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THE IDENTIFICATION OF THE STUDENTS' CONCEPTUAL MASTERY OF FLUID STATICS: AN OVERVIEW OF GENDER

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ABSTRACT

This study aimed to assess the conceptual mastery of fluid statics among students, employing a descriptive quantitative approach. The research involved 22 male and 13 female students from eleventh-grade MIPA at a private school in Surabaya, Indonesia. The primary research instrument comprised 11 multiple-choice and reasoning questions, covering concepts related to Pressure and Hydrostatic Pressure, Pascal's Law, and Archimedes' Principle. Results indicated a higher level of conceptual mastery among male students compared to their female counterparts. While both genders demonstrated relatively high conceptual mastery in Pressure and Hydrostatic Pressure, significant disparities were observed in their understanding of Pascal's Law and Archimedes' Principle. Notably, students encountered challenges in discussing Archimedes' Principle, particularly in analyzing concepts related to sinking, floating, submersion, and buoyancy.

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INTRODUCTION

Conceptual mastery is an essential competency for students engaged in the study of physics, as it enables them to scientifically elucidate phenomena and events, both theoretically and in practical applications (Saputra, 2020; Turhusna & Solatun, 2020). This proficiency is vital as it demonstrates that students have not merely memorized information imparted by teachers but have also achieved a deep understanding of the material. Consequently, conceptual mastery serves as a critical benchmark in assessing the effectiveness of the educational process (Chang et al., 2010; Hatika et al., 2020; Sutarja & Wulandari, 2021; Yang et al., 2021).

One of the challenging concepts in physics for students to grasp is fluid statics. Numerous studies have highlighted the difficulties students face in understanding this subject. Jundu et al. (2020) and Zani et al. (2018) noted that students struggled with complex and abstract concepts in fluid statics unless supplemented with concrete examples. Similarly, research by Atika et al. (2023) and Sofiuddin et al. (2018) revealed that students' conceptual mastery of hydrostatic pressure was inadequate, primarily because they had difficulty solving problems involving systems with different spatial configurations. Additionally, many students found it challenging to explain the concept of buoyancy and the phenomena of floating, submersion, and sinking (Adi et al., 2018; Amaliyah et al., 2021; Tanti et al, 2020; Yadaeni et al., 2018).

However, research on changes in conceptual mastery between different genders is scarce. Gender issues in education encompass socio-biological differences between males and females, which can influence students' learning outcomes (Bohori & Liliawati, 2019; Nurfadilah, 2019; Turhusna & Solatun, 2020). Since students' learning outcomes are closely linked to their conceptual mastery, achieving optimal learning outcomes necessitates a strong grasp of conceptual knowledge. This study aims to investigate the differences in conceptual mastery of fluid statics between male and female students, providing a basis for designing targeted instructional strategies to enhance learning outcomes.

Table 1. The scoring guidelines of multiple-choice and reasoning questions.

Multiple Choice	Reasoning	Score
Correct	Correct	1
Correct	Incorrect	0

Table 2. Conceptual mastery category.

No	Percentage	Category
1.	$x < 20\%$	Very Low
2.	$20\% < x \leq 40\%$	Low
3.	$40\% < x \leq 60\%$	Medium
4.	$60\% < x \leq 80\%$	High
5.	$80\% < x \leq 100\%$	Very High

METHOD

This research employed a descriptive method. The sample comprised students from eleventh-grade MIPA at a private school in Surabaya, Indonesia. The instrument used was a test designed to assess students' conceptual mastery of fluid statics. This test included multiple-choice questions accompanied by reasoning questions, which required students to explain their choices. The test consisted of 11 items: 4 questions on Pressure and Hydrostatic Pressure, 2 questions on Pascal's Law, and 5 questions on Archimedes' Principle. The scoring technique is detailed in Table 1. The data in this study were analyzed using the conceptual mastery percentage, as defined in Equation 1. After calculating the percentage, students' conceptual mastery levels were categorized according to the criteria outlined in Table 2.

$$\text{Conceptual mastery percentage } (\%) = \frac{\text{number of the correct items}}{\text{number of students}} \times 100\% \quad (1)$$

RESULTS

This study aimed to investigate the conceptual mastery of eleventh-grade MIPA students on fluid statics material. The results of the descriptive statistics on conceptual mastery are presented in Table 3. Analyzing the answers to 11 fluid statics questions from 35 students, comprising 22 male and 13 female students, revealed a minimum score of 1 and a maximum score of 10. The average score for male students was 6.27, while the average score for female students was 4.08. Detailed results of the students' conceptual mastery in each topic of fluid statics are shown in Table 4.

Based on Table 4, it is evident that students exhibited weakness in understanding the discussion of Archimedes' Principle. Furthermore, a notable difference in conceptual mastery was observed between male and female students in both the discussions on Pascal's Law and Archimedes' Principle. The inclusion of reasoning in the analysis allowed for the identification of conceptual errors made by students. Despite providing correct answers to multiple-choice questions, students sometimes offered inappropriate reasons, which were crucial in assessing their conceptual mastery.

Table 3. Descriptive statistical results of students' concept mastery.

Results	Male	Female
N	22	13
$\overline{X}$	6.27	4.08
SD	2.39	2.02
Min.	1	1
Max.	10	8

Table 4. The results of the students' conceptual mastery for each discussion.

Discussion	Student	Correct Answer (%)	Category
Pressure and Hydrostatic Pressure	Male	76.14	High
	Female	67.69	High
Pascal's Law	Male	72.73	High
	Female	46.15	Medium
Archimedes' Law	Male	35.45	Low
	Female	16.93	Very Low

8. When a block A is placed in water, it is observed that the block floats. If block A is cut into two parts, where block 1 is larger than block 2, what will be the respective positions of block 1 and block 2 when they are placed in water?
   a. Block 1 sinks and block 2 submerge
   b. Block 1 sinks and block 2 floats
   c. Block 1 floats and block 2 sinks
   d. Block 1 submerge and block 2 floats
   e. Block 1 floats and block 2 floats

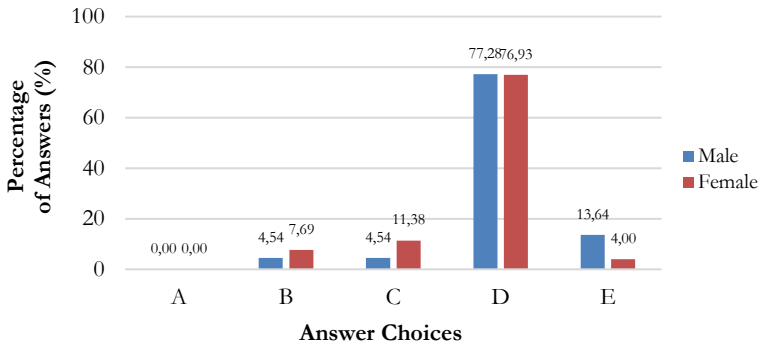


Figure 1. Item number 8 and the percentage of each answer in gender.

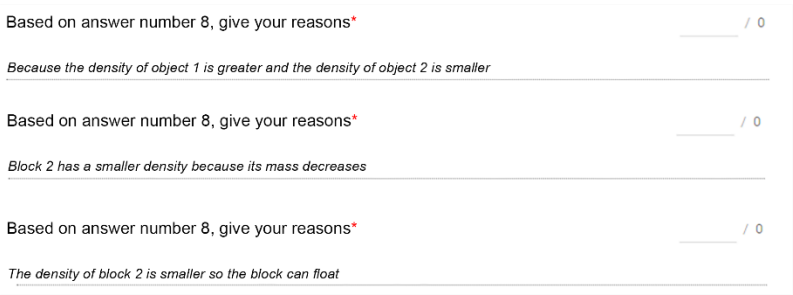
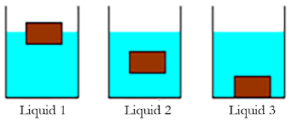


Figure 2. Examples of the students' reasons for number 8.

10. The position of an object when placed in three different liquids is shown in the following figure.



If F_i represents the magnitude of the buoyant force exerted by liquid number i, what is the correct ratio of the buoyant forces $F_1 : F_2 : F_3$?

a. $F_1 > F_2 > F_3$
b. $F_1 = F_2 > F_3$
c. $F_1 < F_2 < F_3$
d. $F_1 = F_2 = F_3$
e. $F_1 = F_2 < F_3$

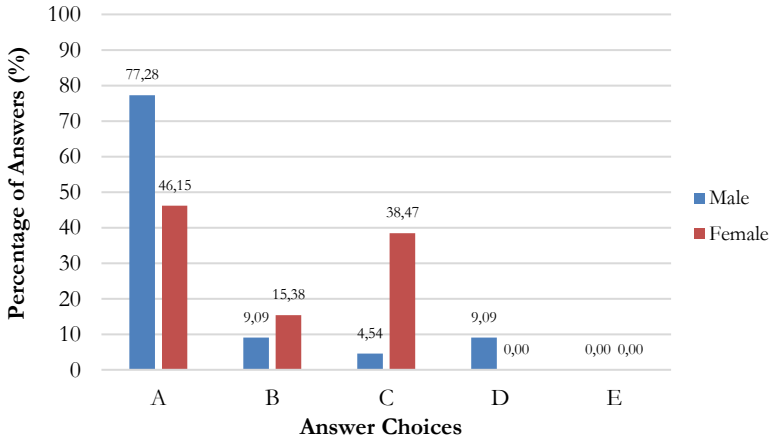


Figure 3. Item number 10 and the percentage of each answer in gender.

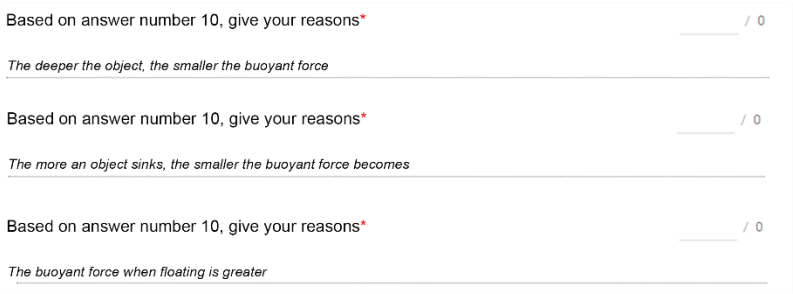


Figure 4. Examples of the students' reasons for number 10.

Examples of questions and the percentage of student responses in the discussion of Archimedes' Principle are illustrated in Figure 1 and Figure 2, respectively. Figure 1 illustrates that male students who selected the correct answer provided the appropriate reasoning, emphasizing that the density of the blocks remained unchanged despite alterations in their mass. Conversely, male students who chose the incorrect answer cited various reasons, such as asserting that Block 1 had a higher density, causing it to sink, while Block 2 had a lower density, leading it to float; some erroneously claimed that both blocks experienced a decrease in density after being cut. Similarly, female students who selected the wrong answer offered diverse rationales, including indicating that Block 1 had a greater density, causing it to submerge, while Block 2 had a lower density, resulting in it floating; some female students failed to provide any reasoning, as presented in Figure 2.

Examples of questions and the percentage of student responses in the discussion of Pressure and Hydrostatic Pressure are illustrated in Figure 3 and Figure 4, respectively. Figure 3 illustrates that both male and female students who selected the correct answer provided the accurate rationale, emphasizing that floating and submerged objects achieve equilibrium when the object's weight equals the buoyant force, whereas sinking objects experience a buoyant force smaller than their weight. However, male students who chose the incorrect answer offered diverse explanations, such as suggesting that the buoyancy decreases as the object descends deeper and asserting that a sinking object has a greater weight. Similarly, female students who selected the wrong answer presented various reasons, including incorrectly stating that the floating object experiences the highest buoyancy, while some failed to provide any reasoning, as presented in Figure 4.

DISCUSSION

Based on the findings of this study, it is apparent that male students generally demonstrated higher conceptual mastery compared to their female counterparts, with significant disparities observed between the two genders. Both male and female students exhibited high conceptual mastery in the discussion of Pressure and Hydrostatic Pressure. However, notable differences in conceptual mastery emerged between male and female students in the discussion of Pascal's Law. Despite this, students' conceptual mastery remained low in the discussion of Archimedes' Principle. In terms of classroom dynamics, male students were more actively engaged in the learning process compared to female students. They demonstrated higher participation levels in responding to teacher-provided questions, contributing to their superior conceptual understanding. Conversely, female students tended to be more passive when tasked with answering questions during the learning sessions.

The obtained results align with previous research conducted by Sagala et al. (2019), indicating that male students tend to grasp concepts more effectively than their female counterparts. This is attributed to male students' inclination to understand concepts through experiential learning, while female students typically approach concepts from a theoretical perspective. Additionally, research by Azizah et al. (2021) suggests that female students often struggle in identifying the appropriate concepts to solve problems, further contributing to their weaker conceptual mastery.

Furthermore, the lower interest of female students in science, as highlighted by Harun and Hasruddin (2021) and Pusfarini (2017), also impacts their conceptual understanding. This lack of interest may hinder their engagement and overall mastery of scientific concepts. Regarding the discussion of Archimedes' Principle, the persistent challenge in understanding the positions of floating, sinking, and submerged objects contributes to the observed low conceptual mastery. This difficulty mirrors findings from research conducted by Pamungkas et al. (2017) and Utari et al. (2023), which suggested that larger objects tend to assume deeper positions. Additionally, students' struggle with grasping the concept of buoyancy, as noted in research by Atika et al. (2023) and Sofiuddin et al. (2018), further exacerbates the comprehension challenges surrounding fluid statics principles.

CONCLUSION

This study leveraged a comparative analysis of conceptual mastery between male and female students, coupled with the utilization of multiple-choice questions complemented by reasoning inquiries. This methodology facilitated a comprehensive understanding of students' conceptual grasp. The findings revealed that male students generally outperformed their female counterparts, with significant discrepancies observed between the two groups. While both genders demonstrated proficiency in discussing Pressure and Hydrostatic Pressure, notable variations emerged in their understanding of Pascal's Law. However, both male and female students struggled with conceptual mastery in the discussion of Archimedes' Principle, indicating a need for further support and instruction in this area.

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AUTHOR CONTRIBUTIONS

Each author contributed to the study's conception and design, as well as to data collection, analysis, interpretation, writing, and revision of the manuscript. Additionally, all authors have approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest related to the research, writing, or publication of this paper.

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