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Analysis of misconceptions in static fluids using four-tier diagnostic test among high school students

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Abstract

This study aims to analyze students' misconceptions in static fluid concepts using the Four-Tier Diagnostic Test instrument. Static fluid material was chosen because of its complex characteristics and its potential to generate misconceptions, particularly in the sub-concepts of hydrostatic pressure, Pascal's law, and Archimedes' principle. This research employed a descriptive method with a quantitative approach. The subjects of this study were 68 eleventh-grade students from a public high school in Garut Regency. The research instrument was a four-tier diagnostic test consisting of 15 items. Data were analyzed based on the combination of students' answers at each tier to identify categories of conceptual understanding, misconception, lack of understanding, and partial understanding. The results show that, overall, 37.74% of students experienced misconceptions, 37.65% understood the concept, 14.31% did not understand the concept, and 10.30% demonstrated partial understanding. At the sub-concept level, the highest misconceptions were found in Pascal's Law (52.20%), followed by Archimedes' Principle (41.47%), and hydrostatic pressure (25%). The highest item-level misconception occurred in question number 7 regarding the lifting force on a piston, with a percentage of 73.53%. These findings highlight the urgent need for identifying and remediating students' misconceptions, as well as the importance of implementing in-depth diagnostic instruments such as the Four-Tier Diagnostic Test in physics learning.

Keywords: Misconceptions, Static Fluids, Four-Tier Diagnostic Test, Physics, High School Students

1. Introduction

Science education, particularly physics, plays an important role in shaping fundamental conceptual understanding necessary to explain natural phenomena. Due to the abstract and concrete characteristics of physics, it is closely related to everyday life. In accordance with the physics curriculum standards at the high school level, the aim of physics education is to develop students' ability to learn and think analytically by applying physics concepts and principles to explain everyday phenomena. Accurate conceptual understanding in physics indicates that students truly comprehend the concept (Sheftyawan et al., 2018). Therefore, proper conceptual mastery is crucial to achieve learning objectives in physics. Each student has different abilities in understanding physics concepts.

Students' conceptual understanding may be shaped by their daily experiences in explaining natural phenomena, which makes them vulnerable to errors when linking personal conceptions with scientifically accepted ones (Didik, Wahyudi, and Kafrawi 2020). Physics concepts cannot be understood in isolation; they are interconnected, forming a complex network of knowledge that supports and strengthens our understanding of physical phenomena. However, students often tend to memorize formulas and definitions without proper conceptual understanding and without paying attention to the relationships among concepts (Khairunnisa, 2020). Such errors in linking concepts often lead to misconceptions (**iriyanti2012identifikasi**).

According to Suparno (2005), misconceptions can arise due to five factors: students, textbooks, context interpretation, teachers, and teaching methods. Misconceptions may result in learning problems in the classroom and persist if students continue to hold inaccurate conceptual frameworks (Gradini, 2016). Hermita et al. (2017) emphasized that students with misconceptions find it difficult to accept the correct concepts. If left unresolved, misconceptions may hinder learning progression and affect understanding of subsequent materials (Yulianti, 2017).

One of the physics topics prone to misconceptions is static fluids. Research by Miftahul Jannah et al. (2022) on eleventh-grade students at SMKN 2 Kendari revealed that misconceptions were at a moderate level (56%). Misconceptions were particularly prevalent in explaining factors affecting hydrostatic pressure and buoyant force (62.%), comparing the effect of density on the position of an object in static fluids (51.3%), applying Pascal's law to static fluids and hydraulic pumps (55%), implementing Archimedes' principle in daily-life buoyancy phenomena (50.6%), and relating Pascal's law to pressure magnitude and lifting force (59.4%).

Such misconceptions need to be analyzed to identify the difficulties students face in learning. Miftahul Jannah et al. (2022) noted the importance of distinguishing between students who truly experience misconceptions and those who simply lack conceptual understanding. One way to detect misconceptions is through diagnostic tests. Diagnostic tests are designed to identify students' weaknesses in order to provide appropriate follow-up or remedial measures (Perwitasari, 2015).

Diagnostic multiple-choice tests can take various forms: one-tier, two-tier, three-tier, four-tier, and even five-tier diagnostic tests. In this study, a four-tier diagnostic test was used to assess higher-level misconceptions. This test is a development of the three-tier diagnostic multiple-choice test (Zaleha and Nugraha, 2017). The researchers highlight the advantages of the four-tier diagnostic test, including: (1) the ability to classify students' confidence in answers and reasoning, providing deeper insights into conceptual understanding; (2) diagnosing misconceptions accurately; (3) identifying concepts requiring more emphasis; and (4) providing a basis for remedial strategies (Fariyani, Rusilowati, et al. 2015).

2. Literature Review

2.1 Students' Understanding

According to Purwanto (in Murizal, 2020:19), understanding is the level of ability where students can grasp the meaning of concepts, situations, or facts. In physics learning, true understanding is not only reflected through memorizing formulas but also the ability to connect and apply concepts to various situations. Due to the concrete nature of physics, students often encounter learning difficulties, making them vulnerable to misconceptions.

Widyanto et al. (2018) define misconception as a strongly held yet scientifically incorrect cognitive structure that deviates from expert-accepted concepts. Misconceptions may be caused by internal factors, such as prior experience, or external factors, such as teachers' explanations, textbooks, or instructional media. Misconceptions may impede learning and perpetuate errors across subsequent topics. Thus, tools that can accurately detect misconceptions are necessary to resolve such issues effectively (**hermita2018identifikasi**).

2.2 Diagnostic Tests

Diagnostic tests are multi-tier multiple-choice tests. They can take forms such as one-tier, two-tier, three-tier, four-tier, and five-tier diagnostic tests. The four-tier diagnostic test used in this research consists of: (1) a multiple-choice question; (2) confidence rating in the chosen answer; (3) reasoning for the chosen answer; and (4) confidence rating in the reasoning. This structure allows differentiation between students who truly understand, guess, do not understand, or hold misconceptions. Compared to other forms, the four-tier diagnostic test provides deeper insights because it evaluates not only correctness of answers but also reasoning and confidence levels (Gradini 2016).

Relevant research includes Maya Sari (2021), who used a four-tier diagnostic test via Google Forms to identify misconceptions in thermodynamics concepts among students at SMA 11 South Tangerang. Results showed that 75.5% of students were categorized as having high-level misconceptions, 17.8% medium-level, and only 6.7% low-level misconceptions. Identified misconceptions included the first law of thermodynamics (62.6%), thermodynamic processes (73%), heat engines (69.4%), Carnot engine (76.7%), and refrigeration (76.1%).

3. Method

This study employed a descriptive method with a quantitative approach. It aimed to identify misconceptions in static fluid topics, which include hydrostatic pressure, Pascal's law, and Archimedes' principle. Students' responses were analyzed using a four-tier diagnostic test validated by two experts (one lecturer and one physics teacher). The instrument consisted of 15 four-tier multiple-choice questions, comprising: (1) the multiple-choice question, (2) confidence rating for the chosen answer, (3) reasoning selection, and (4) confidence rating for reasoning.

The study was conducted with 68 eleventh-grade students from a public high school in Garut Regency who had previously studied static fluid topics. Data collection was carried out through one administration of the four-tier diagnostic test. Students' responses were then analyzed and classified into categories: conceptual understanding, misconception, lack of understanding, and partial understanding (Table 1).

4. Result and discussion

4.1 Overall Misconceptions in Static Fluid Concepts

Findings show that 37.65% of students demonstrated conceptual understanding, 37.74% held misconceptions, 14.31% lacked understanding, and 10.30% showed partial understanding. This indicates that misconceptions are at a medium level overall.

4.2 Misconceptions by Sub-Concepts

Analysis revealed that misconceptions varied across sub-concepts: hydrostatic pressure (25% – low), Pascal's law (52.20% – medium), and Archimedes' principle (41.47% – medium). The highest misconceptions occurred in Pascal's law, mainly because students failed to grasp that pressure in a closed fluid is transmitted equally in all directions and that force depends on cross-sectional area rather than pressure magnitude. In Archimedes' principle, misconceptions were linked to confusion about buoyant force, density, and displaced fluid volume, as well as mixing hydrostatic pressure concepts.

4.3 Misconceptions by Test Items

At the item level, the highest misconceptions appeared in item 7 (73.53%) and item 13 (61.76%), both categorized as high. Several items were in the medium category (items 3, 5, 6, 9, 11, 15), while others fell into the low category. Overall, although the proportion of students with misconceptions (37.74%)

is nearly equal to those with correct understanding (37.65%), the findings reveal that students' conceptual mastery of static fluids remains incomplete. Misconceptions commonly stemmed from overreliance on daily logic, lack of scientific reasoning, and confusion in linking physical quantities. This underscores the importance of conceptual teaching through experiments, simulations, and targeted clarification of common misconceptions Istighfarin 2015.

5. Conclusion and recommendation

This study concludes that students' misconceptions in static fluid topics are at a medium level, with 37.74% of students holding misconceptions. The highest misconceptions occurred in Pascal's law (52.20%). At the item level, the most frequent misconception was in question 7 (73.53%) regarding piston lifting force, while the lowest occurred in question 14 (1.47%) regarding hydrostatic pressure application in infusion.

For future research, it is recommended that: (1) findings from this study be used as a reference for implementing more suitable instructional models to remediate student misconceptions; (2) larger sample sizes be employed for more accurate results.

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