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Using an Isomorphic Instrument: What Do Physics Education Students Think About Buoyance?

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Abstract: Physics education students' understanding of buoyancy can differ from student to student and is difficult to know accurately. Appropriate instruments are needed to diagnose the conception of physics education students. This research aims to determine how physics education students think about buoyancy by applying a five-tier isomorphic instrument. The respondents of this research were physics education students at Padang State University who had studied Archimedes' principle regarding buoyancy, totaling 135 people. The research results show that physics education students have different average percentages of correct answers regarding the number of tiers. The average percentage of correct answers in the first tier is 13%, while in the combination of tier 1 and tier 3 (two-tier) is 7%. Overall, the average percentage of correct scores based on tiers one to four (four-tier instrument) on the buoyancy concept is 4%. They are, furthermore, based on isomorphic analysis: ISO-1 = 8%, ISO-2 = 1%, and ISO-3 = 8%. These results are then classified as poor conceptual understanding because the percentage of conceptual understanding obtained is below 30%. The source of physics education students' conceptions comes from personal thoughts about 80%, from observations about 15%, and the rest from other sources.

Keywords: Buoyancy; Conceptual understanding five-tier diagnostic test; Isomorphic

Introduction

Understanding concepts is the process through which an individual thoroughly comprehends a design or an abstract idea, enabling them to categorize an object or event. This understanding is acquired through the learning process. Grasping these concepts is crucial in physics education, as physics is an applied science intricately connected to everyday natural phenomena and occurrences in our surrounding environment (Azahra & Wasis, 2023; Girwidz et al., 2019; Nabilah & Jumadi, 2022). A firm grasp of concepts forms the foundation for practical problem-solving skills. Students with strong problem-solving abilities apply conceptual understanding when addressing challenges or difficulties (Salsabila et al., 2023; Saputra & Mustika, 2022). If students have conceptions that do not follow scientific concepts but still believe in their understanding, they experience misconceptions (Maison et al., 2022; Sandra et al., 2022; Utami & Khotimah, 2023). Thus, it is essential to evaluate students' understanding of concepts to identify the various types of misconceptions that they may experience. According to Yana et al. (2020) and Ramadhan et al. (2020), the Evaluation of conceptual understanding is a crucial aspect to describe the extent to which students understand certain concepts, such as the concept of buoyancy, for example.

Buoyancy is a natural phenomenon that has an important role in various fields of science and technology. Buoyancy is one of the basic concepts in physics, widely applied in everyday life, including the buoyancy of fluids (water, air, etc.). A strong understanding of buoyancy will make it easier for students to understand various natural phenomena and learn more about fluid mechanics.

Over the past few decades, extensive educational research has concentrated on student perceptions and

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methods to identify and improve them (Ansyah et al., 2021). Various research findings, including those involving diagnostic tests, show that students often face challenges related to conceptual understanding or misconceptions (Parhizgar et al., 2022; Suwono et al., 2021).

A diagnostic test is an assessment tool designed to accurately determine a student's strengths and weaknesses in a particular subject (Laliyo et al., 2019; Juliani et al., 2021; Resbiantoro & Setiani, 2022). In this research, the diagnostic test used is a five-tier isomorphic diagnostic test, which is a development of the four-tier test that has begun to be popularly used by several researchers regarding student misconceptions, for example, misconceptions on the topic of work and energy (Maison et al., 2021) and the topic light (Maison, Asrial et al., 2021). The development is done by adding one more tier to determine the source of students' conceptions. The instrument's power in exploring how students' conceptions will increase with the isomorphic pattern, in which several different items are used to explore the same concept.

Based on observations made on high school students in Jambi, it is known that many students do not understand the concepts related to the topic of buoyancy. However, the available research that addresses and identifies students' conceptual understanding of this subject is still limited, mainly using isomorphic instruments as a five-tier assessment. Isomorphic instruments refer to problem formats where one indicator or theme of a question consists of several question items with the same conceptual solution but different forms of representation (Ningsari et al., 2021). A problem is considered isomorphic if solving the problem involves applying the same physics concepts and solving steps. This isomorphic instrument also maps students' ability to understand specific modes of representation and assesses their ability to transfer what they have learned from one context to another. Therefore, this study aims to diagnose students' conceptual understanding of buoyancy through a five-tier isomorphic instrument diagnostic test.

The results of this study are expected to benefit teachers and students; among other things, diagnostic tests serve as valuable information that can be used to improve the quality of learning and increase student competency. This research will assess students' conceptual understanding of buoyancy using an isomorphic instrument in a five-tier format. What is the isomorphic instrument model in a five-tier format, and what is the student's understanding of buoyancy force? This study attempts to provide a valuable overview of information.

Method

This research uses a quantitative descriptive design to determine how physics education students think about buoyancy. The population in this study were physics education students at Padang State University. Sample selection was carried out using a purposive sampling technique, which is used to select samples from a population with criteria determined by the researcher according to the researcher's needs (Denieffe, 2020; Ernawati et al., 2022; Maharani & Bernard, 2018; Sugiyono, 2015). The sample criteria determined by the researchers were students who had studied buoyancy material, so a sample of 135 physics education students at Padang State University was obtained.

The isomorphic instrument used in this research is a diagnostic test with a five-tier format. The instrument in this research is conceptual questions on buoyancy material consisting of eight multiple-choice items with five tiers of questions. The first tier contains the choice of answers to questions, the second tier contains confidence in the answer to the question, the third tier contains the reasons for the answer to the first tier question, the fourth tier contains confidence in the reasons given at the third tier, and the fifth tier contains sources of information used by students in answering and giving reasons. All instrument items contain isomorphic questions requiring the same knowledge of buoyancy. However, if divided into smaller groups, there are three isomorphic parts, as shown in Table 1.

Table 1. Diagnostic Test Question Grid

Isomorphic Aspects	Number of Items	Question Number
The buoyant force of two objects at different positions (ISO 1)	2	1, 2
Buoyant force due to the volume of fluid being separated (ISO 2)	3	3, 5, 8
Buoyancy and density (ISO 3)	3	4, 6, 7

Based on Table 1, it is known that the isomorphic buoyancy instrument consists of eight items, which are divided into three isomorphic aspects, namely (a) the buoyant force of two objects in different locations (ISO-1), (b) the buoyant force due to the volume of fluid separated by the object (ISO-2), and (c) buoyancy and density (ISO-3). The following examples of items are taken from the ISO-1 group of instruments (Figure 1).

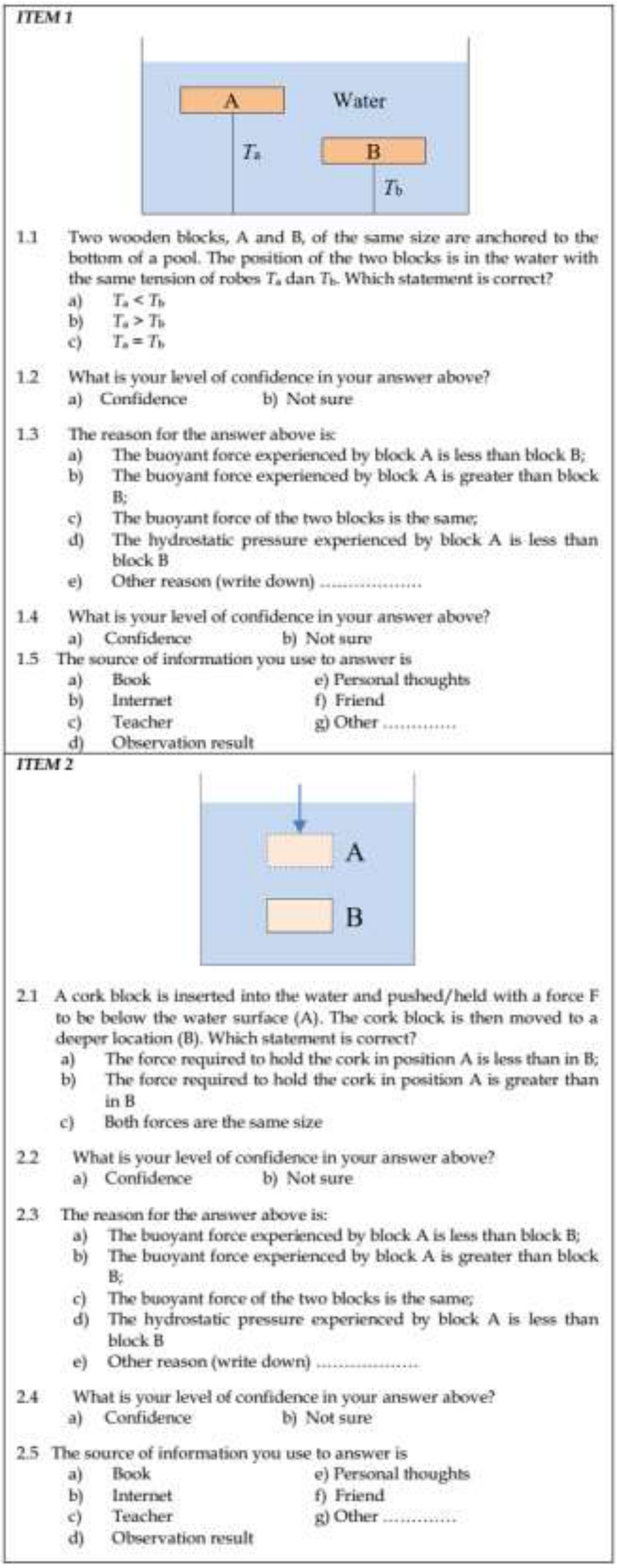

Figure 1. Example of a five-tier isomorphic instrument items (ISO-1)

The scoring method for tiers one to four for each item on the instrument follows the scoring method on the four-tier instrument (Maison et al., 2019). The fifth tier is not given a score, but the percentage is calculated to determine the source of students' conceptions. Next, isomorphic scoring is determined based on the score contribution of each item in the same group (Table 2).

Table 2. Example of Scoring on ISO-1, Which Consists of Two Items

	Item 1		Item 2		ISO-1
	Choice	Score	Choice	Score	Score
1st tier	Answer Correct	1	Answer Correct	1	1
1st, 3rd tier	Answer Correct, Reason Correct	1	Answer Correct, Reason Wrong	0	0.50
1st – 4th tier	Answer Correct, Sure. Reason Correct, Sure	1	Answer Correct, Sure Reason Wrong, Sure	0	0.50

Based on the scoring example in Table 2, it can be seen that there is an inconsistency in a respondent's conception, where based on the answers to Item-1, students are categorized as having a good understanding of concepts (score 1 for 1st – 4th tier), while based on Item-2 students are categorized otherwise (score 0 for 1st – 4th tier). Therefore, in the ISO-1 category, students only get a score of 0.5, the average score of students' answers to the two items.

Result and Discussion

The results of the analysis of raw data based on the correct answer key for tier 1, tiers 1 and 3, and tiers 1 to 4 obtained correct scores for respondents with percentages, as shown in Table 3.

Table 3. Percentage of Correct Answers in Terms of Number of Tiers

Item	1st tier	1st, 3rd tier	1st – 4th tier
Item 1	17	13	11
Item 2	7	5	5
Item 3	11	6	1
Item 4	1	1	0
Item 5	10	4	0
Item 6	13	10	7
Item 7	13	12	9
Item 8	32	3	2
Mean	13	7	4

Based on the data in Table 3, it can be seen that physics education students have different average percentages of correct answers in terms of the number of tiers. The average percentage of correct answers in the first tier is 13%, while the average percentage in the combination of tier-1 and tier-3 (two-tier) is 7%. Overall, the average percentage of correct scores based on levels one to four (four-tier instrument) on the buoyancy concept is 4%. These results are then classified as poor conceptual understanding because the percentage of correct scores obtained is below 30%. These results confirm that the highest level of misconception is in the sub-concepts of Archimedes' law, as (Hunaidah et al. (2022) found. If the data in Table 3 is presented in graphical form depicting the percentage of students' correct answers at one, two, and four tiers, then the results will look like in Figure 2.

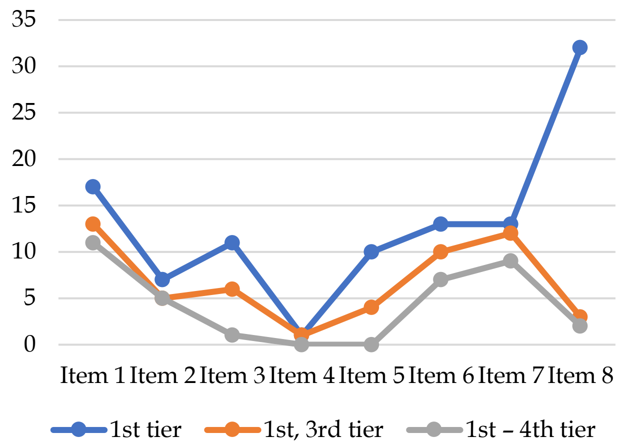

Figure 2. The average percentage of correct scores for physics education students

Figure 2 shows that the ranking order average percentage from highest to lowest is one, two, and four-tier, respectively. The rate of correct scores in the first tier for all items is around 17%. The percentage score on the first tier is always higher because the score is only determined by the answers to the first tier (similar to ordinary multiple-choice questions), without paying attention to the reasons for the answers and confidence in the answers or explanations given. Therefore, if a student answers correctly in the first tier, this does not necessarily indicate a strong understanding of the concept because the correct answer could be due to chance or the student's guess.

Furthermore, the percentage of correct scores for the two-tier item, based on answers to tier-1 and tier-3, is around 7%, lower than the percentage of correct scores for tier-1 alone. This happens because the combined assessment of the two tiers is carried out by considering both the answers and reasons given by students. If the answer and explanation are correct, the score is 1. However, if there is a combination of correct answers and wrong reasons or vice versa, the score is 0.

Additionally, the percentage of correct scores for all tiers is around 4%, which indicates a low baseline score. The assessment considers the students' answers, reasons, and confidence level in choosing answers and reasons. If the answer and reason are correct, and the student's level of confidence is high, then the score given is 1. However, if the answer or reason is wrong or the student is unsure about the answer or reason, then the score given is 0.

Finally, it is necessary to see how physics education students' conceptions are based on the concepts contained in each item. Several different things can be completed similarly and aim to measure the same conception (isomorphic), see Table 1. So, in Table 4 and Figure 3, data from three isomorphic groups of all the items tested can be presented.

Table 4. Average Percentage of Correct Score in Terms of Isomorphic Aspect

Isomorphic Aspect	1st tier	1st, 3rd tier	1st – 4th tier
ISO-1	12	9	8
ISO-2	18	4	1
ISO-3	9	8	8

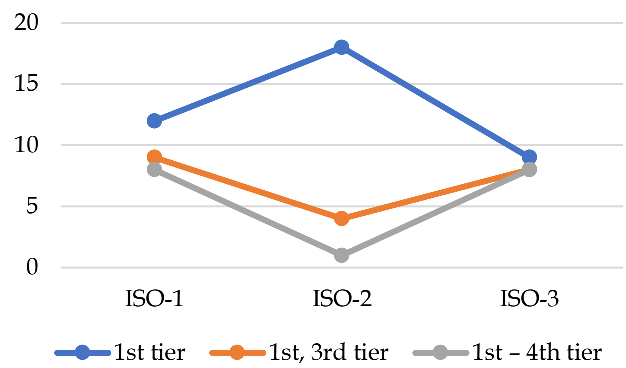

Figure 3. Average percentage of correct score in terms of isomorphic aspect

Based on the average correct score of physics education students in understanding concepts based on isomorphic aspects, it can be seen that ISO-2 has the highest score in the 1st tier but the lowest for the first and third tiers and all four tiers. This means some incorrect reasons for the concepts in ISO-2 accompany the correct answers.

The source of conception for ISO-1, ISO-2, and ISO-3 was obtained from the 5th tier of the five-tier format buoyancy isomorphic instrument used in data collection. Figure 4 displays the sources of conception used by physics education students.

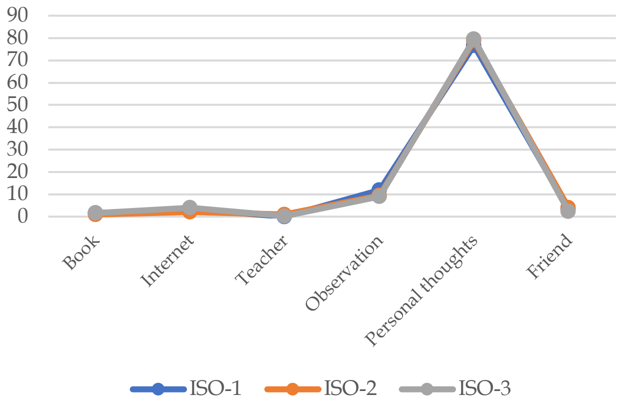

Figure 4. The sources of conception

It can be seen in Figure 4 that the information sources used by physics education students at ISO-1, ISO-2, and ISO-3 are almost the same, so the graphs almost coincide. It turns out that most students' conceptions (around 80%) originate from their thoughts, while about 15% originate from their observations of natural phenomena. The rest comes from books, the internet, teachers, and friends, with a smaller percentage.

Referring to the research results using the isomorphic buoyancy instrument contained in the items in ISO-1, namely Item 1 and Item 2 (Figure 1), the following conceptions of physics education students were obtained.

Conception 1 (ISO-1)

According to data obtained from Item 1, most students think the tension in the rope on wooden block A is smaller than that on wooden block B, namely the answer choice "a) Ta < Tb." Students think the buoyancy force experienced by wooden block A is smaller than by wooden block B because wooden block A is closer to the water's surface. They assume that the closer to the water's surface, the smaller the buoyant force will be. Some of them relate this to the principle of hydrostatic pressure and assume that the hydrostatic pressure experienced by wooden block A is smaller than that of wooden block B. Because the two wooden blocks have the same size and mass, wooden block A is the one that is closer to the water surface and will experience less hydrostatic pressure than block B, which is far from the water surface. Therefore, the tension in the rope on wooden block A will also be smaller than in the string on wooden block B.

The same conception as above was also revealed from their answers to Item 2. Many students chose solution "a"; the force required to hold the cork in position A was smaller than in position B. Students who chose this answer assume that the power needed to keep the pin in position A is more minor because they believe that the hydrostatic pressure in position A is smaller than in place B. This is because the cork in position A is closer to the water's surface, so the hydrostatic pressure will also be smaller. Therefore, the smaller the hydrostatic pressure, the smaller the buoyant force and the smaller the force required to hold the cork.

Conception 2 (ISO-1)

There is also a different conception found from student's answer to Item 1, namely that according to students, the correct answer is that the tension in the rope on wooden block A is greater than the tension in the string on wooden block B, namely the answer choice is "b) Ta > Tb." This conception is based on their view that the buoyancy force experienced by wooden block A is greater than that of wooden block B. Wooden block A, located closer to the water surface, will experience a greater buoyant force than wooden block B, located further from the water surface. They argue that because wooden block A has a greater buoyancy, the rope tension acting on wooden block A will also be greater than the rope tension working on wooden block B.

Not only that, other students have the same answer and conception based on the question in example Item 2. They also think that the correct answer is answer choice "b," namely, the force required to hold the cork in position A is more significant than in B. This is due to their conception of Archimedes' principle and the buoyant force in liquids, where the buoyant force in position A is more significant than in position B, so greater power is needed to hold the cork from rising to the water's surface. They assume that the closer an object is to the surface of the water, the greater the buoyant force, so greater power is needed to balance the buoyancy and prevent the thing from rising.

However, the student's conception needs to be corrected. The correct answer to the question in sample Item 1 and Item 2 is the answer choice "c) Ta = Tb" because the buoyant force experienced by both blocks is the same. In this case, the scientific conception is that the buoyancy experienced by wooden blocks A and B is the same because the size and mass of the two blocks are identical based on the principle of Archimedes' law. Archimedes' law states that any object in a fluid (such as water) will experience a buoyant force equal to the weight of the fluid displaced by the thing (Elaty & Ghazy, 2018; Elisa et al., 2022; Yanarti et al., 2022).

The buoyant force does not depend on the position of the block from the surface of the water but instead on the volume of water displaced by the block (Rismaningsih & Nurhafsari, 2022). Because wooden blocks A and B have the same size and mass, the volume of water displaced by them when they are in water is also the same. For example, assume that wooden block A and block B have a mass of 0.8 kilograms, each with a volume of 1000 cm3 (1 liter). When wooden block A sinks in water, it will push out 1 liter of water to make room for it. Likewise, wooden block B will separate 1 liter of water to be in that place.

With this principle, the buoyant force experienced by wooden blocks A and B is the same because both push the same volume of water while in the water. This means that the tension in the rope or the force acting on wooden blocks A and B will also be the same because the tension in the string is determined by the buoyant force experienced by the block when it is in the water. By understanding this concept, we can know that the answer by scientific concepts is "c) Ta = Tc."

The factors causing this misconception are students not understanding the concept of density of substances and incomplete/wrong reasoning (Hunaidah et al., 2022). These misconceptions can be traced back to early childhood and are also observed in secondary school students (Beniermann, 2019; Beggrow & Sbeglia, 2019; Aptyka et al., 2022). Students spontaneously express their ideas without researching or reasoning. This is in line with research conducted by Yudhittiara et al. (2017) that the highest misconceptions are found in the material on Archimedes' law. Students do not understand that the condition of an object is not influenced by the size of the object but is influenced by density, mass, and volume.

Based on the misconceptions that occur in students, to minimize student misconceptions, teachers should choose learning methods that are appropriate and appropriate based on the material to be taught. In addition, teachers should provide evaluation questions that can measure or identify whether students do not understand concepts or experience misconceptions about material that has been taught (Maison et al., 2019; Mukramah et al., 2023).

Conclusion

Based on the research results, data analysis, and discussion, it can be concluded that the isomorphic buoyancy instrument in a five-tier format can reveal how physics education students think about buoyancy. Based on students' responses on tiers 1 - 4, which involve answers, confidence in answers, reasons, and confidence in the reasons given, it is indicated that they have high misconceptions. Further analysis is needed to investigate these misconceptions. Meanwhile, based on the fifth tier, the sources of students' conceptions are known, which are dominated by their thoughts.

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Author Contributions

Conceptualization, methodology, designing isomorphic instruments in a five-tier format, formal analysis, writing - review, and editing, M; H. and D.A.K.; investigation by applying isomorphic instruments to collect data, H and D. A. K; analyzed data and wrote the initial draft of the article, R. F.

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Conflicts of Interest

The authors declare no conflict of interest.

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