysis study was chosen because of its ability to quantitatively integrate different research results, thereby providing a clearer and more comprehensive picture of the misconceptions that often occur in the context of static fluid teaching.

Data was obtained through systematic searches using the Publish or Perish application with a database on Google Scholar. A total of 200 articles discussing misconceptions about static fluids were taken from Google Scholar. Studies that were not relevant to the topic or that did not include data that could be used for further analysis were excluded from the analysis. From 200 articles, 47 articles were selected which were considered relevant as data sources. Of the 47 articles, 15 articles were taken which were considered to discuss the forms of misconceptions in their presentation in the most detail.

After the research data has been collected, the next step is data extraction which includes the types of misconceptions found, the characteristics of the students (such as age and level of education), and the methodology used in the study. The extracted data is then analyzed using descriptive statistics to describe the distribution of misconceptions found in various studies.

Result and Discussion

The following are some of the misconceptions experienced by students regarding static fluid material based on the results of analysis of 15 articles from previous research.

Table 1. Distribution of Misconceptions among Students

Subject Matter	Misconception	Percentage
Hydrostatic Pressure	Hydrostatic pressure is directly proportional to the cross-sectional area.	38,85%
	Hydrostatic pressure is inversely proportional to cross-sectional area.	40,38%
	Hydrostatic pressure is proportional to the volume of the liquid.	32,55%
	Hydrostatic pressure is only affected by the depth of the liquid.	39,32%
Pascal' Law	Pressure is directly proportional to the area of the pressure field.	36,52%
	Pressure is inversely proportional to the area of the pressure field.	35,12%
	Force is inversely proportional to cross-sectional area.	33,10%
	The direction of the force on the large cross section is the same as the direction of the force on the small cross-section.	50,08%
Archimedes' Law	The direction of the force acting at a point in a liquid is only up and down. The upward force is the buoyant force and the downward force is the weight of the object.	45,87%
	The lifting force (Archimedes force) is influenced by the position or depth of the object.	45,89%
	The lifting force (Archimedes force) is directly proportional to the density of the object immersed in the liquid.	36,60%
	The lifting force (Archimedes force) is inversely proportional to the density of an object immersed in a liquid.	33,92%
	The lifting force (Archimedes force) is inversely proportional to the density of the liquid.	37,17%
	The greater the mass of the object, the greater the lifting force experienced by the object.	46,86%
	In floating objects, the weight of the object is less than the lifting force (Archimedes force) felt by the object.	38,22%
	The lifting force (Archimedes force) is directly proportional to the volume of the object.	43,09%

One form of misconception that is often encountered by students regarding static fluid material is assuming that hydrostatic pressure is directly proportional to the cross-sectional area of the vessel. This can be seen from students' answers when given a problem regarding the comparison of hydrostatic pressure at points that have the same depth but with different cross-sectional areas.

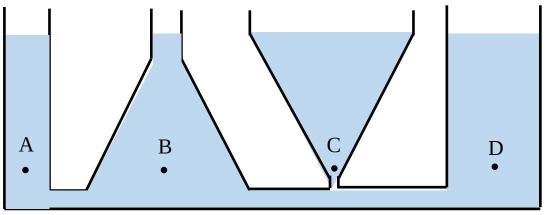

Figure 1. Question to identify students' conceptions: the relationship between cross-sectional area and hydrostatic pressure

On average, 38.85% thought that the greatest hydrostatic pressure was at point B because it has a wider cross-sectional area. They believe that the wider the cross-sectional surface, the greater the pressure it causes ((Jannah et al., 2022; Putri et al, 2021; Yolanda et al., 2017; Inggit, et al., 2021; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023; 2019). However, there are also some students who have the concept that hydrostatic pressure is inversely proportional to the cross-sectional area of the vessel. On average, 40.38% of students answered that the greatest pressure is at point C because it has a smaller cross-sectional area. They believe that the smaller the cross-sectional area, the greater the hydrostatic pressure generated (Jannah et al., 2022; Inggit, et al., 2021; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023; Sholahuddin et al., 2019). h), density (ρ), and gravitational acceleration (g). The cross-sectional area (A) plays a role in determining the total force received by the plane surface (F = P A).

Apart from that, another form of misconception is that students assume that hydrostatic pressure is directly proportional to the volume of a liquid. As many as 32.55% of students believe that the hydrostatic pressure felt by someone swimming in a large dam is greater than the pressure felt by someone swimming in a column whose volume is relatively small compared to the volume of the dam even though both are swimming at the same depth ((Putri et al, 2021; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023). Hydrostatic pressure at a point in a fluid does not depend on the volume of liquid present, but instead depends on depth, density, and gravitational acceleration. In this equation, there is no direct relationship between pressure and liquid volume the total force exerted by a surface, which is related to the cross-sectional area and depth, but not to the magnitude of the pressure itself. Therefore, the correct understanding is that hydrostatic pressure depends on the depth of the fluid (as the column of liquid above that point), not on the amount or volume of the liquid Alone.

One form of misconception that often arises among students in static fluid material is the assumption that hydrostatic pressure is only influenced by the depth of the liquid. This can be seen from students' answers when given a problem regarding the comparison of hydrostatic pressure at points that have different depths and types of liquid.

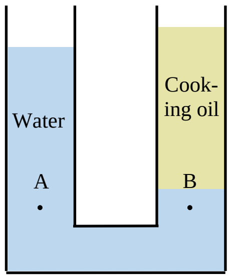

Figure 2. Question to identify students' conceptions: the relationship between fluid density and hydrostatic pressure

As many as 39.32% of students answered that the greater hydrostatic pressure was at point B because it was in a deeper position (Imtiyaz, F., 2020; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023; Salahuddin et al., 2019). In fact, although depth is the main factor that influences the pressure at a point in a fluid, there are other factors that also play a role, namely the density of the fluid and the acceleration of gravity. Therefore, apart from depth, the density of a liquid also influences how much pressure there is at a certain depth. For example, the pressure at the same depth in water (which has a lower density) will be less than the pressure at the same depth in mercury (which has a higher density).

Apart from the sub-material of hydrostatic pressure, students' misconceptions also occur in the sub-material of Pascal's law. One form of misconception that is often found among students regarding Pascal's Law material is assuming that the direction of force on a large cross-section is the same as the direction of force on a small cross-section of the jack system (Jannah et al., 2022; Yolanda et al., 2017; Cahyani et al. ., 2019; Irwansyah, 2023). In fact, although Pascal's law states that the pressure in a closed fluid will be transmitted evenly to all parts of the fluid and is related to the force received by the cross-section, the direction of the force produced at large and small cross-sections can be different depending on the orientation of the cross-section.

In principle, Pascal's Law states that if a force is applied to a small cross-section, the force will be transmitted through the fluid and produce a greater force at the larger cross-section, according to the cross-sectional area ratio. However, the direction of the force at large and small cross-sections depends on the direction of the force applied to the small cross-section and how the fluid acts in a closed system. If the force is applied vertically to a small cross-section, the force on the large cross-section will also be vertical, but if there is an angle or other direction in the cross-section, the applied force will be directed according to the orientation of the cross-section. Therefore, assuming that the direction of force in the two cross-sections is always the same is a misconception that does not correctly reflect the basic principles of Pascal's Law.

Apart from that, one form of misconception that often arises among students regarding Pascal's Law is the assumption that the cross-sectional area influences the amount of pressure that occurs on the piston in a fluid system. As many as 36.52% of students experienced misconceptions about this concept (Putri et al, 2021; Inggit, et al., 2021; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023; Salahuddin et al., 2019). This view is certainly wrong. Pressure is defined as force per unit area. The pressure at small and large cross-sections will remain the same, even though the cross-sectional areas are different. The difference will be seen in the force produced, which is greater at a larger cross-section, but the pressure remains the same. Thus, students are often trapped in understanding that increasing the cross-sectional area will change the pressure, even though what changes is the total force received by the cross-section, not the amount of pressure itself.

The pressure principle in Pascal's Law states that the pressure exerted on a fluid in a closed container will be transmitted evenly to all parts of the fluid without decreasing. This means that if a force is applied to one part of the fluid in a closed system, the resulting pressure will spread to all parts of the fluid and be transmitted to the walls of the container or other objects in the system with the same magnitude (the pressure at point A is the same as the pressure at point B).

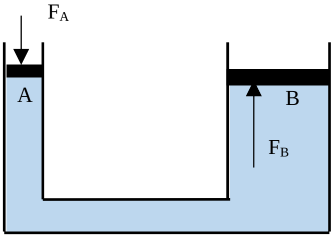

Figure 3. Pascal's law on hydraulic jacks

Equations based on the principles of Pascal's law:

$$P_A = P_B$$
$$\frac{F_A}{A_A} = \frac{F_B}{A_B}$$

Based on this equation, it can be seen that the cross-sectional area will have an impact on the magnitude of the force but not the pressure at each cross-section. The larger the cross-sectional area, the greater the force produced.

Misconceptions regarding the sub-material of Archimedes' Law also often occur among students. One form of misconception that often arises regarding Archimedes' Law is the assumption that the direction of the force acting on an object that is in a liquid is only in the vertical component (up and down). The upward force is considered as the buoyant force and the downward force is the weight of the object. As many as 45.87% of students have this kind of conception (Imtiyaz, F., 2020; Simamora et al., 2023; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023).

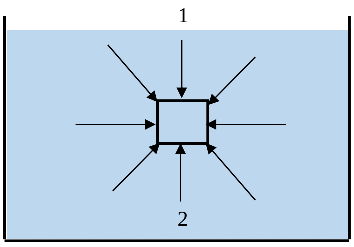

Figure 4. Direction of force at a point in a liquid

While it is true that the buoyant force acts upwards as opposed to the force of gravity, which is the gravitational force acting downwards, this understanding oversimplifies the interaction of forces in fluids. In reality, the buoyant force acting on an object submerged in a fluid has a vertically upward direction, but the pressure force acting on the surface of an object in a fluid does not only function in these two directions. The force on the fluid will vary with depth so that the force acting on the bottom of the object is greater than the force acting on the top of the object. This pressure difference creates a net force that points upwards (buoyant force). Thus, a more complete understanding is that the force acting on an object in a fluid is not only limited to the vertical direction (up and down), but also involves various other force components depending on the condition of the object and the surrounding fluid.

Another form of misconception is that students assume that the lifting force (Archimedes' force) is influenced by the position or depth of an object in a fluid. As many as 45.89% of students have this kind of conception (Inggit, et al., 2021; Imtiyaz, F., 2020; Simamora et al., 2023; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023).

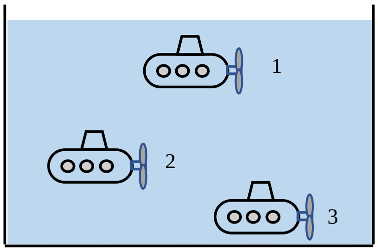

Figure 5. Comparing the buoyancy force on three identical submarines with different depths

When given a problem in the form of an image as in Figure 5 above, 45.89% answered that the greatest buoyancy force was experienced by submarine number 3. They believed that the position or depth of the submarine influenced the magnitude of the buoyancy force felt by the submarine.

According to Archimedes' Law, the lifting force acting on an object submerged in fluid depends only on the volume of fluid displaced by the object, not on the depth of the object. Archimedes force is defined as the force produced due to the pressure difference above and below an object immersed in a fluid. The lifting force does not depend on the depth of the object, but only on the volume of the object submerged and the density of the fluid. Therefore, even though the depth of an object in the fluid increases, as long as the volume of the object submerged remains the same, the lifting force received by the object will not change.

Another form of misconception related to Archimedes' Law is the assumption that the lifting force (Archimedes' force) is directly proportional to the density of an object immersed in a liquid. As many as 36.60% of students have this kind of conception (Simamora et al., 2023; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023; Salahuddin et al., 2019). In fact, the lifting force received by an object submerged in a fluid does not depend on the density of the object itself but rather depends on the density of the fluid and the volume of the object submerged. This misconception arises because students often think that the denser an object is, the greater the lifting force it receives. In fact, even though an object's greater density can influence whether the object will sink or float, the lifting force itself still depends on how much volume the object is submerged in the fluid, and the density of the fluid itself.

Apart from that, another form of misconception is that students assume that the greater the mass of an object, the greater the lifting force experienced by the object. As many as 46.86% of students have this kind of conception (Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023; Salahuddin et al., 2019). This misconception often occurs because students assume that the heavier an object (which means the mass of the object is greater), the object will experience a greater lifting force. In fact, the lifting force remains the same for objects that have the same volume, regardless of the weight or mass of the object. For example, two objects with different masses but the same volume will experience the same lifting force, even though the heavier object has a greater mass. The lift force does not change with the mass of the object but rather depends on how much fluid the object displaces, which is directly related to its volume.

Another misconception related to Archimedes' Law is the assumption that for objects floating in a fluid, the weight of the object is less than the lifting force (Archimedes' force) felt by the object. As many as 38.22% of students have this kind of conception (Imtiyaz, F., 2020; Simamora et al., 2023; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023).

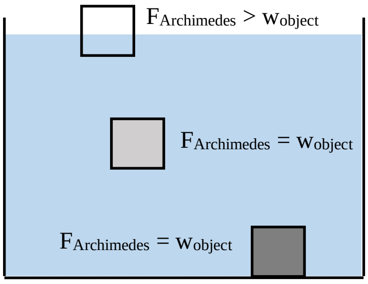

Figure 6. Forms of misconceptions among students regarding Archimedes' Force

When an object is floating (such as an object floating on the surface of water or gas), the weight of the object and the lifting force (Archimedes force) must be balanced. When floating or floating, the lifting force acting on an object is equal to the weight of the object, so that the object does not sink down or rise up. If the lifting force is greater than the weight of the object, the object will rise upwards, and if the lifting force is less, the object will sink.

This misconception arises because students often think that objects that float or float are in a state of imbalance and that the lifting force is still greater than the weight of the object. In fact, when hovering or floating, the balance between the lifting force and the weight of the object is the key to the object remaining in a stable position. This also explains why lighter objects (with a density less than the fluid) will float, while heavier objects (with a greater density) will sink, even though in both cases the lifting force remains equal to the weight of the object when the object is in equilibrium.

Another misconception is that students assume that the lifting force (Archimedes force) is directly proportional to the volume of the object. As many as 43.09% of students have this kind of conception (Inggit, et al., 2021; Imtiyaz, F., 2020; Simamora et al., 2023; Cahyani et al., 2019; Asrida et al., 2024; Irwansyah, 2023). This misconception arises because students often equate lifting force with "object volume" without taking into account that lifting force depends on the volume of the object submerged in the fluid, not the total volume of the object. If an object is only partially submerged in a fluid, then the lifting force will only depend on the part that is submerged, not the entire volume of the object.

Conclusion

It can be concluded that in learning physics there are several misconceptions experienced by students, especially regarding static fluid material. These misconceptions often arise due to inaccurate personal experience and intuitive understanding, as well as teaching that lacks contextualization. Difficulty in visualizing abstract concepts, as well as limited learning experience, also contribute to these misconceptions. Therefore, it is important for educators to identify and overcome these misconceptions through more explicit and concept-based teaching approaches, as well as the use of teaching aids or simulations that can help students build a more precise understanding of static fluids.

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