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Exploring physics sensemaking among students across different academic years: Beliefs and practices

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ABSTRACT

Sensemaking is a critical aspect that enables students to integrate physics concepts into their deep and sustainable understanding. Without sensemaking, students find it difficult to apply this knowledge in real-life situations. Therefore, this study aims to explore physics sensemaking from both the belief and practice perspectives of different academic years as an initial and important step to improve the quality of physics learning. This study uses an explanatory sequential mixed-method design. Quantitative data were obtained from survey questionnaires, and qualitative data were obtained from semi-structured interviews. The subjects of this study were 226 physics education students. Quantitative data analysis used descriptive statistics, while qualitative data analysis used content analysis. The results reveal differences in physics sensemaking among first-, second-, and third-year students, with students becoming more proficient each year. The sensemaking constructs that emerged consist of belief in the calculation process, satisfaction through understanding phenomena, the importance of understanding formulas, attitudes toward the history of formulas, flexible approaches to problem solving, explicit physics thinking, and the association of information with existing knowledge. These results were supported by the first interview but not by the second interview. When students were presented with phenomena based on PhET acceleration simulations, the physics understanding of first-year students, where the sensemaking of "Student M1" occupied level 2, tended to be higher than the sensemaking of "Student H1," who occupied level 1. The qualitative pattern was observed in the sensemaking of these students. The implications of this study reinforce that sensemaking can be supported through interventions in physics learning.

Contribution/Originality: This study explores physics sensemaking based on beliefs and practices among physics education students at different academic levels. It offers insights into the development of physics sensemaking through students' long lecture experiences. The contribution specifically provides an overview and reinforces the role of physics sensemaking in students' conceptual understanding.

1. INTRODUCTION

Sensemaking plays a crucial role in physics learning for students. It acts as a bridge between students' understanding, intuition, and explanations, thereby overcoming knowledge gaps. This bridging function helps students construct new knowledge and understand related physics material (Sari, Purwaningsih, & Khusaini, 2024). Sensemaking is more than just memorizing physics formulas; it is about deep conceptual understanding and the ability to apply it in various situations (Boudreaux et al., 2020; Hammer, Elby, Scherr, & Redish, 2005). However, students may acquire ideas, both from class and daily experiences, that conflict with the concepts being studied (Gafoor & Akhilesh, 2010) and some physics concepts studied in class may not be relevant to real-life situations (Bouchée, de Putter-Smits, Thurlings, & Pepin, 2022; Daud, Karim, Hassan, & Rahman, 2015; Wangchuk, Wangdi, Tshomo, & Zangmo, 2023) and examples of physics phenomena tend to be more intuitive and emotional, which may make sense to one person but not to another (Odden, 2021). This may indicate that students' understanding of physics concepts is fragmented.

Sensemaking in physics refers to a person's ability to make sense of physics concepts and phenomena. However, existing research shows that physics sensemaking abilities are still low. Students need to understand the entire problem-solving process so that they can have various approaches that may be taken, the potential advantages and disadvantages of these approaches, and their relevance in various physics content while solving problems (Odden & Russ, 2018; Zhang & Soergel, 2014). However, while solving problems, students tend to limit sensemaking due to high cognitive demands (Ibrahim & Ding, 2023). In addition, low sensemaking results from a gap between students' intuition based on their experiences of phenomena and educators' explanations during physics learning, where educators tend to "make answers" with mathematical equations without explaining their connection to everyday phenomena (Odden, 2021). Research by Ingerman, Booth, and Linder (2007) shows that sensemaking in physics is low because some students face difficulties in integrating the physics knowledge they have learned; students tend to see each topic or concept as a separate entity that is not connected. Although students can recognize sensemaking when it occurs, it is not yet known how to make it happen reliably or how the process continues (May, Barth-Cohen, Gerton, De Grandi, & Adams, 2022). Research by Kaldaras and Wieman (2023) and Kaldaras and Wieman (2025) explores how students identify blended mathematical and science sensemaking. However, this research focuses on sensemaking in practice; it is necessary to compare whether the beliefs and practices of students support each other. This initial exploration of physics sensemaking by students, particularly in Indonesia, is a crucial step. It not only helps identify how students process and interpret physics concepts but also provides a strong foundation for the development and implementation of effective educational interventions. Therefore, this research focuses on the research question:

To what extent and how do the academic years of students influence their physics sensemaking, both in terms of belief and practice?

2. LITERATURE REVIEW

2.1. Sensemaking in Physics

Sensemaking, particularly in the context of physics education, refers to the process whereby individuals develop an understanding of a concept by integrating and making coherent their knowledge and experiences (Kuo, Hull, Elby, & Gupta, 2020). Sensemaking is defined as a dynamic process in which an individual engages in the selection and application of knowledge to interpret and create representations to achieve a goal or perform a task (Namvar, Cybulski, Phang, Ee, & Tan, 2018; Nokes-Malach & Mestre, 2013). Odden and Russ (2018) propose a theoretical definition of sensemaking as a dynamic process of constructing or revising an explanation to understand the mechanisms underlying a phenomenon, thereby overcoming gaps or inconsistencies in existing understanding. This process involves constructing explanations by iteratively mixing everyday knowledge and formal knowledge, as well as connecting various ideas about the subject. In addition, this process also involves checking the coherence between these connections and ideas, both within themselves and in relation to other ideas in a person's knowledge system.

Sensemaking is generally conceptualized as describing intuition and developing conceptual understanding (Hahn, Emigh, & Gire, 2019). The difference between sensemaking and conceptual understanding is that sensemaking is a dynamic process involving the construction and revision of explanations to understand complex physical phenomena, while conceptual understanding focuses more on mastering theory and the practical application of established physics concepts (Odden & Russ, 2018). Sensemaking involves identifying gaps or inconsistencies in knowledge and then constructing explanations to bridge those gaps. Students already have knowledge or beliefs about phenomena and concepts before learning takes place; this knowledge can be in harmony with or in conflict with science concepts (such as physics) (Duit & Treagust, 2003).

Physics sensemaking has been established as a scientist-like activity, making it important for students to develop (Hahn et al., 2019). The sensemaking process consists of at least three main stages (Sands, 2021). The first stage is understanding the problem, which involves identifying the physical situation at hand, determining relevant information, and formulating questions or issues that need to be clarified. The second stage is ensuring the model's plausibility, which involves assessing whether the model or representation used is logically consistent and in accordance with the principles of physics. The third stage is making sense of the physical world through the model, which involves using the model to explain, predict, and interpret physical phenomena occurring in the real world. Also important in this sensemaking process is the idea of gaps and bridges (Weinberg, Wiesner, & Barr, 2016). Gaps are questions that must be answered for students to engage with or construct meaning in a mathematical situation or activity, while bridges are the answers that students construct. The ideas of frames, gaps, and bridges complement each other: frames influence the nature of the gaps that arise, and, after building bridges, students can notice different aspects of the text or interpret aspects of the text in new ways.

2.2. Sensemaking as Part of the Beliefs Category

Sensemaking is mentioned as a form of students' beliefs in physics and learning. It is one of the categories in the Colorado Learning Attitudes about Science Survey (CLASS) developed by Adams et al. (2006). Its validation found that many students understand sensemaking as an additional effort, where the decision to make the effort or not will depend on the analysis of the benefits of the effort required. Further research on sensemaking from the perspective of belief has been conducted by Sulaiman, Rosales Jr, and Kyung (2023). This study demonstrates that interventions such as the use of STEM-PjBL-based physics modules can improve sensemaking in secondary schools, compared to traditional interventions quantitatively. This study used the Egg-Drop project, which covers the concepts of momentum, impulse, and impulsive force. Using the CLASS-Sensemaking/Effort instrument, this study found that this intervention was able to improve students' sensemaking, particularly in changing their perceptions of physics.

A student and teacher evaluation of physics using CLASS to identify difficulties in learning and teaching physics in the classroom was conducted by Suwonjandee, Mahachok, and Asavapibhop (2018). A survey of 196 physics teachers and 211 secondary school students in Thailand found that sensemaking/effort was above 50%, with teachers expressing more confidence than students. The difference in student and teacher difficulties lies in students learning physics by memorizing formulas and not understanding physics concepts, while teachers perceive students as lacking basic mathematical knowledge. Furthermore, the integration of PhET simulations into the Metacognitive Argument-Driven Inquiry approach improved attitudes toward physics learning (Antonio, Cruz, Pagsanjan, & Castro, 2026). Using a single-group pretest-posttest design within a pedagogical action research framework, this study utilized both quantitative and qualitative data. Participants consisted of 26 students. Sensemaking/Effort received favorable responses in the pretest (86.81) and posttest (84.62), although there was a decrease, but it was not significant. One of the interview results regarding students' attitudes toward physics, as shown in this interview excerpt, indicates that students viewed the learning activities as effective because they helped them develop a more meaningful understanding of concepts. Scientific concepts previously considered difficult or incomprehensible became more understandable when connected to everyday life situations. The use of PhET activities and simulations in this context contributed to the development of students' positive attitudes toward physics.

Synthetically, the third study confirms that physics sensemaking as a belief category is strongly influenced by students' learning experiences. When learning is dominated by traditional approaches, students' physics sensemaking as a belief tends to remain at a beginner level. In contrast, project-based interventions, metacognitive inquiry, and interactive technology play a significant role in shaping and strengthening physics sensemaking and emphasize that the activities of meaning-making, reasoning, and conceptual construction, thus making sense, become a key characteristic of expert-like beliefs in physics learning.

2.3. Blended Math-Sci Sensemaking

Another finding was that some researchers developed instruments to observe and understand the sensemaking of students and university students in physics. There are two types of sensemaking in physics that are often used, namely, science sensemaking and mathematical sensemaking. Mathematical sensemaking involves searching for meaning and coherence in mathematical formalism itself and between mathematics and the systems it describes. In other words, mathematical sensemaking is the tendency and ability to translate back and forth between mathematical relationships on the page and causal or functional relationships in the world (Gupta & Elby, 2011). Meanwhile, science sensemaking is an effort to construct and articulate explanations of observed phenomena based on the coordination of knowledge, thinking, and understanding of scientific concepts (Audet, Hickman, & Dobrynina, 1996; Newman, Morrison, & Torzs, 1993). This depends on the ability to distinguish between theory, evidence, and one's intuitive beliefs. Zhao and Schuchardt (2021) state that mathematical equations in science contain conceptual knowledge about mathematics based on the arrangement of symbols and operations contained in the equation. These equations also contain links to scientific phenomena. Physics sensemaking is not simply a learning outcome but rather a cognitive process that requires deliberate and sustained exploration throughout learning. Kaldaras and Wieman (2023) described a theoretical framework that suggests that physics sensemaking develops through complex stages, from describing phenomena to recognizing patterns to understanding mathematically quantified causal mechanisms. Achieving the highest levels is only possible when students are given the space to explore the relationships between physics concepts and mathematical representations through activities that require in-depth reasoning, not simply the application of formulas. Empirical findings by Sari et al. (2024) reinforce this by showing that although the learning module effectively improved sensemaking in general, limited exploration of pattern recognition caused most students to remain at the qualitative level. This indicates that exploring physics sensemaking through open-ended questions, conceptual discussions, and activities that encourage students to test and revise their understanding is key to fostering the transition from description to understanding patterns and mechanisms. Thus, exploring sensemaking is not only important for improving levels but also essential for building a holistic, integrated, and in-depth understanding of physics, oriented toward scientific explanation.

3. METHODOLOGY

3.1. Research Design

This study used an explanatory sequential mixed methods design, which allowed quantitative data to be collected first, followed by qualitative data to help explain the results of the quantitative data (Creswell & Creswell, 2018). Figure 1 illustrates the research design flow. The process begins with the collection and analysis of quantitative data, then uses the results to select participants and collect qualitative data through interviews. The flow concludes with the interpretation of the results by combining the quantitative and qualitative findings narratively.

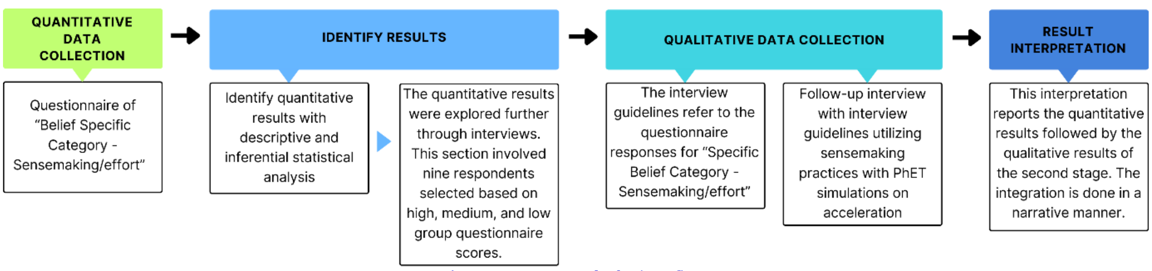

Figure 1. Research design flow.

Quantitative data were collected using a survey method targeting first-, second-, and third-year physics education students at Universitas Negeri Malang.

First-year students have taken the first part of introductory physics courses, second-year students have taken various physics and basic education courses, while third-year students have taken courses with peer-teaching assignments. Sampling was based on random sampling, and 226 physics education students were obtained. Participant demographics are presented in Table 1.

Quantitative data collection used Google Forms, and data analysis was performed using descriptive statistics. Next, respondents were selected for qualitative data collection, namely three students from each level who had high scores (H1, H2, H3), medium scores (M1, M2, M3), and low scores (L1, L2, L3), to be interviewed using semi-structured interviews.

The qualitative data results then served as an explanation of the quantitative data.

Table 1. Research participants.

Academic years	Gender	Number of students	Percentage (%)
1st year course	Male	13	15.5
	Female	71	84.5
2nd year course	Male	6	9.7
	Female	56	90.3
3rd year course	Male	16	20.0
	Female	64	80.0

3.2. Research Instrument

The research instruments used in this study consisted of two types, namely quantitative data instruments and qualitative data instruments. The quantitative data instrument was adapted from the questionnaire on the sensemaking/effort indicator by Adams et al. (2006), which consisted of seven statement items and has been statistically validated and has a robustness value of 5.91, indicating adequate internal coherence. Meanwhile, the qualitative data instrument consisted of two interview guidelines.

The first interview protocol (IP1) contained questions to confirm the questionnaire answers, such as "Why do you feel satisfied with why something (a phenomenon in physics) can happen that way?" An expert with extensive experience in physics education assessment research reviewed IP1. The purpose of this expert review is to ensure the relevance of the content, conceptual consistency, and clarity of the interview questions. Given the exploratory nature of IP1 in terms of questionnaire responses, reliability is ensured through the consistency of the coding scheme in line with the questionnaire items.

The second interview protocol (IP2) is a form of deeper exploration of blended math-sci sensemaking taken from Kaldaras and Wieman (2023), which asks students to explore and practice acceleration simulations before the interview. Previous researchers have mentioned that interview analysis is evidence of the validity of IP2, with results showing that students' consistency tends to achieve the same level of performance in various disciplinary contexts, suggesting that blended math-sci sensemaking is a unique cognitive construct, regardless of the specific disciplinary context. IP2 will provide an overview of the level of sensemaking possessed by physics education students (Table 2). Physics education experts have translated the language in the instruments into Indonesian, preserving the original meaning to facilitate respondents' understanding.

Table 2. Interview answer rubric to justify the level of blended math-sci sensemaking in acceleration practices.

Level of Blended Math-Sci Sensemaking		Description
1. Qualitative	Description	Students recognize that force and mass influence acceleration and velocity.
	Pattern	Students see general patterns, such as greater force, greater acceleration/Velocity, and vice versa.
	Mechanism	Students recognize that force causes acceleration, but are unable to accurately explain the physical mechanism.
2. Quantitative	Description	Students express the force-mass-acceleration relationship quantitatively using data or simulations.
	Pattern	Students identify the linear relationship between force and acceleration and the effect of mass, but their mathematical reasoning is still limited.
	Mechanism	Students begin to use mathematical equations (e.g., $a = F/m$), but their explanations of the physical mechanism and choice of variables are still inconsistent.
3. Conceptual	Description	Students understand acceleration as the result of the resultant force on mass and can relate this to the correct equation.
	Pattern	Students understand acceleration as a derived quantity and can consistently explain the mathematical relationship between force, mass, and acceleration.
	Mechanism	Students explain the physical mechanism as a whole: how force distributed over mass produces acceleration, and can justify the use of appropriate equations and variables.

3.3. Data Analysis

Data analysis was carried out in two stages: quantitative data analysis and qualitative data analysis. The quantitative data obtained were then analyzed using descriptive statistics and inferential statistics using SPSS version 26. Descriptive statistics were used to describe and summarize the data in an easily understandable form using tables, graphs, and statistical figures (Creswell & Creswell, 2018). Meanwhile, inferential statistics used the Kruskal-Wallis test to compare the three groups based on academic level. Kruskal-Wallis was used because the data were not normally distributed (*p-value* < 0.05). The second stage, qualitative data analysis (Miles & Huberman, 1994), involved transcribing the interviews from the IP1 results. Next, reduction and coding were carried out, followed by narrative and visual data presentation, and verification was conducted with the IP2 results by determining the level of sensemaking of physics education students.

4. RESULTS

4.1. Sensemaking as Part of the Beliefs Category

The physics sensemaking of physics education students in their first, second, and third years of study has characteristics in terms of variability, namely minimum, maximum, and standard deviation values. Table 3 shows that the minimum and maximum values obtained indicate that the longer students study physics, the higher their physics sensemaking. In addition, the standard deviation values show that there is not much variation in the students' questionnaire responses. Meanwhile, the mean value, which is a measure of central tendency, shows differences between first-, second-, and third-year students.

Table 3. Descriptive statistic results.

Academic years		N	Mean	Min.	Max.	Std. Dev
1st year course						
	Male	13	20.62	12	27	4.874
	Female	71	19.76	9	28	4.770
2nd year course						
	Male	6	19.33	11	23	4.274
	Female	56	21.84	14	28	2.891
3rd year course						
	Male	16	21.31	15	27	2.960
	Female	64	21.73	14	28	2.644

The differences in results are shown in Figure 2. It appears that physics sensemaking among physics students has improved year by year. This improvement is also due to the various experiences and physics contexts they have learned during their studies. However, this result contradicts the statistical analysis of differences between the three groups. It was found that there was no difference between the three groups of students with different levels of study [*p-value* = 0.064 > *Sig.* 0.05].

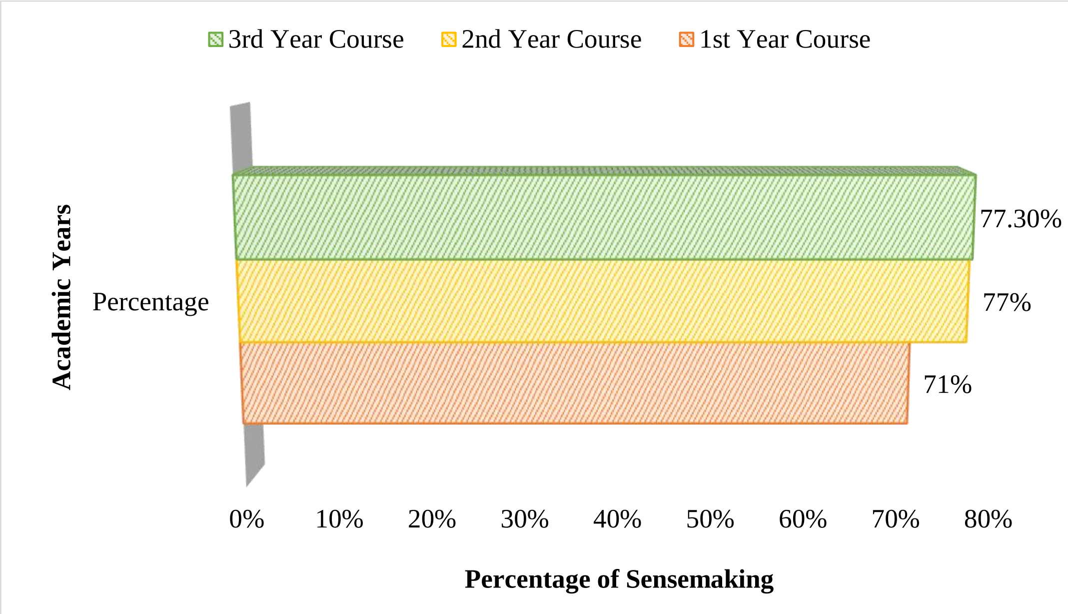

Figure 2. Physics sensemaking results diagram.

The physics sensemaking possessed by students forms a construct that contributes to the understanding of physics concepts. This construct is based on each statement item in the questionnaire and is revealed in the qualitative data findings. The construct that emerges consists of belief in the calculation process, satisfaction through understanding phenomena, the importance of understanding formulas, attitudes towards the history of formulas, flexible approaches to problem solving, explicit physics thinking, and the association of information with existing knowledge. The following are the constructions that emerged based on the interview results presented in Figure 3.

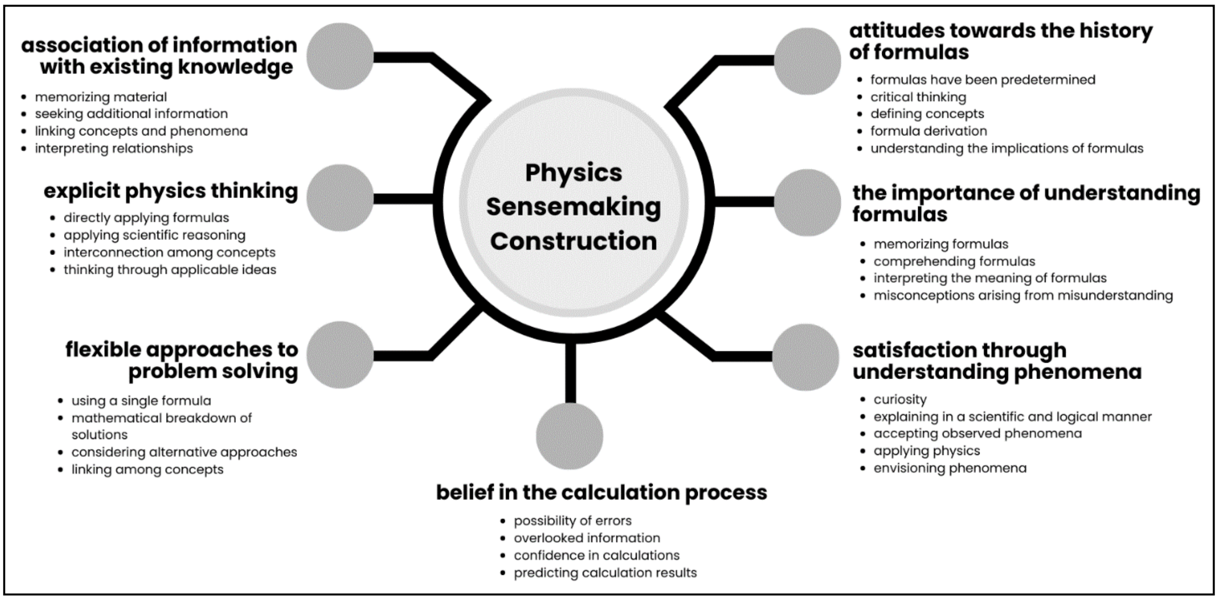

Figure 3. Physics Sensemaking Constructions of Students.

Confidence in the calculation process is essential when solving physics problems. Students feel confident in their calculations and, conversely, need to reread the questions presented. Students with low sensemaking tend to prefer rereading over students with higher sensemaking. This is evident in the following interview excerpts.

I think that when working on physics problems, there may be some information that is overlooked, for example, not converting the temperature unit of 20 degrees Celsius to Kelvin, so it would be better to reread the question and check the answer. (Student L2)

I am sure that the formula I have used is the correct one. If there is a difference between the result and what I expected, I will still trust my calculation. (Student M1)

I am quite confident about my answer, so I think that rereading the question will not change my answer. (Student H2)

Students can only feel satisfied when they truly understand the reasons behind phenomena in physics. However, students with low sensemaking tend to accept or be satisfied with the results of phenomena in physics. This is shown in the following interview answers:

I am not curious about how things work in physics; I feel it is enough to simply accept the phenomena that have occurred. (Student L3)

I am not satisfied with the reasons why a physical phenomenon occurs because often what happens is not in line with what I think. An example is a badminton shuttlecock. Every time we hit it and give it to our opponent, the round part always touches the racket first. Then I asked other people about this phenomenon, and I got the answer that the round part is the heavy part, so it falls first and hits the racket. However, I am still not satisfied with that answer. (M2 Student)

There is a feeling of unease/invalidity/incompleteness when I don't understand why it happens. I also prefer to imagine the phenomenon when working on physics problems. If I don't know why something happens, it is difficult for me to imagine it, especially for cases that are different but have the same concept. If you only memorize the formula, it seems meaningless. I think it is important to understand why a phenomenon occurs and how to translate that real phenomenon into a mathematical equation. Then, from the information obtained in the basic/simple/general phenomenon, more complex/specific concepts are derived based on cause-and-effect relationships. (H3 student)

Emphasis on the importance of understanding formulas. Students tend to feel it is important to understand formulas before they can use them correctly. The following are the students' interview responses.

I disagree that in physics it is important to understand formulas before applying them because there are some theories that are not in the form of formulas or do not include formulas, so only concepts can be explained logically. In my opinion, if you already understand the concept, you should be able to apply it in solving problems. (Student L2)

I need to understand the explanation of the physics concept first, so that when I use the mathematical formula, I can apply it to the right concept. (Student M1)

The concept of physics is not just memorizing formulas but must be understood how the concept in a formula, for example $F = ma$, then you must know the concept of why $F = ma$. (Student H2)

The attitude towards spending time to understand the origin of physics formulas may be useful or a waste of time. Spending a lot of time understanding where the formulas come from is, in my opinion, a waste of time. Students with low physics sensemaking will feel that understanding formulas is a waste of time because formulas are fixed. This can be seen in the following interview excerpt.

Understanding where formulas come from is a waste of time because they have already been established with a history of their origins. (Student L1)

In my opinion, the origin of the formula is important; the way we understand the formula is the history of the formula itself. For example, in mathematics, negative times negative equals positive, which means there is an explanation as to why it must be positive. Moreover, this is not a waste of time, especially as a prospective teacher who should teach not only mathematical formulas. (Student M2)

In my opinion, it is essential to know where the formula comes from (whether it originates from other formulas or from direct phenomena/experimental formulas). This way, I can fully understand all the physics material related to the formula. By knowing the origin of the formula, different problems with the same concept can be solved consistently. However, if we do not know the origin of the formula, then when we encounter a different problem within the same scope, we will definitely have difficulty solving it. (H3 student)

Students demonstrate flexibility in finding solutions using various approaches to deepen their understanding. Students with low sensemaking tend to use one method to solve physics problems, but students with high sensemaking tend to use two methods, the second as an alternative or by using the interrelationship between concepts. This is shown in the following interview answers.

I only use one method to solve physics problems by using one formula that remains the same even though I have to check it repeatedly. (Student L2)

In physics, in my opinion, even though one main formula is given, it can be derived into several formulas, or if you understand the theory, you can reveal the relationship between one theory and another, so there are other methods that can be applied to the problem. I use one common method first, and if I cannot solve the problem, I look for and find other alternative solutions. (M3 Student)

By solving problems using different methods, I will understand them better and, most importantly, know the relationship between each subject. For example, solving problems related to the motion of objects using an energy review and using Newton's dynamics review alone (without energy). It is even possible to connect two seemingly different courses. (H3 Student)

Students demonstrate awareness in considering relevant physics principles when solving physics problems. When solving physics problems, students with moderate and high sensemaking explicitly think about which physics ideas apply to the problem. This is shown in the following excerpt.

I just look at what is known and then put it into the mathematical formula. (Student L1)

I assume that if there is a physics problem, I will connect it with various physics concepts and then look for a more appropriate subtopic, after which I will find the equation to use. (M3 student)

When solving physics problems, I often explicitly apply them in everyday life, and I can immediately understand the problem and relate the concepts and phenomena I have encountered. (H1 student)

The need to connect new information with existing knowledge is a way to understand physics. When learning physics, students tend to connect important information with what they already know rather than just memorizing it as presented. This is supported by the following interview responses.

I feel that connecting other information that I already know is also necessary when learning physics, so it's not just memorization. (Student L2)

I find it enjoyable to learn to understand and reread physics concepts even though they often don't make sense and are abstract, and I have thought about physics concepts when I see physical phenomena, such as when I draw water. (Student M2)

Sometimes there is knowledge that is not written in books, but I may not know it, so I look for information from journals, Google, or discussions with friends to gain new knowledge. Sometimes I also see a physical phenomenon and then I remember which physics concept is used in that phenomenon. (Student H1)

4.2. Sensemaking Level with Acceleration Practices with PhET Simulations

This section presents the results of an analysis of students' physics sensemaking levels on the topic of acceleration through PhET simulation practice. These findings are supported by in-depth interview data with nine respondents involved in the "acceleration" simulation exploration activity, with the aim of uncovering how students construct, relate, and interpret physics concepts in mathematical and scientific phenomena contexts. The sensemaking levels demonstrated by respondents are classified into several levels based on the characteristics of their answers during the interviews. A summary of the sensemaking levels, along with representative answer quotes from each respondent, is presented in Table 4 to provide a qualitative overview of the variations in the depth of understanding and physics reasoning processes that emerged during the use of the PhET simulation.

Table 4. Level of blended math-sci sensemaking respondents in physics context.

Respondent	Level	Interview answer excerpts
Student L1	Level 1 Qualitative description	To exert a force, energy is required. The greater the force, the greater the energy needed. This energy causes a change in the object's position, and thus the acceleration increases.
Student L2	Level 1 Qualitative pattern	The constant quantity is mass. When the force applied to an object is increased, the resulting acceleration also increases. For example, if a 50 kg object is subjected to a force of 150 N, its acceleration is 3 m/s^2. This data shows that force and acceleration are directly proportional; that is, the greater the force acting on an object, the greater its acceleration.
Student L3	Level 2 Quantitative description	In Table B, the mass remains constant while the force is varied, resulting in an acceleration that increases proportionally with the applied force. This aligns with the data, as when the frictional force is unknown, the equation $\Sigma F = ma$ cannot be directly applied, where m is constant. For example, if we calculate a, we divide the applied force by the mass. For instance, 150 N / 50 kg = 3 m/s^2. This is consistent with the obtained data.
Student M1	Level 2 Quantitative description	If we apply a force to an object, for example, 10 N with a mass of 5 kg, the acceleration can be calculated using the equation $\Sigma F = ma$. Rearranging gives $a = \Sigma F/m$, so 10 N / 5 kg = 2 m/s^2, provided the object moves without friction. If friction is present, then the kinetic constant must be considered. If the applied force is large, the acceleration will increase and the object will move faster. Conversely, if the applied force is small and friction is present, the object will move more slowly.
Student M2	Level 1 Qualitative mechanism	If the force is large, then the acceleration will also be greater. Acceleration is important because it is a measure of how quickly the velocity of an object changes. Therefore, in the simulation, understanding acceleration helps in predicting how an object will move in response to the applied force.
Student M3	Level 2 Quantitative mechanism	From the mathematical equation $\Sigma F = ma$, with F varied while the frictional force remains constant, the resultant force changes while the mass remains constant. Thus, it can be seen that as the resultant force acting on the object increases, the acceleration also increases. This is evident from the numerical data obtained. Furthermore, from the provided data and after conducting the simulation, it is shown that the force acting on the object affects its acceleration, and that mass is inversely proportional to acceleration.
Student H1	Level 1 Qualitative pattern	The quantities that change are force and acceleration, while the constant quantity is mass. When a force acts on an object, the object experiences acceleration, so acceleration is directly proportional to the magnitude of the force. If the applied force is large, the acceleration will also be large.
Student H2	Level 2 Quantitative pattern	From $\Sigma F = ma$, it can be seen that the greater the force, the greater the acceleration, since they are directly proportional. For example, if the mass is 20 kg and the acceleration is 0.5 m/s^2, then the resulting force will be 10 N.
Student H3	Level 3 Conceptual mechanism	In the equation $\Sigma F = ma$, acceleration is the result of the resultant force acting on an object. In the PhET simulation, the robot exerts a thrust that acts as an external force on the object. When the magnitude of the thrust increases while the object's mass remains constant, the object's acceleration also increases. This acceleration causes the object's velocity to change over time because acceleration is the rate of change of velocity. As a result, an object that was initially at rest will move faster. This relationship is in accordance with Newton's Second Law, which states that acceleration is directly proportional to the resultant force and inversely proportional to the object's mass. Data obtained from the simulation also show a pattern consistent with the equation $\Sigma F = ma$.

Based on these results, it was found that the longer students' experience in attending lectures, the more mature their understanding of the concepts became. This indicates that students' physics sensemaking will also be stronger after attending lectures, although some students are still at level 2 (qualitative) in their third year of the course.

5. DISCUSSION

This study has revealed that the attitudes/perceptions of physics education students towards sensemaking do not differ based on their level of education. However, different results show that third-year students tend to have a higher level of sensemaking when conducting PhET simulations. There are several explanations for how different perceptions and practical sensemaking abilities are found in students. First, perceptions/attitudes toward how to interpret phenomena have been formed for a long time. This perception begins with how students interpret physics lessons from high school, which tend to focus on mathematics but diminish the connection between the fundamental applications of physics and everyday phenomena. To change these perceptions, students need to step out of their "comfort zone," which they tend to avoid. For example, research Poulou (2005) found that the level of education of prospective teachers in Greece did not affect their perceptions of the severity of emotional and behavioral difficulties. Furthermore, their research found a slight improvement due to the fact that in their third year, students had begun practicing in schools and learning about student needs. We assume that, in addition to their time spent in college lectures, their teaching experience in schools encourages physics education students to construct explanations in the classroom (Bada & Jita, 2023). Consequently, when high school students ask questions or point out misconceptions, they are encouraged to reinterpret the physics concepts being taught. They must explain why a concept works, not just how to use a formula. Second, computer simulations can directly stimulate students to engage in physics sensemaking. Technological tools that contain various data representation features used by students in learning have been proven to facilitate the sensemaking process (Rogers, Connelly, Hazlewood, & Tedesco, 2010). The interactive environment and attractive visual representations encourage prospective teachers to engage more deeply. Third, scientific uncertainty and gaps in understanding encourage and determine how sensemaking activities are carried out. Without PhET simulations, students tend to have a static and rigid perception of sensemaking. They only imagine how meaning-making is done without interacting with anything. This is in contrast to PhET simulations, which provide a platform for students to explore and resolve these uncertainties (Ha, Park, & Chen, 2024).

In addition to differences in sensemaking between each level, each student also has a different level of sensemaking to understand information from the same situation. This can be seen from the findings that students with level 1 math-sci sensemaking are not only found among respondents in the group with low sensemaking perceptions, but also among first-year students who have strong beliefs about sensemaking (student H1). This contrasts with the findings by Kaldaras and Wieman (2025), where only two out of twenty-two students are at level 1. Students at level 1 sensemaking must be supported in developing a deeper mathematical understanding and, when understanding phenomena, being able to integrate mathematics and science (Kaldaras & Wieman, 2025). It can be seen from the answers of H1 that students fail to build bridges, making it difficult for them to understand the gaps or questions that construct the meaning of mathematical situations or activities. This is supported by Weinberg et al. (2016) that an alternative way of sensemaking thinking is to focus on scientific practices and discourse patterns. This also depends on the understanding of the language used for the gaps/questions asked; the importance of language is also expressed.

Students with higher sensemaking abilities tend to be able to provide perceptions and bridge knowledge gaps by providing explanations that integrate mathematics and phenomena. This can be seen from the results of the third-year student questionnaire of 77.30% and the results of capturing three students for further exploration show that third-year students are able to explain their beliefs about physics science and learning, in addition, they can represent sensemaking in the context of acceleration practice, especially in student H3 who can answer in detail how the cause and effect mechanisms occur between knowledge and mathematics in simulations. This proves the balance between belief and sensemaking practices possessed by these students. Sensemaking here can indicate the deep understanding that students have of physics concepts and their applications, as in the research by Cannady, Vincent-Ruz, Chung, and Schunn (2019) that sensemaking, when faced with an explanation of a phenomenon, requires an understanding of scientific content and scientific practice. This proves that sensemaking is a process that facilitates the generation of new knowledge by connecting existing ideas (Sirnoorkar, Bergeron, & Laverty, 2023). An indication that students may have strong sensemaking is by repeatedly engaging in activities to understand physics content related to their prior knowledge and identifying relevant physics principles to solve problems.

The results of this exploration reinforce previous research findings, thus highlighting the need to support sensemaking in physics education. Strong indications of the need for further research to support sensemaking in physics. There are several important implications for physics teaching practice. First, educators need to realize that teaching physics is not just about transferring formulas and procedures, but also creating space for students to connect formal concepts with their experiences (Odden, 2021). The application of learning strategies such as project-based learning (Juan & Sulaiman, 2016; Sulaiman et al., 2023), epistemic games (Odden & Russ, 2018), calculation-concept crossover (Kuo et al., 2020), and multiple representations (Rau, 2018; Rau, Aleven, & Rummel, 2017), PhET-based simulations (Kaldaras & Wieman, 2023), and the use of learning modules (Sari et al., 2024). In addition, sensemaking can be developed through problem presentation (Rogers et al., 2010), as in the research by Setiani, Kade, and Darsikin (2018), which states that the use of hypothetical debate problems resulted in a 40% qualitative shift in sensemaking and a 35.56% quantitative shift in sensemaking. Several of these learning interventions are expected to strengthen physics sensemaking, but the success of sensemaking depends on how the instructions are tailored to student needs, topic context, and educator readiness. Second, teacher training needs to focus on developing pedagogical skills that support sensemaking, including how to facilitate meaningful discussions, provide reflective feedback, and use simulation technology to strengthen students' conceptual understanding (Syiem & Türkay, 2025).

6. CONCLUSION

This study successfully explored the phenomenon of sensemaking in the context of physics learning among physics education students. It was found that third-year students scored higher, followed by second-year students and then first-year students. This difference was not statistically significant but was visible in the mean scores and percentage of physics sensemaking. The findings were supported by IP1, where the emerging constructs included belief in the calculation process, satisfaction through understanding phenomena, the importance of understanding formulas, attitudes towards the history of formulas, flexible approaches to problem solving, explicit physics thinking, and the association of information with existing knowledge.

However, different results emerged in students' answers on IP2. Physics education students with moderate sensemaking and understanding scores did not show improvement, as second-year students scored lower than first-year students. Similarly, at the student level, first-year students with moderate scores (Student M1), who were at level 2 in quantitative description, tended to score higher than students with high sensemaking scores (Student H1), who were only at level 1 in qualitative pattern.

The implications of this study reinforce previous research on responding to students' thoughts related to physics sensemaking, and sensemaking can be supported through interventions in physics learning. Future research can utilize these findings, especially for first-year students, as a guide for learning interventions to build sensemaking at the high school level. This foundation is crucial for students, particularly Indonesian students, to acquire complex physics knowledge that supports their career interests.

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