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Analysis of Students' Problem-Solving Skills and Learning Difficulties in Dynamic Fluid Topics through a Preliminary Study in Physics Education

[1]Azrisa Mutia, [1]Muhammad Minan Chusni*
[1]UIN Sunan Gunung Djati Bandung, Jawa Barat, Indonesia

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Corresponding Author
Muhammad Minan Chusni
Universitas Islam Negeri Sunan Gunung Djati Bandung, Indonesia
*E-mail:
minan.chusni@uinsgd.ac.id

ABSTRAC

This study examines a fundamental question: how students' problem-solving skills develop and what difficulties they face in learning fluid dynamics. The research is positioned within physics education, focusing on the importance of conceptual understanding and problem-solving skills.A qualitative descriptive approach was applied using triangulation methods, including diagnostic tests, interviews, and classroom observations. The diagnostic test measured students' ability to analyze problems and apply concepts, while interviews and observations explored learning difficulties and instructional practices.The results indicate that students' problem-solving skills are low and mostly procedural. Students tend to rely on memorizing formulas rather than understanding concepts, leading to difficulties in solving contextual problems and relating key variables such as pressure, velocity, and height. Additionally, teacher-centered instruction limits students' opportunities to think critically and solve problems independently.These findings suggest the need for more interactive and problem-based learning approaches to enhance students' conceptual understanding and problem-solving skills in physics.

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INTRODUCTION

The educational paradigm required in the era of Industry 4.0 and Society 5.0 must undergo a transformation. Learning should shift from merely focusing on content acquisition to fostering higher-order thinking skills. Problem-solving ability is a crucial competency in this context (Mestre et al., 2011). Problem solving in physics education constitutes a complex cognitive process involving the representation of phenomena, the integration of conceptual understanding, and logical evaluation, extending beyond the mere application of mathematical formulas (Kuo et al., 2013). Physics, as a fundamental science underlying technology, requires students to connect abstract concepts with practical solutions. However, it is still perceived as difficult and intimidating by many students (Singh et al., n.d.).

These difficulties often contribute to low problem-solving performance, as students tend to rely on formulaic approaches without a proper understanding of the underlying physical concepts represented by the variables used (Kurniawati & Ermawati, 2020) This issue is particularly evident in dynamic fluid topics, where visualization of concepts such as streamlines and flow rate is essential. Furthermore, applying Bernoulli's principle to technologies such as venturimeters or airplane wings requires a deep conceptual understanding (Docktor et al., n.d.). ecent literature indicates that learning dynamic fluids involves multiple aspects. Students frequently encounter difficulties in processing non-linear equations, interpreting graphs, and representing flow diagrams (Redish, n.d.). In addition, previous studies reveal a discrepancy between curriculum expectations which emphasize scientific literacy and instructional practices that remain teacher-centered. As a result, students have limited opportunities to develop independent problem-solving skills (*PISA 2018 Results*, 20192020).

Although numerous studies on dynamic fluids have been conducted, research that integrates the analysis of problem-solving skills with the identification of learning difficulties using comprehensive preliminary methods (such as tests, observations, and interviews) remains limited. Such preliminary studies are essential for developing more effective learning models or instructional media. Therefore, this study aims to compare students' problem-solving skill profiles and identify the sources of their learning difficulties in dynamic fluid topics..

METHOD

This study employs a qualitative descriptive method to obtain an in-depth understanding of students' learning obstacles and problem-solving skill (PSS) profiles in dynamic fluid topics. This method was chosen due to its ability to reveal learning phenomena contextually and comprehensively, particularly in understanding students' cognitive processes when dealing with complex physics problems (Sugiyono, 2013; Creswell, 2017). This research not only focuses on outcomes but also examines how students conceptualize and solve problems (Miles, Huberman, & Saldaña, 2014).

Data were collected using method triangulation, which combines multiple instruments to enhance data reliability and validity. The three primary instruments included diagnostic tests, semi-structured interviews, and classroom observation sheets (Denzin, 2012; Sugiyono, 2021). Triangulation enables researchers to compare and verify data from various sources, resulting in more accurate interpretations of students' learning difficulties..

First, the diagnostic test consisted of open-ended, context-based problems designed to assess students' problem-solving abilities. The problems were based on real-life phenomena, such as fluid flow in medical infusions, water pressure in faucets, the working mechanism of fountains, and the design of automatic plant irrigation systems. These contexts were selected to connect abstract dynamic fluid concepts with students' empirical experiences, thereby promoting meaningful learning (Heller & Heller, 2010; Docktor & Mestre, 2014). The test evaluated students' abilities to understand problems, apply physics concepts, plan solution strategies, and evaluate obtained solutions. These components represent key indicators of problem-solving skills from a cognitive perspective (Polya, 1973; Heller et al., 1992).

For example, students are expected to understand the relationship between pressure, velocity, and fluid height, which can be mathematically expressed using Bernoulli's equation: : = P + 1/2 ρv2 + ρgh This equation requires deep conceptual understanding, not merely memorization, but also comprehension of the physical meaning of each variable.

The second instrument, a semi-structured interview guide, was used to gather in-depth information from educators regarding students' learning difficulties, instructional approaches, and challenges in teaching dynamic fluid material. Semi-structured interviews allow flexible exploration of data while maintaining research focus (Creswell, 2014).

The third instrument, a classroom observation sheet, was used to evaluate the implementation of the learning process based on the scientific approach. The observed components included orientation, apperception, core activities (observing, questioning, experimenting, and reasoning), and evaluation stages.

According to the Ministry of Education and Culture (2018), these observations are essential for assessing the alignment between classroom implementation and instructional planning. Overall, this research methodology aims to identify gaps between the competencies expected by the curriculum and students' actual abilities, particularly in physics problem-solving skills.

RESULTS AND DISCUSSION

The results show that students' problem-solving skills (PSS) in dynamic fluid topics remain low and are largely procedural in nature, with students relying heavily on formulas rather than demonstrating a solid conceptual understanding (Docktor & Mestre, 2014). This is reflected in the diagnostic test findings, where many students encounter difficulties at the early stages of problem solving, particularly in interpreting and representing the problem correctly (Polya, 1973).

In more detail, students frequently struggle to recognize relevant physical variables and often ignore key information presented in the problem. For example, when dealing with Bernoulli's equation, they tend to directly insert numerical values into formulas without first examining the relationships among pressure, velocity, and fluid height. As a result, the solutions produced are often not aligned with the actual context of the problem (Heller et al., 1992).

Interview data with teachers further support these findings, indicating that students predominantly depend on memorization strategies instead of building meaningful conceptual understanding. This reliance makes it challenging for them to address open-ended or contextual problems that require the analysis of multiple variables (Creswell, 2014). Bernoulli's equation, in particular, is widely regarded as difficult because it requires students to synthesize several concepts simultaneously, including fluid pressure, kinetic energy, and potential energy (Serway & Jewett, 2018).

Beyond cognitive aspects, internal factors also play a role in the low level of students' problem-solving abilities. These include limited literacy in understanding problem statements and insufficient mastery of mathematical procedures. Many students have difficulty interpreting word problems, especially when translating physical situations into mathematical representations (OECD, 2019). Moreover, students rarely engage in reflection or evaluation of their solution processes, which leads to unnoticed conceptual misunderstandings (Polya, 1973).

Table 1. Results of Problem-Solving Skills Test

Indicator	Precentage (%)	Category
Useful Description	26,14	Very Low
Physics Approach	26,89	Very Low
Specifics Application of Physics	20,27	Very Low
Mathematical Procedures	18,75	Very Low
Logical Progression	20,64	Very Low
Rata-Rata	22,54	Very Low

Classroom observations revealed that, although teachers have adopted a scientific approach, instruction is still largely dominated by expository practices, where example problems are presented directly and followed by similar exercises. This approach reduces opportunities for students to actively develop critical thinking and independent problem-solving abilities (Hmelo-Silver, 2004).

The limited emphasis on independent exploration hinders students in forming well-structured mental models of dynamic fluid concepts. In response to these findings, there is a need for pedagogical interventions aimed at enhancing students' problem-solving skills more effectively. One potential approach is the adoption of Creative Problem Solving (CPS) or Problem-Based Learning (PBL), supported by interactive technology-based learning media.

Such models encourage students to participate actively in identifying problems, exploring possible solutions, and evaluating outcomes in a systematic manner (Ndlela & Barnes, 2024). Furthermore, the use of conceptual scaffolding plays a crucial role in assisting students to grasp complex ideas. Through gradual guidance, scaffolding helps students achieve independence in solving problems, thereby connecting theoretical knowledge with practical application (Vygotsky, 1978).

Overall, the results of this study suggest that students' low problem-solving skills are influenced not only by cognitive limitations but also by instructional practices that are not yet optimal. Consequently, there is a need for innovative physics teaching strategies that prioritize higher-order thinking skills and promote deeper conceptual understanding.

CONCLUSION

he findings of this study indicate that students' problem-solving skills (PSS) in dynamic fluid topics remain at a low level and are predominantly procedural in nature. Students tend to depend on formula application without demonstrating a thorough understanding of the underlying concepts. A key challenge is their difficulty in integrating essential physical variables such as pressure, velocity, and height—into a unified conceptual framework, particularly when applying Bernoulli's equation.

This low level of problem-solving ability is influenced by several internal factors, including limited understanding of contextual problems, insufficient proficiency in mathematical procedures, and a learning tendency that emphasizes memorization. From an instructional standpoint, the continued reliance on expository teaching methods limits students' opportunities to engage in critical thinking and to independently develop effective problem-solving strategies.

In response to these issues, there is a need to adopt innovative, problem-based instructional approaches supported by scaffolding techniques. Such strategies can facilitate deeper conceptual understanding and help students improve their problem-solving skills in a more structured and applicable way.

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