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Development of Four-tier Diagnostic Test Instrument to Introduce Misconceptions and Identify Causes of Student Misconceptions in the Sub-topic of Bernoulli's Principle

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Abstract: The objective of this study is to create a misconception test instrument for identifying and understanding misconceptions in students regarding Bernoulli's Principle, particularly during hybrid learning. The validity and reliability of the test instrument are described in order to assess its effectiveness. Descriptive analysis techniques were employed to analyze the data. The findings revealed that the test instrument exhibits high validity (94.16%) and reliability (0.72%). On average, 34.9% of students were found to possess misconceptions regarding the sub-topic of Bernoulli's Principle. Item number 5 was identified as having the highest misconception rate (53%), specifically in relation to determining the speed of airflow above and below an aircraft's wings. These findings indicate that some students lack a comprehensive understanding of the fundamental concepts underlying Bernoulli's Principle, relying solely on its equations. Consequently, this research suggests that teachers can mitigate misconceptions and identify their causes by employing a four-tier diagnostic test, especially in the context of the sub-topic of Bernoulli's Principle.

Keywords: Hybrid learning; Misconceptions; Students.

Introduction

A lack of comprehensive understanding of physics learning materials often results in difficulties for students when it comes to problem-solving and grasping concepts. Consequently, many students develop misconceptions while studying physics. Misconceptions in physics can occur at any educational level, including high school, vocational school, and college, affecting students, learners, and even teachers or lecturers. Students with different mental structures can develop unscientific concepts as they construct knowledge in their minds. When a student's conception differs from the scientific conception, it is referred to as a misconception. Previous researchers have demonstrated that students' misconceptions act as barriers to their learning progress and may persist even after instruction (Ferdinand, 2014). Understanding concepts is crucial in the learning process as it allows learners to retain knowledge for an extended period, even after a considerable time has passed since the concept was taught (Sheftyawan, Prihandono, & Lesmono, 2018). Conversely, a lack of understanding can hinder the learning process, as learners need a solid grasp of a concept to comprehend subsequent concepts (Monita & Suharto, 2016). Misunderstandings arise when the concepts derived from personal experiences do not align with scientifically accepted concepts (Erdogan, 2003 in Balci & Gölcü 2020). In the Curriculum 2013, physics is a subject that necessitates a deep understanding of specific concepts within the field.

A teaching system is an application of the curriculum by educational institutions with the aim of guiding students towards achieving predefined goals (Nisa & Agung, 2014). The system's significance lies in its ability to actively engage students in the learning

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process, facilitate character development, cultivate a positive learning environment, and promote a sense of fulfillment among learners. Students become more receptive to the knowledge they acquire as they perceive it as preparation for their future endeavors. In the field of physics, the goal is to equip students with a mastery of physics concepts and their application in everyday life (Saputri & Nurussaniah, 2015). This allows students to develop a synchronized understanding of physics concepts supported by relevant literature and expert consensus. Understanding physics concepts forms the foundation upon which students can then translate these concepts into exclusive formulas during physics lessons (Amin, Wiendartun, & Samsudin, 2016).

However, in practice, classroom learning activities still tend to revolve around the teacher as the primary source of knowledge. Research findings indicate that a significant portion (66.20%) of teachers still rely on conventional teaching methods when explaining dynamic fluid concepts (Sholihat, Samsudin, & Nugraha, 2017). Consequently, students become passive participants in the learning process (Alfiyah, Bakri, & Raihanati, 2016; Nugraha, Kaniawati, Rusdiana, & Kirana, 2016). This signifies a hindrance to information absorption since students may not always fully grasp the information conveyed by the teacher, particularly in physics, where scientific concepts are introduced. As a result, students may not always comprehend the concepts that experts consider valid (Syahrul, 2015). Therefore, students' misconceptions of physics concepts can be regarded as errors stemming from a lack of understanding.

Mursalin (2014) emphasized that physics learning places importance on understanding concepts rather than mere memorization. Physics learning not only introduces new ideas to students but also necessitates updating existing ideas based on their experiences. By employing the scientific thought process, this process aids students in bridging the divide between their existing knowledge and the assimilation of new concepts, principles, rules, and theories. As students progress to new stages of learning, they bring with them the original knowledge obtained from their environment (Zuhri, 2014). However, obstacles still exist in physics learning that impede students' understanding of the subject matter, resulting in misconceptions. In line with Suparno's (2005) findings, misconceptions can be attributed to a range of factors, as highlighted by Yuliati (2017), including “students' preconceived notions or initial concepts, associative thinking, humanistic thinking, incomplete or incorrect reasoning processes, erroneous intuition, students' cognitive development stage, their abilities, and their level of interest in the subject.” Consequently, it is crucial to promptly address the conflicts caused by misconceptions in physics subjects, as they hinder students' comprehension of scientific concepts (Alfiani, 2015). Supporting this, a previous study conducted on the concept of Dynamic Fluids found that 42.61% of students potentially experienced misconceptions (Sholihat et al., 2017).

The utilization of diagnostic tests proves to be an effective approach in identifying misconceptions among students. Diagnostic tests enable accurate determination and identification of a student's strengths and weaknesses in specific subjects, including physics (Zaleha & Nugraha, 2017). The implication of Zaleha and Nugraha's (2017) research is that teachers can develop and utilize diagnostic tests to precisely identify a student's strengths and weaknesses based on the discipline or subject being taught, thereby reducing misconceptions among students.

Fariyani and Rusilowati (2015) assert that “the four-tier diagnostic test is an advancement of the three-level multiple-choice diagnostic test.” It has several advantages, such as the ability to diagnose students' misconceptions in-depth by analyzing their answers and reasons. Furthermore, the four-tier diagnostic test incorporates students' confidence levels in their answers, facilitating differentiation based on both the chosen answers and the reasons provided. This approach enhances the understanding of students' conceptual comprehension, identifies specific areas of the material that require further emphasis, and assists teachers in planning lessons to effectively address and reduce student misconceptions.

Setiawan (2020) found that 23 questions were suitable for testing students' understanding of concepts. The study discovered 70 misconceptions among students in seven fluid-related topics. The most common misconception, making up 46.5% of cases, was about the buoyancy force. Students mistakenly believed that the deeper you go in a fluid, the stronger the buoyant force becomes. This misunderstanding was influenced by their everyday intuition and how they understood the concept. The smallest misconception, found in 35.2% of cases, was related to applying Pascal's law.

Data analysis and identification results from Sholihat et al. (2017) demonstrate that in the sub-topic of the principle of continuity in dynamic fluid material, student conceptions can be categorized as follows: “6% exhibit conceptual understanding, 35% have partial understanding, 28% possess misconceptions, 30% do not understand the concept, and 0% cannot be coded.” The study concludes that “in dynamic fluid material, particularly in the sub-topic of the principle of continuity, 28% of misconceptions were identified using a four-tier diagnostic test instrument.” This is due to students' belief that in a small pipe, the fluid exhibits high velocity as a result of the large fluid pressure.

Rusilowati (2015) emphasizes the benefits of utilizing the Four-Tier Test in uncovering misconceptions. This test provides more detailed insights by considering students' confidence levels in their answers and explanations. It also helps pinpoint areas that require further clarification. Therefore, developing a Four-Tier Test instrument is crucial for effectively identifying misconceptions and creating a reliable diagnostic tool.

This study introduces a novel approach to identify and rectify misconceptions among students regarding Bernoulli's Principle in the context of hybrid learning. The uniqueness of the research lies in its application of a four-tier diagnostic test, which assesses not only correctness but also students' confidence and reasoning. Focused on Bernoulli's Principle, the study delves into specific misconceptions prevalent in this domain. The test instrument's rigorous validation process adds credibility to its application. Overall, the study advances educational assessment methods by combining innovation, targeted focus, and rigorous validation to enhance understanding and address misconceptions in a hybrid learning environment.

The objective of this study is to describe the validity and reliability of the misconception test instrument. By doing so, it aims to identify misconceptions among students and investigate their underlying causes. The specific focus of this research is on hybrid learning within the Bernoulli Principle Sub-topic using a four-tier diagnostic test.

Method

The development of this test instrument follows a research design model known as 3D + 1I, which includes the defining, designing, developing, and implementing stages (Aminudin et al., 2019; Malik, Setiawan, Suhandi, Permanasari, & Sulasman, 2018). In the defining stage, the research literature on misconceptions related to Bernoulli's material was reviewed. In the designing stage, a test instrument in the form of a two-tier open-ended test was created to assess understanding of Bernoulli's material. The developing stage involved transforming the two-tier open-ended test into a four-tier open-ended test through a preliminary study that involved students and expert input. Lastly, in the implementation stage, the four-tier open-ended test instrument was administered to students.

The process of developing the test questions for the instrument incorporated elements related to students' confidence levels. Students were asked to choose answers and provide reasons while indicating their level of confidence for each response.

The initial level of the test instrument consists of multiple-choice questions that present four options, with students selecting the correct answer among them. The second level involves assessing student confidence levels based on their belief in the chosen answers. The third level consists of student reasoning for their answers, offering four pre-listed options and an additional open-ended option. Lastly, the fourth level measures student confidence in the chosen reason for their answer (Amin et al., 2016).

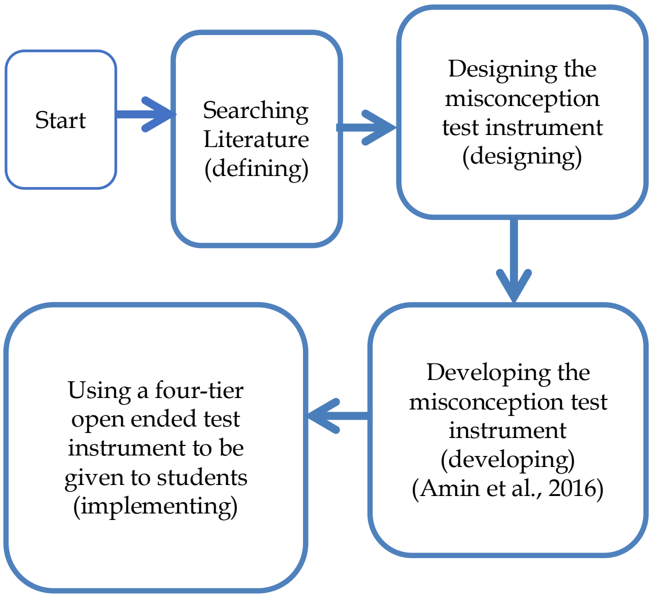


Figure 1. the research design (3D+1I)

The diagnostic test offers several notable advantages to the educational landscape. Firstly, it facilitates the differentiation of confidence levels among students, affording teachers a valuable tool to gauge the certainty students hold in their responses and the rationale they provide, thereby illuminating the depth of their conceptual grasp. Secondly, the test serves as a potent instrument for unearthing intricate misconceptions harbored by students, enabling educators to delve deeper into these misconceptions and unravel the underlying cognitive pitfalls. Thirdly, it aids in pinpointing precise areas within the subject matter that demand heightened attention, allowing for a targeted approach to effectively rectify student misunderstandings. Lastly, the insights gleaned from the diagnostic test empower teachers to devise more refined and effective pedagogical strategies, harnessing their understanding of student misconceptions to tailor learning methodologies that ameliorate and ultimately mitigate these misconceptions, as proposed by Amin et al. (2016). In essence, the diagnostic test emerges as a pivotal tool, transcending mere assessment to become a catalyst for nuanced instruction and enhanced comprehension. Table 1 provides an overview of consolidated misconception test instruments that have been developed and will be further described.

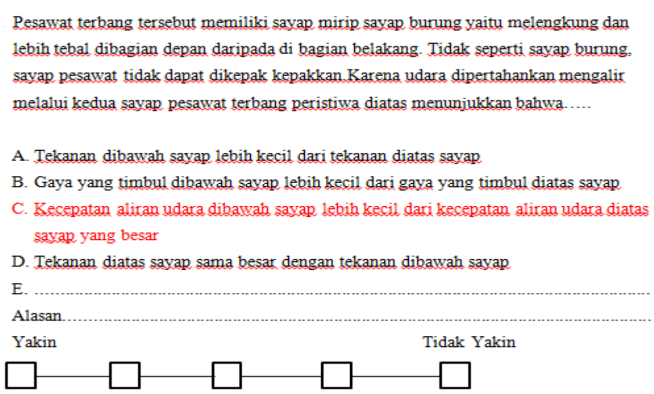
Table 1. Consolidated misconception test instrument

Category	Option	Reason	Level of Confidence	F
High Misconception	False and Sure	False	Sure	19 Peoples
Partially grasp the concept	Correct and Fairly Sure	Correct	Fairly sure and correct	6 Peoples
Understand the concept	Correct and Sure	Correct	Sure and True	4 Peoples
Cannot be encoded	Did not choose an option	No Reason	Not Choosing	1 People
Does not understand the concept	Wrong	Wrong	Less sure, fairly sure	6 Peoples
		Total	36 Peoples	100 %

This study employed the one-shot research method (Sugiyono, 2017). The test instrument consisted of 10 items, which were administered to 36 students in the eleventh grade of IPA in Kutai Kartanegara. The research process consisted of the following stages: 1) Development of Misconception Test Instrument Questions; 2) Expert Evaluation of the Diagnostic Test Instrument; 3) Data Collection; 4) Data Processing and Analysis; and 5) Drawing Conclusions.

Result and Discussion

The processed results of the research indicate a weak understanding of concepts in the sub-topic of Bernoulli's principle, which contributes to student misconceptions. These misconceptions were identified by analyzing the choices of students' confidence levels in the form of answers on the developed misconception test instrument, specifically in the second and fourth tiers. The causes of these misconceptions were identified by examining students' choices in the reason element of the third tier. To illustrate, an example of a developed misconception test instrument is provided. This four-tier test was utilized to assess student misconceptions and identify the consequences or causes of these misconceptions. In the third tier, column E is provided as a blank space where students can provide their answers if they believe they have the correct response for each item on the developed misconception test instrument.


Pesawat terbang tersebut memiliki sayap mirip sayap burung yaitu melengkung dan lebih tebal dibagian depan daripada di bagian belakang. Tidak seperti sayap burung, sayap pesawat tidak dapat dikepak kepakkan.Karena udara dipertahankan mengalir melalui kedua sayap pesawat terbang peristiwa diatas menunjukkan bahwa.....

A. Tekanan dibawah sayap lebih kecil dari tekanan diatas sayap
B. Gaya yang timbul dibawah sayap lebih kecil dari gaya yang timbul diatas sayap
C. Kecepatan aliran udara dibawah sayap lebih kecil dari kecepatan aliran udara diatas sayap yang besar
D. Tekanan diatas sayap sama besar dengan tekanan dibawah sayap
E. ....
Alasan..........
Yakin Tidak Yakin

Figure 2. Sample Questions of the Developed Four-Tier Test Instrument

The evaluation of the test instrument was conducted by two expert lecturers using a review sheet. Each item was assessed based on 20 aspects, which included material, construction, and language. The assessment was performed on a total of 10 items to ensure the instrument's validity and identify areas that required improvement (Fariyani & Rusilowati, 2015). The percentage of instrument validity and students' misconceptions for each question are presented in Table 2.

Table 2. Percentage of instrument validation and students' misconceptions

Indicator	Aitem	Validity (%)	Reliabilities (%)	Misconception (%)
Point-1	1	91,67	85,71	30 %
Point-2	2	100	100	22 %
Point-3	3	100	100	27 %
Point-4	4	100	100	33 %
Point-5	5	91,67	85,71	53 %
Point-6	6	100	100	41%
Point-7	7	91,67	85,71	44 %
Point-8	8	91,67	85,71	36 %
Point-9	9	100	100	25 %
Point-10	10	75	100	38 %
Average		94,16	94,28	34,9 %
Category		Good	Good	Not Good

In Table 2, the theoretical validity of the instrument is 94.16%, indicating a high level of validity. A valid instrument ensures that it measures the intended aspects accurately (Sugiyono, 2013).

In this study, all indicators of the misconception test instrument were found to be reliable as the instrument consistently revealed the occurrence of students' misconceptions on the Bernoulli sub-topic (Cortina, 1993)(Ebel & Frisbie, 1972) (Cronbach, 1951; de Vet, Mokkink, Mosmuller, & Terwee, 2017; McNeish, 2018; Poitras et al., 2019).

The findings from the application of the Four-Tier Test revealed that students exhibited misconceptions in the Membrane Transport material, with an average percentage of 34.9%. The specific percentage of student misconceptions for each question can be found in Table 2. Through data processing, valuable insights were obtained regarding the different categories of students' conceptions related to the Bernoulli principle sub-topic, as illustrated in Figure 3.

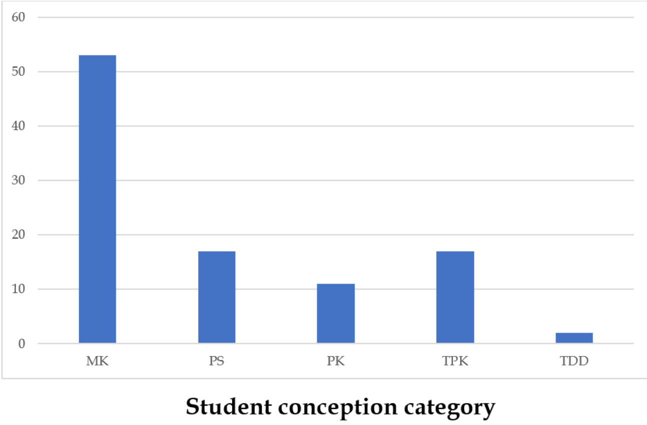


Figure 3. Percentage Category of Students' Conceptions on The Bernoulli's Principle Sub-Topic

Information :
MK : Misconceptions
PS : Partial Understanding
PK : Concept Understanding
TPK : Do not understand the concept
TDD : Cannot be coded

Based on the analysis of Figure 3, the research findings provide insights into the distribution of student conceptions within different categories. The percentages of students falling into each category, including "conceptual understanding, partial understanding, misconception, not understanding the concept, and inability to be coded, are as follows: 11% of students demonstrate a conceptual understanding, 17% exhibit partial understanding, 53% hold misconceptions, 17% lack understanding of the concept, and 2% cannot be classified due to their responses in the four-tier diagnostic test instrument." These percentages shed light on the prevalence of misconceptions among students and emphasize the need for targeted interventions to address these misunderstandings.

It is worth noting that misconceptions are not solely a result of the research instrument but can also occur during the classroom learning process. Classroom instruction plays a critical role in shaping students' understanding of physics concepts, and it is crucial for teachers to be aware of the common misconceptions that students may develop. By identifying these misconceptions and understanding their underlying causes, teachers can tailor their instructional strategies to effectively address and correct student misunderstandings.

To mitigate misconceptions during classroom learning, teachers can adopt various instructional approaches. For example, they can incorporate hands-on experiments and demonstrations that allow students to directly observe the principles of physics in action. Engaging in collaborative problem-solving activities and discussions can also encourage students to actively participate in the learning process and challenge their misconceptions through peer interactions.

Moreover, providing explicit and targeted feedback to students can help clarify misconceptions and guide them towards a more accurate understanding of the concepts. Teachers can use formative assessment strategies, such as quizzes or concept mapping exercises, to gauge students' understanding and address misconceptions in real-time. By addressing misconceptions promptly and providing ongoing support, teachers can facilitate the process of conceptual change and promote a deeper understanding of physics principles.

Furthermore, creating a supportive and inclusive classroom environment is crucial for students to feel comfortable expressing their thoughts and asking questions. Encouraging open discussions and fostering a growth mindset can help students recognize that misconceptions are a natural part of the learning process and that they can be overcome through effort and reflection.

In conclusion, the research findings provide insights into the distribution of student conceptions within different categories, highlighting the prevalence of misconceptions in the studied sub-topic. By recognizing the occurrence of misconceptions and employing effective instructional strategies, teachers can play a vital role in helping students overcome their misunderstandings and develop a more accurate and comprehensive understanding of physics concepts. Through targeted interventions, ongoing support, and a positive classroom environment, teachers can promote conceptual change and facilitate meaningful learning experiences for their students.

In Figure 2, the graph displays the percentage of categories in dynamic fluid material, specifically the Bernoulli's principle sub-topic, where misconceptions arise. On average, 53% of the items in the dynamic fluid material related to the Bernoulli's principle sub-topic resulted in misconceptions. This can be attributed to students' intuitive understanding, which leads them to misconceptualize dynamic fluid material, particularly the Bernoulli's principle. Additionally, the lack of learning models that can foster students' conceptual understanding contributes to the issue. Unfortunately, teacher-centered learning approaches are still prevalent, making it challenging to develop students' understanding and build concepts without student-centered activities. Similarly, learning models often neglect the incorporation of strategies that can enhance students' conceptual understanding. The analysis of this study introduced the following student category percentages for the Bernoulli sub-topic: 17% of students had a partial understanding, 11% had a conceptual understanding, 53% had misconceptions, 2% could not be coded, and 17% did not understand the concept. In conclusion, this research identified misconceptions in dynamic fluid material, particularly in the sub-topic of Bernoulli's principle, using a three-tier diagnostic test instrument. The indicator related to determining the flow velocity below and above the aircraft wing contributed to the 53% misconception rate due to students' limited understanding, primarily focusing on equations rather than grasping the fundamental concepts effectively.

Based on Figure 2, the level of misconception in this question item is 75%. The question focuses on the application of Bernoulli's principle to aircraft. This question can be categorized into four different conceptions. Approximately 25% of students have the correct conception, while very few students believe that the flow velocity under the wing is smaller than the airflow velocity above the wing. The majority of students hold misconceptions related to the relationship between the airspeed and the top and bottom of the wing.

Students who chose options A and D fail to realize that the pressure under the wing is greater and the pressure above the wing is less. Consequently, they incorrectly assume that the pressure under the wing is lower than the pressure above the wing or that the pressure is equal above and below the wing. Students who selected option B also have the misconception that the force under the wing is smaller than the force above the wing, which is actually the opposite.

Furthermore, students who chose answers A and B, as well as D and E, demonstrate a failure to understand that the equation $v_A > v_B$ implies $p_A > p_B$. A simple example that illustrates the application of Bernoulli's principle is seen in birds' ability to fly. In this case, the principle is applied accordingly. The air moving over the bird's wings creates lower pressure above the wings compared to the pressure beneath the wings. Consequently, the speed above the bird's wings is higher due to the low pressure, while the air velocity beneath the wings is relatively smaller due to the higher pressure. This difference in air velocity results in the existence of lift force. Bird wings are curved and thicker at the front than at the back, further supporting the application of Bernoulli's principle in flight.

The air passing over the top of the wing follows a longer path, resulting in higher speed compared to the airflow beneath the wing. This velocity difference contributes to the generation of lift force, which exceeds the weight of the bird, enabling it to fly. Additionally, as the wings move downward, they push the air backward. According to Newton's third law, the air pushes forward, propelling the bird in the opposite direction. When the wings move upward, they twist, allowing air to pass between the slightly spread feathers, thereby reducing drag.

Aerodynamics involves the application of Bernoulli's principle to the lifting force of an airplane. According to Lubis (2020), objects flying in the air experience various forces, including upward pressure force, lift force (thrust), weight force of the aircraft (weight), and friction force with air (drag). The curved shape of the top side of an airplane causes the air to flow faster above the plane than beneath it. Consequently, the pressure above the plane is lower compared to below the plane. This pressure difference, as noted in the research by Jumini (2018), results in the production of lift force, enabling the aircraft to ascend. The ability of an aircraft to fly depends on factors such as its speed, weight, and wing size. A larger wing size leads to a greater lifting force, facilitating flight.

Relevant research, such as the study conducted by Aprita, Supriadi, and Prihandono (2018), indicates that high school students' understanding of dynamic fluid material, assessed using the four-tier test, can be categorized into several groups. The findings show that 29.21% of students have misconceptions, 7.09% do not understand the concept, 22.86% understand the concept, 34.92% partially understand the concept, and 5.93% provide incomplete answers at each level of the question, making it difficult to code their responses.

Multiple studies highlight students' lack of understanding in physics concepts, particularly in static fluid and dynamic fluid subjects. For instance, research by Yadaeni and Kusairi (2016) reveals low mastery of static fluid concepts, with an average score of 49.51 on a scale of 0 to 100. Students struggle with problem-solving related to hydrostatic pressure in vessels and Pascal's principle.

Similarly, Alfensianita and Tandililing (2016) conducted research involving 29 students, which found that 7% of students had misconceptions regarding the relationship between cross-sectional area and fluid velocity in horizontal pipes, 58.6% had misconceptions regarding the comparison of fluid discharge in horizontal pipes with different cross-sectional areas, 65.5% had misconceptions regarding the relationship between fluid velocity and pressure in blown paper events, and 24% had misconceptions regarding the relationship between fluid velocity and pressure passing through the wings of an airplane.

The current findings are in line with Susanti (2013), which focused on student misconceptions in the realm of dynamic fluid material. Susanti's study specifically identified misconceptions in various concepts, including the continuity equation, Bernoulli's principle, Torricelli's theory, venturimeter pipe, and aircraft lift force. The findings of the current study, which also highlight student misconceptions in the sub-topic of Bernoulli's principle, further support and reinforce the patterns observed in Susanti's research. These consistent findings across different studies underscore the prevalence of misconceptions in these specific fluid-related concepts among students.

Conclusion

The research findings and subsequent discussions lead to the conclusion that the misconception test instrument, employing the Four-Tier Test approach for the Membrane Transport material, exhibits a high level of validity and reliability. The test instrument demonstrates a validity percentage of 94.16% and a reliability coefficient of 0.72. These results affirm the effectiveness and trustworthiness of the test instrument in accurately assessing student misconceptions in the context of the Membrane Transport material. Despite this, there are still students who exhibit misconceptions, with an average misconception rate of 34.9%. The highest misconception occurs in item number 5, specifically, 53% of students struggle with the indicator of determining the flow velocity below and above the wing of the plane. This suggests that some students lack a comprehensive understanding of the Bernoulli sub-topic, as they only grasp the Bernoulli equation without fully comprehending the fundamental concepts of the sub-topic. To address this, teachers can develop and implement a four-tier diagnostic test to help mitigate misconceptions among students.

Author Contribution

Jumilah : writing-original draft preparation, result, discussion, methodology, conclusion; Wasis: analysis, proofreading, review, and editing.

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Conflicts of Interest

The authors declare no conflict of interest.

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