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RESEARCH ARTICLE

Profiling students' critical thinking skills and the implementation of Problem-Based Learning using innovative digital modules on static fluid concepts

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Abstract: This research aims to determine the profile of students' critical thinking skills and the application of Problem-Based Learning using three-dimensional digital modules, particularly in physics education focusing on static fluid material. Preliminary research with a sample of 106 students employs research methods including critical thinking skills tests, student response surveys, and interviews with students and teachers. The findings were analyzed using qualitative descriptive data analysis. The results of this research are as follows: Questionnaire responses reveal that students' critical thinking skills are predominantly in the low category, with 100 students in the low category, six in the medium category, and none in the high category; Among critical thinking skills, strategy and tactics rank the lowest; Teachers have implemented Problem-Based Learning through active teaching strategies, such as presentations and open-ended questions, to improve students' critical thinking skills. However, three-dimensional digital book media have not yet been utilized in physics learning; and the application of a Problem-Based Learning model supported by three-dimensional digital modules is expected to improve students' critical thinking skills in physics education. This study highlights the need for innovative learning approaches to enhance students' critical thinking skills, especially in physics education. The integration of Problem-Based Learning with three-dimensional digital modules offers significant potential for addressing this need.

Keywords: Problem-Based Learning, critical thinking skills, 3-D digital module

1 Introduction

Learning in the 21st century is pivotal as it drives transformative changes in education, particularly through advancements in science and technology (IPTEK) (Putri & Prahani, 2024). These developments have shifted the learning paradigm, influencing curriculum, media, and technology (Fadillah et al., 2024; Kalogiannakis & Papadakis, 2017; 2020). Human civilization has transitioned from primitive societies to agricultural, industrial, and now digital and information-based societies (Rahayu et al., 2022). Critical thinking skills are essential for success in this era, enabling individuals to analyze, assess, and make rational decisions. Education prioritizes developing critical thinking, especially in mathematical contexts, through problem-solving, drawing conclusions, and informed decision-making (Alzoubi, 2024; Kusumawati et al., 2022).

Critical thinking enhances the ability to address complex problems effectively, both in and outside the classroom (Bidiyah et al., 2024; Wiratman et al., 2023). Project-Based Learning (PBL), a constructivist, student-centered approach, fosters these skills by encouraging students to take an active role in learning (Lapuz et al., 2020). PBL integrates problem-solving, collaboration, and critical thinking by presenting real-world scenarios for students to analyze, hypothesize, and develop solutions (Bohara, 2024; Istiqomah et al., 2023). Through this method, students connect prior knowledge with new learning experiences, enhancing critical thinking skills such as reasoning, communication, and contextual application (Brandhofer & Tengler, 2024; Siswanti & Indrajit, 2023). The teacher's approach significantly influences learning outcomes and the development of critical thinking (Purba et al., 2022). Research highlights the effectiveness of PBL in improving students' critical thinking and learning outcomes, particularly in physics (Papadakis et al., 2021; Wijaya et al., 2021). PBL also motivates students by presenting problems that require innovative and analytical solutions (Susetyo et al., 2021).

Physics, as a study of natural phenomena, fosters critical and creative thinking and contributes to cognitive, affective, and psychomotor skill development (Papadakis & Kalogiannakis, 2020).

However, many students perceive physics as challenging, leading to low engagement and poor learning outcomes (Gusmayenti, 2023). Studies reveal that a significant proportion of students exhibit low or very low critical thinking skills due to teacher-centered learning, limited use of varied media, and difficulty understanding physics concepts (Susilawati et al., 2020; Ardiyanti & Nuroso, 2021). Innovative teaching materials, such as e-modules, are crucial for addressing these issues.

E-modules, characterized by being self-instructional, adaptive, and user-friendly, enhance independent learning and critical thinking skills (Papadakis & Orfanakis, 2017; Wahyuni et al., 2020). Tools like 3D page Flip PDF Professional allow for creating interactive e-modules that integrate text, images, animations, and quizzes, making learning engaging and effective (Papadakis, 2022; Saprudin et al., 2021; Siburian et al., 2022). Research shows that such modules are feasible and effective in improving students' critical thinking skills in physics (Latifah et al., 2020; Papadakis, 2018; 2020; Retnaningtyas & Huda, 2024).

Based on these insights, this research aims to profile the application of the problem-based learning model supported by 3-dimensional digital modules and assess the critical thinking skills of high school students in physics learning.

2 Materials and methods

This research is preliminary, using qualitative descriptive analysis techniques for data analysis (Petousi & Sifaki, 2020). Researchers conducted this preliminary research to learn more about the actual situation at school and provide more in-depth information about existing problems (Shorey et al., 2020). This study did not test a hypothesis. The results of this exploration are used as food for thought to develop further creative learning models and tools in schools that can improve the critical thinking skills of high school students. This research was conducted on 106 class XI students at SMA Negeri 1 Wonoayu in May 2024, consisting of 55 female and 51 male students. This research uses several instruments to collect data, namely 1) a critical thinking skills test questionnaire consisting of five indicators on static fluid material, 2) a teacher interview sheet, 3) a student interview sheet, and 4) a student response questionnaire survey.

Purposive sampling was used in this research. The data analysis method includes determining student responses from response surveys and test questionnaires (Rizki et al., 2021). After that, researchers also conducted interviews with several students and teachers. The actual conditions and circumstances in high school regarding students' critical thinking skills are determined through data analysis. This exploration stage is completed as in Figure 1.

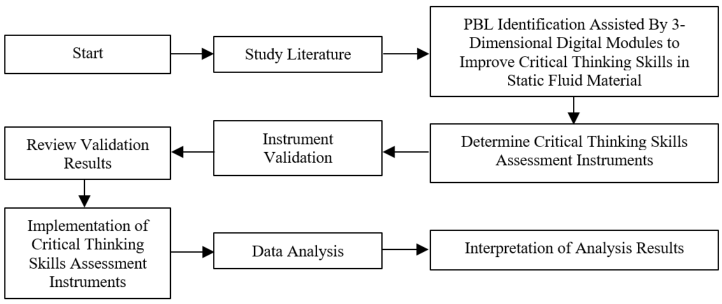

Figure 1 Research methods

This research aims to determine the profile of students' critical thinking skills, especially in static fluid material. Fifteen static fluid essay questions are critical thinking ability test questions for students. These questions provide indicators of critical thinking skills. Choosing the type of question in an essay is used to present more in-depth answers than just choosing multiple-choice answers (Maryani et al., 2021). Next, students were given 11 questionnaires in response to physics learning at school. Then, the level of critical thinking skills is calculated through responses from students' answers. If the response is logical, complete, and systematic, then the points obtained are 4; if the answer only has two components (logical and complete or logical and systematic), then the points obtained are 3; If the answer only has one component, then you will only get 2 points; If the student's answer is wrong with a reason, the point they get is 1; and if the student's answer is not filled in (blank), then the point obtained is 0. So, the maximum value obtained is 40. Then, to determine the value of each student, use the following formulation.

$$\text{Total Value} = \frac{\text{value obtained}}{\text{maximum value}}$$

The applicable categories are shown in Table 1:

Table 1 Value range category

Range of Score	Category
$75 < \text{Score} \leq 100$	High
$45 < \text{Score} \leq 75$	Medium
$\text{Score} \leq 45$	Low

3 Results and discussion

3.1 Students' critical thinking skills in static fluid material

Students' critical thinking ability values can be determined using the abovementioned criteria. This examination is carried out by controlling a structured survey test of fifteen questions. There are three questions for each indicator. Students are expected to be able to respond to the problems given. Researchers can then assess students' critical thinking abilities based on these responses. Students are expected to be able to break down the question, then elaborate and conclude and evaluate the consequences of their answer based on the markers in the question. Students' critical thinking abilities in static fluid material with PBL and Facione indicators determined based on research are as in Figure 2.

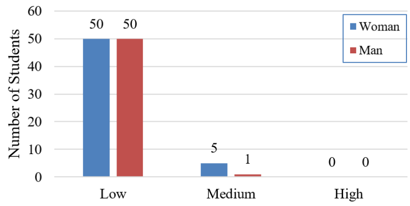

Figure 2 Levels of critical thinking skills for women and men

Figure 2 shows that female and male students' critical thinking skills are still low. There is no apparent difference between the two. This distinction occurs at both low and medium levels of critical thinking skills. Uniquely, no male or female students had high levels of critical thinking skills among all the students who responded. From Figure 2, the critical thinking skills of female and male students are in the low category. There are 50 female and 50 male students in the low-level critical thinking skills category, one male student in the moderate critical thinking skills category, five female students in the moderate critical thinking skills category, and not a single student in the thinking ability category—high critical level.

In Figure 3, the essay test results include indicators of critical thinking skills. The average student score was found for each indicator. Based on this figure, female students have a higher average score on each indicator than male students. Although the five markers are not significantly different, it can be concluded that female students still have higher critical thinking skills than male students.

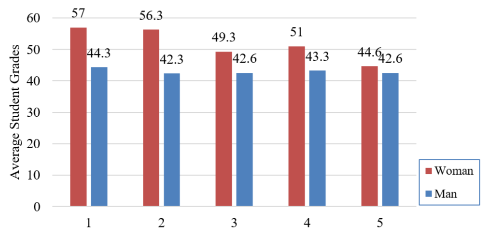

Figure 3 Comparison of the average value of critical thinking skills for women and men

Examples of student answers to the critical thinking skills essay test for each indicator, namely elementary clarification, essential support, inference, advanced clarification and strategy, and tactics, are as follows:

3.1.1 Elementary clarification

Students' answers to elementary clarification:
Both will experience the same water pressure because the depth they reach measured from the water surface is the same. However, there are several differences between swimming in the sea and in a river. The sea tends to have bigger waves than rivers.

Meanwhile, rivers usually have stronger currents, and it can be more difficult for swimmers to fight these currents.

Students are asked to explain their understanding of two talented swimmers who often train to swim in the sea and rivers. One day, Budi and Amir were swimming in the river and ocean. If measured from the water surface, both reach the same surface; which water pressure is more significant? Moreover, explain the differences and similarities. From the results of the students' answers, it can be seen that students are still unable to understand the pressure differences, which are influenced by depth, the thickness of seawater for Amir, and the thickness of river water for Budi. In addition, students do not provide the physics equations that make up the hydrostatic pressure equation.

3.1.2 Basic support

Students' answers to essential support:
The person is not injured because of the many nails; the tight position of the nails and the even/equal length of the nails will not hurt the person because of the many nails as support.

Students are asked to build fundamental skills regarding the phenomenon presented of a person sleeping on nails arranged so that they can support his body so that the person is not injured. However, what if there is only one? Provide with the pressure concept. From the results of the student's answers, it was found that the average student's basic skills were that the answers were only related to the phenomena presented, not relating the occurrence of these phenomena to the concept of pressure in a static fluid.

3.1.3 Inference

Student answers to inference:
Liquid 1, because it was dropped for a very short time and then fell into the liquid so that the marble had downward pressure.

Students are asked to conclude an experiment with three tubes with different liquids but with the same volume and height. The marbles are then dropped into each liquid in the same place, and the time required for each marble to sink is measured. Which is the thickest? Explain. The results of the students' answers showed that the experiment's conclusions were still incorrect. Because students still do not understand the viscosity experiment, where the concept of viscosity is that the higher the viscosity of a liquid, the more excellent the resistance to the movement of objects in it. So, it takes longer for the object to fall through the liquid.

3.1.4 Advance clarification

Students' answers to advance clarification:
The dam must be built with proper materials in the right location to prevent collapse.

Students are asked to explain further the dam that was built and can utilize irrigation. However, several dams have collapsed. To prevent this, evaluate the dam and provide suggestions for producing a good dam using the pressure concept. From the results of students' answers, it is known that students only contributed to building a proper dam to withstand very high water pressure. However, students did not explain the evaluation, which resulted in the dam collapsing.

3.1.5 Strategy and tactics

Student answers to strategy and tactics:
To make plasticine float on the surface of water, the student needs to make a plasticine shape with a large enough volume so that its density is lower than the density of water.

Students are asked to organize strategies and tactics regarding students using plasticine to carry out practical work investigating the phenomena of floating, drifting, and sinking. Then, when the plasticine is formed into a ball, the ball sinks into the water. How do you make plasticine float? Explain. From the results of the answers, students can answer how to make plasticine float. However, students cannot explain the shape of plasticine with a clear picture regarding plasticine being able to float on the surface of water.

3.2 Results of student responses to physics learning

On the next page, students are asked to fill in their responses to the physics lessons they studied at school after taking an essay test measuring critical thinking abilities on static fluid material. 11 statements were selected for the total questionnaire responses, and responses ranged from strongly disagree to agree on a scale of 1 to 4 strongly. Table 2 displays responses to the questionnaire results. Apart from administering questionnaires, researchers also conducted interviews with students to understand better how to view physics teaching, especially at school.

Table 2 Student responses to learning Physics and critical thinking skills at school

Statement	Answer (106 students)			
	Strongly Disagree	Disagree	Agree	Strongly agree
Physics subject is a fun lesson	3% (3)	36% (38)	53% (56)	8% (9)
Static fluid material is essential to understand	1% (1)	11% (12)	74% (78)	14% (15)
Static fluid material is complex to understand	3% (3)	22% (23)	58% (61)	18% (19)
Teachers often use conventional book-assisted lecture methods compared to laboratory--experimental or simulation methods	6% (6)	14% (15)	54% (57)	26% (28)
You feel comfortable and happy with the learning methods used by your current teacher	3% (3)	14% (15)	52% (55)	31% (33)
You have carried out learning activities to improve your critical thinking skills	1% (1)	14% (15)	64% (68)	21% (22)
You have been trained with critical thinking skills test questions	4% (4)	14% (15)	58% (62)	24% (25)
Critical thinking skills are essential to teach in schools	3% (3)	5% (5)	40% (42)	53% (56)
Do you know what a 3-dimensional digital module is	11% (12)	57% (60)	29% (31)	3% (3)
You have learned physics with the help of 3-dimensional digital modules	25% (26)	49% (52)	18% (19)	8% (9)
You are interested in learning physics with the help of 3-dimensional digital modules	6% (6)	20% (21)	44% (47)	30% (32)

Table 2 shows that students agree that physics is a fun lesson. Students agree that it is essential to understand static fluid material in the following statement. However, they had difficulty understanding static fluid materials. The students then agreed that the teacher's learning approach was more traditional, with many lectures rather than experimental. So that students can investigate various physics concepts in their daily lives, teachers must facilitate learning by providing real-world problems to students (Helmeyanto & Hariyono, 2021). However, students are happy and comfortable with the teacher's learning methods.

In addition, most students have been trained with questions for critical thinking skills tests and have participated in learning activities designed to improve critical thinking skills, as shown in Table 2. In addition, students have the same belief that essential thinking skills must be taught in schools. Most have never studied learning supported by three-dimensional digital modules for physics subjects. In addition, students will be interested in studying physics using 3-dimensional digital modules in the future.

3.3 Results of interviews with physics teachers

This research examines learning outcomes from the student's perspective and asks the teacher's opinion regarding the learning model used in class. Further information was collected through interviews regarding Physics learning at school. The interview results, which consisted of 7 questions, are written in Table 3.

Table 3 Results of interviews with Physics teachers regarding the implementation of Physics learning

No.	Question	Teacher's Answer
1	According to the teacher, what are the students' attitudes, motivation and interest in learning physics?	A small number of children do not like physics because many formulas have to be learned
2	According to the teacher, are the learning methods implemented in the learning process by the Merdeka Belajar Curriculum for physics learning, especially in static fluid material?	The learning method uses PBL.
3	According to the teacher, are there any weaknesses, shortcomings, or limitations of the learning methods used to teach physics concepts to students, especially regarding static fluid material?	Some children experience weaknesses and deficiencies due to a lack of interest; more time is needed because exploration, discussion, and in-depth problem-solving take a long time.
4	According to the teacher, have critical thinking skills ever been trained specifically for students, especially during learning activities at school?	Often, because it can train children to be able to make decisions and train students to solve problems
5	According to the teacher, are critical thinking skills necessary for students? Give a reason!	It is essential because, with critical thinking, students shape their character and help students analyze problems more effectively and find creative and innovative solutions
6	According to the teacher, what efforts should be made to improve students' critical thinking skills?	Always be given material that is always presented and use active learning methods, encouraging open questions and problem-based learning
7	Have you ever heard of or even taught with the help of 3-dimensional digital modules? If you know or have, please provide feedback regarding 3-dimensional digital modules!	Never before, because facilities are limited

Table 3 shows that SMA Negeri 1 Wonoayu teaches physics using the PBL learning method, especially static fluid material. Teachers provide exceptional teaching to improve students' critical thinking skills through active learning, presentations, and encouraging open questions in problem-based learning. However, physics learning at SMA Negeri 1 Wonoayu has not implemented problem-based teaching methods using innovative 3-dimensional digital module media.

4 Conclusion

The critical thinking abilities of students at SMA Negeri 1 Wonoayu are still in the low category, as evidenced by the findings and analysis of the data obtained. Based on the findings of this research, appropriate physics teaching strategies can impact students' critical thinking skills. Therefore, one effort that can be used to improve students' critical thinking skills is to apply the PBL model assisted by e-module books. Future research is expected to be able to carry out research with more samples, indicators and types of existing physics material.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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