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Student's perspective: Mathematical reasoning ability and correlations between mathematics and physics

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Abstract: The purpose of this study is to understand students' perspectives on the process of solving physics problems using the mathematical reasoning approach during physics learning that has been passed. This study used qualitative methods with data condensation analysis, data collection through semi-structured interviews. Participants were 36 students from a high school in Jember, East Java. Obtained themes and sub-themes in accordance with the research objectives and the list of questions that have been made, namely: (1) mathematical reasoning ability–presenting conjectures, predicting answers and the solution process, mathematical manipulation, drawing conclusions, and (2) the correlations between mathematics and physics–mathematics and physics, examples of mathematical applications in physics. Students need to develop mathematical reasoning skills and an understanding of the relationship between mathematics and physics.
Keywords: student's perspective; mathematical reasoning ability; mathematics and physics

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Introduction

Physics is the science that analyzes and studies how nature behaves and physics becomes one of the old disciplines (Sokolowski, 2021). Physics is a subject that high school students study. Physics education is intended to provide students with a platform to explore themselves and the natural world around them, as well as to create practical applications for everyday life (Sujito et al., 2021). Some students consider physics to be a difficult subject to understand, so the interest in studying physics is low (Nurjannah & Sucahyo, 2022). Therefore, physics is a subject with a high failure rate among senior high school students (Nggadas & Ariswan, 2019).

Mathematical reasoning ability is one of the abilities needed in physics learning. The process of thinking about something to make a decision is called reasoning (Ekowati et al., 2024). Reasoning ability is one of the high-level thinking talents that children should develop and master because it will be useful later in solving everyday challenges (Hidayat et al., 2022). Making judgments requires reasoning in addition to just thinking through them; conclusions must also have logical justifications (Gaudêncio, 2020). The capacity to think analytically, recognize organized patterns or regularities in actual circumstances, and undertake proof in order to draw conclusions and make judgments is known as mathematical reasoning ability (Linda & Asyura, 2021). Apata (2022) asserts that students must have good mathematical reasoning ability because solving physics problems requires mathematical understanding. To use proper ideas and complete proofs, students must use mathematical reasoning by following the instructions of each task (Mastuti et al., 2022).

The mathematical reasoning ability of students in Indonesia is still relatively low. Based on the results of the 2018 Program for International Student Assessment (PISA) study, it can be seen that the

average value of Indonesian students' mathematical ability is 379 where the OECD average value that has been set is 480 (Marianah et al., 2020) placing Indonesia in 73rd place out of 79 PISA countries (OECD, 2019). This is substantiated by the TIMSS research, which found that 17% of students have cognition with low levels of mathematical reasoning ability, the lowest percentage ever recorded in Indonesia (Hasna et al., 2023).

Physics and mathematics have had a tight association throughout human history. Every great revolution in physics is inevitably followed by the introduction of mathematical methods (Chen et al., 2021). One of the defining aspects of physics is the ability to solve problems mathematically. Further analysis reveals that mathematics plays a part in physics in numerous ways, including: 1) as a tool (pragmatic standpoint), 2) as a language (cognitive linguistics), and 3) as a logical method of reasoning (structural function) (Palmgren & Rasa, 2024). The application of mathematics will be critical when studying physics further; consequently, students in high school must exercise mathematical understanding for physics problem solving and cultivate this awareness (Turner, 2020). When studying physics, students frequently need accurate mathematical reasoning and argumentation, as well as the ability to perform studies using a wide range of mathematical approaches (Jihe et al., 2021). Mathematical rigor is frequently the cause of difficulty for students when studying physics (Badmus & Jita, 2024). One of the most prevalent scenarios is that many students can list the equations according to the physical situation and physical rules, but they cannot solve them (Jihe et al., 2021; Papadopoulos, 2019).

Based on the previous points, the aim of this research is to better understand high school students' impressions of the process of solving physics problems using mathematical reasoning abilities, as well as students' perceptions of the relationship between mathematics and physics and its application. By asking pupils to talk from their own perspectives. Individuals have recognized perspective as an internal process that occurs when they pick and organize stimuli from the outside world utilizing their five senses in order to provide meaning to already existing stimuli (Sujarwo et al., 2020). Mathematical reasoning ability has four indicators from Gultom et al., (2022): 1) presenting conjectures, where students identify known and unknown elements; 2) predicting answers and the solution process, where students highlight key information to address the question; 3) mathematical manipulation, where students utilize appropriate formulas and carry out calculations correctly; and 4) drawing conclusions, where students articulate and summarize the final outcomes.

Method

This study employs a qualitative research design, with data collected using semi-structured interviews. The qualitative technique was chosen to investigate real-world events and situations in greater depth and detail (Tenny, et al. 2017). Interviews are used to acquire information about a person's subjective experiences, opinions, and motives (Busetto et al., 2020). Semi-structured interviews begin with main questions based on themes organized in the interview guide and then move on to follow-up and deepening inquiries that are not included in the interview guide (Mashuri et al., 2022).

This study involved 36 students from class XII of a senior high school's science program in Jember, East Java, Indonesia. The students included four males and 32 females who had studied physics for more than two years. Students discussed their experiences working on physics problems in high school for more than two years, using questions tailored to indications of mathematical reasoning ability. Students also discussed the relationship between mathematics and physics, as well as examples of how they are used.

In this study, interview guidelines were employed as the instrument. The questions were aimed at eliciting students' thoughts on the process of addressing physics problems using the mathematical reasoning ability method, as well as the relationship between mathematics and physics and their application. Students must answer six questions, which are organized around the theme of mathematical reasoning skills and a study of research findings on the relationship between mathematics and physics. Table 1 shows a list of questions.

Table 1. List of Questions

Mathematical Reasoning Ability	
Q1	Do you struggle to understand and identify what is known and what is asked in physics problems? Explain!
Q2	How do you predict the solution process for physics problems? Explain!
Q3	Do you have difficulty determining and applying formulas to solve physics problems? Explain!
Q4	Are you able to correctly conclude the end outcome after solving physics problems? Explain!
The correlation between mathematics and physics	
Q5	What is the correlation between physics and mathematics? Explain!
Q6	Do you know the Phytagorean Theorem? If so, do you know how to utilize it? Do you understand how the Phytagorean theorem is applied in physics?

The recorded student interviews were transcribed and then analyzed. Data analysis uses data condensation techniques, which consist of 1) collecting data, 2) data condensation, 3) data display, and 4) drawing conclusions or verification (Miles et al., 2014). Figure 1 shows the components of data condensation. There are two primary themes and six subthemes based on the developed questions. To achieve adequate results, the researcher analyzed the interview transcripts multiple times, utilizing data condensation. Prolonged interaction with the data aided in the credibility of the information collected (Tan, 2021).

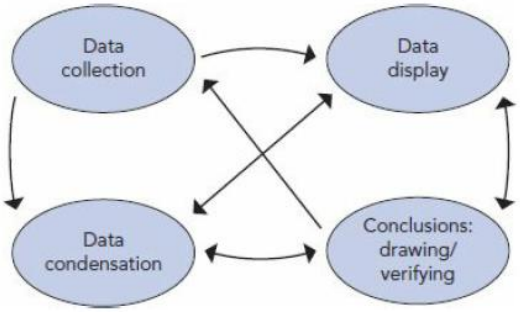

Figure 1. Components of Data Condensation

Results and Discussion

Mathematical Reasoning Ability

Presenting Conjectures

Presenting conjectures is the first indication of mathematical reasoning abilities. The criteria for this indicator are that students can identify what is known and what is being requested when working on problems. A hypothesis is an oral or written statement that stems from logical thought (Yuniati, 2018). Based on the findings of interviews on this indicator, numerous data points were gathered about students' challenges in discovering significant information in the problem, namely symbols or symbols in physics material, as well as the format of physics problems. Some students believe that physics includes many terms, which causes them to forget symbols and have difficulties choosing symbols based on key information in the problem. Symbols are the core of the written language of physics and mathematics, but their inconsistent use presents a difficulty for students, leaving them perplexed by their symbolic nature (Begg & Pierce, 2021). Some students believe that symbols in physics are identical between materials, making it difficult to determine. However, some students can retain and draw symbols when they understand significant information in physics problems.

> "If the difficulty is quite difficult because what is it like eee this is usually the symbols, there are many of them and sometimes there are the same ones that are different." (S1-AEP, SSBD, Interview).
>
> "Yes, besides that because there are a lot of formulas and a lot of terms like these signs that c is for what this k is for." (S27-RIAS, PS, Interview).

"Sometimes the difficulty is in determining the symbol." (S33-TAR, DDS, Interview).

The structure of physics issues also influences their ability to locate vital information within the problem; this is referred to as problem modification. They comprehend the example problems provided by the teacher, but while performing exercises, the shape of the problem differs from the example problem, causing uncertainty while working.

"Sometimes I am confused because eee the example given by the teacher is a but the one in the problem is different, the modification is different." (S29-SAPS, DQF, Interview).

Predicting Answers and The Solution Process

In this second indicator, pupils are supposed to offer relevant knowledge in order to answer the question. Based on the data analysis that was carried out, the results on how students predict the answer and the solution procedure are acquired. Read the problem several times to understand and determine what is known and what is asked (indicator criteria 1). by applying relevant facts to the situation. Almost all students forecast the answer and solution procedure in physics problems by reading and comprehending the problems received, so that the terms or keywords gained pertain to formula determination. They study the problem several times to grasp and determine what is known and what is asked (indicator criteria 1). Students who have good conjecture indicators will be able to read and identify problems so that students understand what is known and what needs to be solved (Hasanah et al., 2019). After gathering information about what is known and what is asked, the prediction process begins by analyzing the various formulas that could be utilized. After obtaining the formula, they review its value, which has no worth and later becomes the solution to the problem.

"Ooo yes, if like that you can know, then it means that this is what is asked about, for example, if the distance and time are known, then maybe in the question it is asked about the speed like that, you can know." (S23-NFS, UWK, Interview).

"Eee it's in ... yes, it is separated first known what is asked what from there then right ohh known tuh this means use this formula." (S26-RSAS, UWK, Interview).

Mathematical Manipulation

The standards for mathematical manipulation indications include pupils' ability to utilize the proper formula and complete calculations accurately. After reviewing the data, it was discovered that some students had difficulty performing calculations to solve physics questions. According to them, the difficulty in performing calculations stems from physics' numerous formulas, formula combinations, and limited practice situations. Students believe there are numerous formulas in physics, making it difficult for them to determine and apply them. Furthermore, when students do not understand the content in one chapter and then proceed to the following chapter, they have difficulties answering practice questions and frequently apply the incorrect formula.

"Yes, it's like a lot of en kak, especially when, for example, material one already doesn't understand, then material two, one just doesn't understand, let alone two kak, yaaa can't already." (S11-EIS, PF, Interview).

"physics….there are many formulas." (S28-SNR, PF, Interview).

"Yes, the formulas are very, very many." (S30-SAW, PF, Interview).

The next cause of students' difficulty in performing calculations is the combination of formulas. According to their perception, formula combination is the use of two or more formulas in one problem to find an answer or solution. With this combination of formulas, students have difficulty determining the first and next formulas. Not only that, sometimes formulas are combined with other formulas to find the answer to the question. According to some students, the cause of difficulty in performing mathematical manipulation is a lack of practice problems.

"Sometimes yes, because in my opinion physics is not enough with one formula because ..., physics needs, for example, if you use formula a and then combine it with b to make c so it's like ... yes." (S4-AO, CF, Interview).

"This is what eee the bias is like the formula, right, there is formula a, usually in the problem, formula a needs to be modified to be able to do the problem, the modification is to process the formula." (S15-IA, PFM, Interview).

Yes, that's why I think I don't do enough practice problems." (S23-NFZ, LPP, Interview).

Mathematical manipulation is a crucial sign for finding a solution since it demonstrates how to compile evidence by systematically calculating until a solution is obtained (Susanto et al., 2022). However, the mathematical manipulation indicator is an indicator of mathematical reasoning ability that is still low (Agustyaningrum et al., 2019) so that it has an impact on reasoning abilities in general (Sukirwan et al., 2018).

Drawing Conclusions

The final indicator of mathematical reasoning skill is forming conclusions. This indicator allows pupils to compose and conclude the final result. Based on the data analysis of interview transcripts, practically all students believe they are competent at writing and presenting the final results. Students rely on the problem-solving process to compose and conclude their final results. When they work on the problem, they comprehend and are able to fix it, and then the problem is resolved. However, if they are unable to solve the problem, they will not reach a conclusion. The ultimate outcome is the culmination of various phases in mathematical reasoning abilities. Mathematical reasoning is the process of obtaining conclusions from a concept based on existing data using logic and critical thinking (Rohana, 2015). Students utilize their own words to explain and write conclusions, which they then present verbally (Gultom et al., 2022). Problem solving by students allows teachers to see the stages of students' arguments and identify the challenges or hurdles in developing conceptual comprehension (Novitasari et al., 2021).

"the problem is if the question can be analyzed or understood, the conclusion can be obtained, unless the question is difficult for me to understand so the conclusion cannot be obtained [holding back laughter]." (S1-AEP, DQ, Interview).

"Yes, from the process itself, it was a bit difficult, the first one was that, so most likely when making conclusions, it was also a bit difficult." (S13-FFM, DOP, Interview).

"….eee usually when it comes to physics problems, sometimes we have already searched, searched for the answer, well but sometimes it doesn't match like it's hard, what is it?", Like the answer doesn't match, it's not in the option, then the calculation is wrong, you know, entering the wrong formula is usually difficult there. (S5-A, UFA, Interview).

The Correlations Between Mathematics and Physics

Mathematics and Physics

In general, based on the data analysis results, the majority of students were able to describe or narrate the relationship or link between mathematics and physics. The vast majority of pupils believed that math and physics were equally important. Furthermore, numerous students stated that arithmetic provides the foundation for anyone wanting to learn physics. Because, according to them, arithmetic is a tool for performing physics. If you want to learn physics but don't have a strong foundation in arithmetic, you will struggle. When students improve their math skills, learning physics becomes easier (Chen et al., 2021). High failure rates in high school may be caused by difficulties in understanding physics-mathematics ideas (Mwangala & Shumba, 2016). Here are some of the students' statements regarding the correlation between math and physics.

"If, for example, we are already proficient in math, usually doing physics is usually directly like oh this is how to do it like this, then the basic point is in math." (S5-A, MaF, Interview).

"In my opinion, math is like a tool for doing physics. (S17-LPW, MaF, Interview).

Examples of Mathematical Applications in Physics

Based on the data analysis, only a tiny number of students can respond and provide examples of the usage of mathematical approaches in physics. They know a lot more about math than physics. One example is the Pythagorean theorem, a mathematical master piece. The Pythagorean theorem is commonly utilized in physics to address difficulties. Some students mentioned using the Pythagorean

theorem in physics materials like vector materials and alternating current circuits. According to the findings of the previous study, the Pythagorean theorem can be used to answer physics problems found in high school materials (Supriadi et al., 2019; Supriadi et al., 2023).

> "The one that has F F one what and then use it is Phytagoras and then there is sin cos also forget the name of the material." (S6-AAN, KPTP, Interview).
>
> "You know..., So if the Phytagoras theorem in physics can be made what, okay usually we use it in the vector chapter, yes, it's like finding the resultant can also be." (S13-FFM, KPTP, Interview).

Conclusion

The outcomes of this small-scale study highlight the importance of developing high school students' mathematical reasoning abilities across physics learning, as well as their conceptual knowledge of mathematical relationships in physics. As a result, students require monitoring to gain awareness and conceptual knowledge about these topics earlier and deeper in order to benefit them in their future studies. In this scenario, the most essential factors are the students' perceptions of solving physics issues using mathematical ability, as well as the relationship and application of mathematics to physics. Students must practice solving physics issues independently using a range of existing mathematical methods in order to develop their own mathematical reasoning abilities.

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