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Profile of Students' Physics Problem-Solving Skills and the Implementation of Digital Book-Assisted PBL for SDG 4

Dhea Wanda Irani[1*], Elvia Reza Lutfiani[1], Siska Agustin Sha Hareni[1], Nofri Hidayatin[1], Nurul Muawiyan[1], Binar Kurnia Prahani[1], Hanandita Veda Saphira[2]

[1]Universitas Negeri Surabaya, Surabaya, Indonesia
[2]University ofWollongong, Wollongong, Australia

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ABSTRACT

***Objective**: This study aims to analyze the profile of students' physics problem-solving skills as a basis for applying the digital book-assisted Problem-Based Learning (PBL) model to sound wave material at the high school level. This analysis was conducted to determine the level of students' problem-solving abilities and to identify differences in abilities based on gender as a basis for developing more effective learning strategies. **Method**: This study used a quantitative descriptive approach involving 108 high school students as research subjects. The research instruments included a physics problem-solving skills test, a student response questionnaire, and interviews with physics teachers. The test was compiled based on problem-solving skill indicators that included understanding the problem, planning the solution, implementing the strategy, and evaluating the solution. The data were analyzed using the Rasch model to obtain more accurate measurements of student ability levels and question difficulty levels. **Results**: The results showed that students' physics problem-solving skills were generally still in the low category. Most students had difficulty understanding problems conceptually, determining the appropriate solution strategy, and evaluating the results of the solution. Analysis based on gender shows that the abilities of male and female students are relatively balanced. However, female students tend to be more thorough in descriptive and evaluative aspects, while male students are more prominent in the solution planning stage. **Novelty**: The novelty of this study lies in the analysis of students' physics problem-solving skill profiles from a gender perspective using the Rasch model as an empirical basis for developing a more interactive and contextual 3D digital book-assisted PBL model to improve students' physics problem-solving skills.*

INTRODUCTION

Quality education is a key pillar of global sustainable development, as outlined in the United Nations Sustainable Development Goals (SDGs), particularly SDG 4, which ensures inclusive and equitable quality education and promotes lifelong learning opportunities for all. To achieve SDG 4 targets, especially target 4.4, which emphasizes the mastery of skills relevant to 21st-century education, there has been a paradigm shift. This shift requires a learning process that was originally dominated by the role of the teacher (teacher-centered) to now shift to learning that places the student at the center (student-centered) (Muliana et al., 2024).

This paradigm shift encourages students to master 21st-century skills, which are a set of abilities needed for them to participate effectively in education and the world of work in the current era (Saphira et al., 2022). Learning and innovation skills are one of the main aspects in the development of 21st-century skills (Tika, 2024). These skills are known as the 4Cs, which include creative thinking, critical thinking and problem solving, communication, and collaboration (Viyanti et al., 2025).

One of the important skills that students must have in facing the current era is problem-solving skills (Sunarti et al., 2025). Problem-solving skills reflect students' ability to analyze facts, test assumptions, and formulate appropriate strategies to find solutions to problems they face, followed by an evaluation of the chosen solution (Henra et al., 2025). The process of developing this ability is usually carried out through several stages, namely identifying and visualizing the problem. describing problems in terms of physics concepts, planning solutions, using solutions, and evaluating the results of problem solving (Dwikoranto et al., 2025).

Although problem-solving skills problem-solving are are one of the important skills in 21st-century learning. In reality, students' problem-solving skills are still relatively low, especially in the context of physics learning (Pristianti & Prahani, 2022). Physics education emphasizes the understanding of scientific concepts and their application in everyday life (Sari et al., 2023). Indeed, physics education is closely related to everyday life. In addition, physics also trains logical, analytical, and critical thinking in solving various problems related to everyday life and natural phenomena (Dwiyanti & Perdana, 2024).

In physics lessons, many materials are abstract and difficult to visualize, making it difficult for students to understand the concepts in depth (Pradana & Supahar, 2025). One example of such abstract material is sound waves, where the process of wave propagation and interaction cannot be observed directly by the human senses, but must be understood through models and conceptual representations (Asrizal et al., 2025). The difficulties experienced by students in learning about sound waves can be influenced by several factors, one of which is the low representational ability of students to construct, interpret, and connect various forms of representation in order to understand and communicate concepts (Silaban & Jumadi, 2022).

The low problem-solving skills of these students are due to the fact that physics education in schools is generally still teacher-centered, oriented towards procedural problem solving, and does not emphasize conceptual understanding and its application in real-life situations (Hutasoit, 2021). Many students tend to simply memorize formulas without understanding the physical meaning behind them, making it difficult for them to apply these concepts to solve contextual problems (Asyhari & Sifa'i, 2021). In addition, the limited availability of interactive learning media and the lack of experiments or exploration activities cause students to become passive in their learning.

This is in line with research conducted by Cindikia et al. (2020), which states that students are still passive and have low problem-solving skills. Research conducted by Mashurin et al. (2021) states that the problem-solving abilities of high school students are still low and there are limitations in practical tools. Research by Meisaroh et al. (2020), Musengimana et al. (2025), and Kinasih et al. (2023) also confirms that students' problem-solving skills are still relatively low. These conditions indicate that efforts to improve problem-solving skills in physics learning cannot be done using conventional methods, but rather require innovation so that the learning process becomes more active, contextual, enjoyable, and not monotonous (Satipa et al., 2024).

One effective learning model for this purpose is the Problem-Based Learning (PBL) model, which is a learning approach that encourages active student involvement in identifying, analyzing, and solving problems scientifically (Haris and Mahir, 2025). PBL is a model that promotes deep and analytical learning in line with SDG 4's demand for high-quality and relevant education. According to Annisa and Haryadi (2023), the model Problem-Based Learning (PBL) can improve students' problem-solving skills. This problem-based learning model, or Problem-Based Learning (PBL) model, has several advantages, one of which is encouraging increased student participation in learning activities at school, especially in physics lessons (Ghofur et al., 2023). Basically, this model places students at the center of the learning process, or in other words, it is student-centered, so that students are not only recipients of information, but also play an active role in discovering, analyzing, and solving problems that arise within themselves, while teachers act as guides in the process (Alvarez et al., 2025).

The paradigm shifts in the 21st century has not only occurred in the field of education, but in all aspects of life. One area that has also experienced rapid development is technology. With this technological development, the learning process also needs to adapt through the use of technology as an integral part of learning activities (Zakaria et al., 2023). The integration of technology in learning can create a more interesting and interactive learning atmosphere, thereby increasing students' interest, curiosity, learning outcomes, and motivation to learn (Prahani et al., 2022).

Research conducted by Neswary and Prahani (2022), as well as Andani et al. (2022) confirms that the use of 3D digital books is very effective in physics learning because it can help students solve various problems in physics. Digital books are one of the learning media that teachers can use to support the teaching process in the classroom (Prahani et al., 2022). By using these digital books, problem-solving skills can be continuously trained to meet the demands of 21st-century skills. In addition, 3D digital books have advantages in terms of efficiency and flexibility, as they can be accessed anytime and anywhere via mobile devices, which is in line with SDG 4 (Septikasari et al., 2021).

To address the issue of low problem-solving skills that could potentially hinder the achievement of SDG 4.4 target and as a basis for more equitable and effective learning innovation, further studies are needed to understand the problems, factors, and conditions of students in carrying out learning. Therefore, a preliminary study is needed with the aim of analyzing the conditions of physics learning and differences in problem-solving skills based on gender as a basis for more equitable and effective learning innovation. Based on the previous description, this study aims to:

1. What are the current conditions of physics learning among high school students?
2. How do students' physics problem-solving skills differ based on gender?
3. How are the physics problem-solving skills of high school students on the subject of sound waves as a basis for applying the Problem-Based Learning (PBL) model assisted by 3D digital books?

RESEARCH METHOD

Research design

This study uses quantitative descriptive research based on collected data. The quantitative approach serves to test a sample that produces data in the form of numbers and is then analyzed using WinStep programming and statistical techniques. Figure 1 shows the research flowchart adapted from the study (Kinasih et al., 2023).

Figure 1. Research methods

Sample and data collection

The subjects of this study were 108 high school students in the 2025/2026 academic year, consisting of 3 classes with a total of 65 female students and 43 male students. Data collection in this study was obtained from primary and secondary data. Primary data was obtained through direct observation by the researcher. Overall, the data used in this study was sourced from tests, interviews, and questionnaires given to students. Meanwhile, secondary data was obtained from the analysis of previous relevant studies and was used to reinforce the primary data (Rachmawati et al., 2022).

Measurement instruments

The research instruments used included problem-solving skill tests, student response questionnaires, and interviews with physics teachers. The problem-solving skill test consisted of five essay questions based on problem-solving skill indicators. Each question measured five problem-solving skill indicators (Lestari I, 2023). Each question is worth 20 points, with a maximum score of 100 points. Students are given approximately 45 minutes to complete the questions. The questions have been validated by three undergraduate physics education students who have graduated and are deemed suitable for use in research.

After the students completed the test, a student response questionnaire was distributed in the form of a Google form to find out their responses to physics learning. The student response questionnaire contains 10 statements that must be answered on a 4-point scale (4= strongly agree, 3= agree, 2= disagree, and 1= strongly disagree). The questionnaire covers three main aspects, namely physics learning, problem-solving skills, and digital book media.

In the next stage, interviews were conducted with physics teachers to obtain more in-depth information about the learning process in the classroom, such as the use of digital books as learning media and the extent to which students were trained in problem-solving skills. These interviews aimed to align the answers between teachers and students.

Table 1. Indicators of problem-solving skills by question type (Basse, 2025)

No	Indicator	Information	Number of Questions
1	Visualize the problem	Identify important information from the question and describe the problem situation in the form of a sketch or diagram.	1, 2, 3, 4, and 5
2	Physics description	Describe everything that is known and asked in the question.	
3	Plan a solution	Systematically develop steps for solving problems based on relevant physics concepts.	
4	Execute the plan	Performing calculations by substituting known values into mathematical equations.	
5	Check and evaluate	Review the results obtained and draw conclusions based on the analysis and physics concepts used.	

Data analysis

In this study, the instruments were analyzed using Rasch modeling with the help of WinStep software. This modeling was chosen because it is a probabilistic model that assumes that the probability of a person answering an item correctly is not only determined by the characteristics of the item, but is also influenced by the individual's ability to answer the question (Nisa et al., 2024). In other words, students with high abilities have a greater chance of answering correctly than students with low abilities.

This analysis was conducted with the aim of obtaining a valid and reliable instrument for measuring problem-solving abilities (Simamora et al., 2022). Rasch modeling has a number of advantages, namely: 1) it can produce a linear scale with equal intervals, 2) it can estimate or predict missing data, 3) it provides more accurate parameter estimates, 4) it has the ability to detect discrepancies between data and models, and 5) it produces consistent and replicable measurements (Simamora et al., 2022). The clustering of the data to be analyzed is shown in Figure 2.

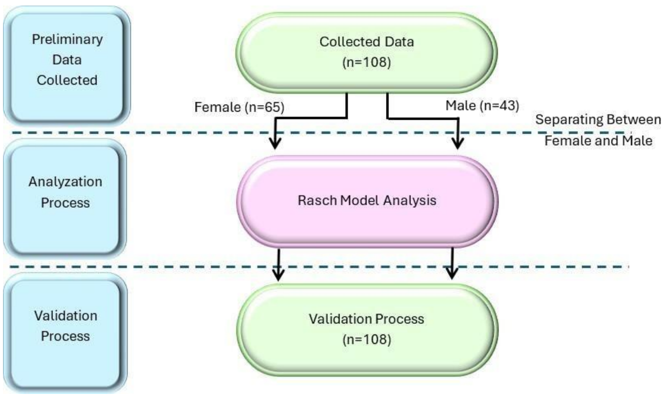


Figure 2. Analyzing collected data scheme

Table 2. Unidimensionality criteria (Ahmad et al., 2025)

Percentage Value of Raw Variance Explained by "Observed" Measures	Criteria
>60%	Very good
40%-60%	Good
20%-40%	Fair
≥20%	Minimum
<20%	Poor
<15%	Unexpected variation

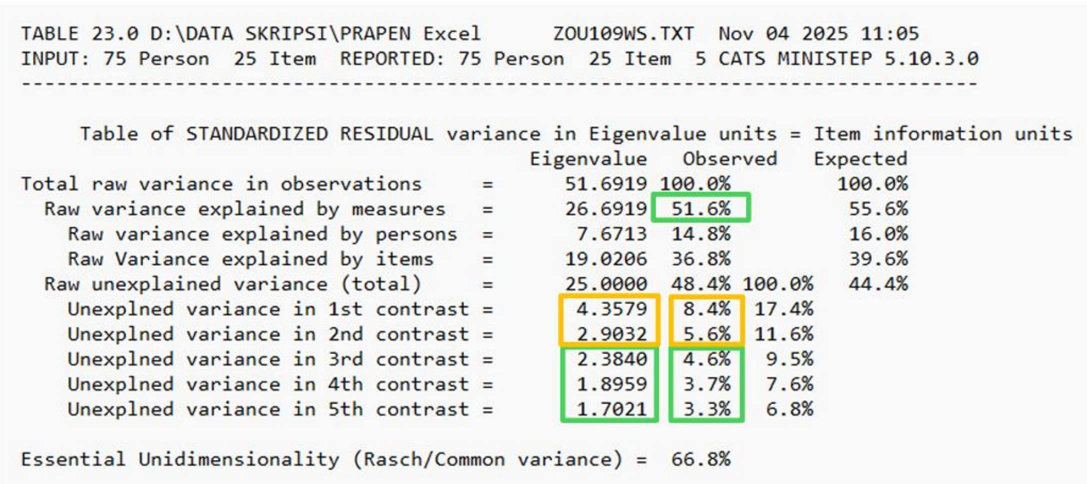
The instrument is declared to meet the assumption of unidimensionality if the raw variance explained by measures is more than 40%, which indicates that most of the data variation can be explained by the measured construct. In addition, the analysis was also conducted by looking at the unexplained variance value through Principal Component Analysis (PCA) of Residuals. This analysis aims to ensure that there are no other dimensions that significantly affect the measurement results. The criteria for interpreting the unexplained variance value are shown in Table 3.

Table 3. Criteria for unexplained variance (Ahmad et al., 2025)

Variasi Unexplained pada 1st -5th Residucal PCA	Criteria
<3%	Very good
3%-5%	Good
5%-10%	Fair
10%-15%	Minimum
>15%	Poor

RESULTS AND DISCUSSION

Results



```
TABLE 23.0 D:\DATA SKRIPSI\PRAPEN Excel      ZOU109WS.TXT  Nov 04 2025 11:05
INPUT: 75 Person  25 Item  REPORTED: 75 Person  25 Item  5 CATS MINISTEP 5.10.3.0
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = Item information units
                                          Eigenvalue  Observed   Expected
Total raw variance in observations     =     51.6919 100.0%         100.0%
  Raw variance explained by measures   =     26.6919  51.6%          55.6%
    Raw variance explained by persons  =      7.6713  14.8%          16.0%
    Raw Variance explained by items    =     19.0206  36.8%          39.6%
  Raw unexplained variance (total)     =     25.0000  48.4% 100.0%   44.4%
    Unexplned variance in 1st contrast =      4.3579   8.4%  17.4%
    Unexplned variance in 2nd contrast =      2.9032   5.6%  11.6%
    Unexplned variance in 3rd contrast =      2.3840   4.6%   9.5%
    Unexplned variance in 4th contrast =      1.8959   3.7%   7.6%
    Unexplned variance in 5th contrast =      1.7021   3.3%   6.8%

Essential Unidimensionality (Rasch/Common variance) =  66.8%
```

Figure 3. Unidimensionality

TABLE 13.1 D:\DATA SKRIPSI\PRAPEN Excel ZOU109WS.TXT Nov 04 2025 11:05
INPUT: 75 Person 25 Item REPORTED: 75 Person 25 Item 5 CATS MINISTEP 5.10.3.0

Person: REAL SEP.: 1.61 REL.: .72 ... Item: REAL SEP.: 3.76 REL.: .93

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
18	4	75	1.24	.36	1.90	1.15	.55	-.14	.15	.11	98.6	96.9	I43
22	4	75	1.24	.36	1.90	1.15	.55	-.14	.15	.11	98.6	96.9	I52
23	12	75	.71	.20	1.65	1.33	.71	-.24	.21	.19	88.7	85.8	I53
25	13	75	.67	.19	1.13	.43	.62	-.45	.23	.19	87.3	85.4	I55
24	14	75	.63	.18	1.45	1.07	.61	-.49	.24	.20	87.3	84.0	I54
13	15	75	.60	.18	1.21	.62	.42	-.99	.30	.21	88.7	81.4	I33
21	15	75	.60	.18	1.43	1.06	.92	.08	.21	.21	85.9	81.4	I51
20	23	75	.40	.15	1.30	.98	.90	-.04	.27	.25	78.9	74.6	I45
17	24	75	.37	.14	.69	-1.03	.43	-1.28	.39	.26	76.1	72.2	I42
19	24	75	.37	.14	.90	-.23	.44	-1.26	.36	.26	76.1	72.2	I44
12	29	75	.28	.13	.90	-.28	.70	-.57	.35	.28	69.0	66.9	I32
16	33	75	.22	.12	.78	-.86	.61	-.92	.37	.30	64.8	65.0	I41
15	36	75	.17	.12	.77	-.98	.50	-1.38	.42	.31	67.6	61.5	I35
8	40	75	.12	.12	1.60	2.35	1.27	.77	.27	.32	57.7	57.6	I23
11	60	75	-.11	.10	.97	-.13	.83	-.51	.40	.38	42.3	38.4	I31
14	74	75	-.24	.09	.99	.02	.80	-.76	.49	.42	32.4	31.8	I34
3	76	75	-.26	.09	1.95	4.71	2.44	4.22	.23	.42	25.4	32.3	I13
9	77	75	-.27	.09	.59	-2.94	.52	-2.29	.51	.42	43.7	32.2	I24
10	96	75	-.43	.09	.71	-2.19	.65	-1.83	.53	.46	33.8	23.4	I25
7	104	75	-.49	.09	.99	-.02	.86	-.68	.47	.47	29.6	24.3	I22
6	105	75	-.49	.09	.97	-.16	.92	-.34	.47	.47	22.5	20.0	I21
1	124	75	-.63	.08	.61	-3.38	.83	-.94	.52	.50	36.6	20.2	I11
2	152	75	-.83	.08	1.82	4.95	2.03	4.63	.24	.54	16.9	22.4	I12
5	257	75	-1.92	.15	1.39	1.23	1.52	1.25	.63	.70	69.0	69.1	I15
4	258	75	-1.94	.15	.88	-.27	.96	.05	.73	.71	69.0	69.5	I14
MEAN	66.8	75.0	.00	.15	1.18	.34	.86	-.17			61.9	58.6	
P.SD	69.0	.0	.78	.07	.42	1.86	.48	1.54			25.2	25.5	

Figure 4. Item fit statistic based on rasch model analysis

Table 4. Item DIF data

Indicator	Person Female	Person Male	Indicator	Person Female	Person Male
I11	-0.67	-0.39	I34	-0.24	-0.33
I12	-0.91	-0.33	I35	0.1	0.47
I13	-0.31	-0.02	I41	0.34	-0.13
I14	-2.02	-1.42	I42	0.49	0.1
I15	-2.11	-1.06	I43	1.1	1.85
I21	-0.49	-0.49	I44	0.4	0.3
I22	-0.49	-0.44	I45	0.34	0.58
I23	0.15	-0.02	I51	0.56	0.72
I24	-0.23	-0.49	I52	2.59	0.58
I25	-0.39	-0.64	I53	0.58	1.1
I31	-0.14	-0.02	I54	1.1	0.1
I32	0.28	0.23	I55	0.9	0.3
I33	0.65	0.47			

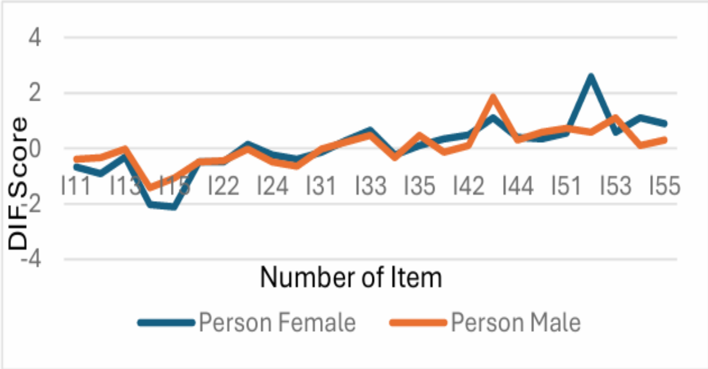


Figure 5. DIF score comparison in 5 problem-solving skills indicator items

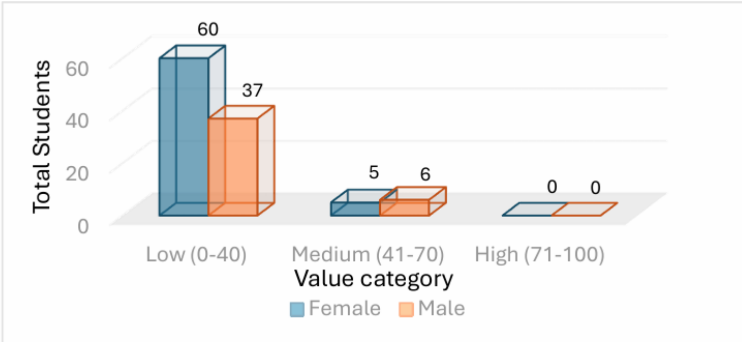


Figure 6. Graph of the value category and the quantity of students

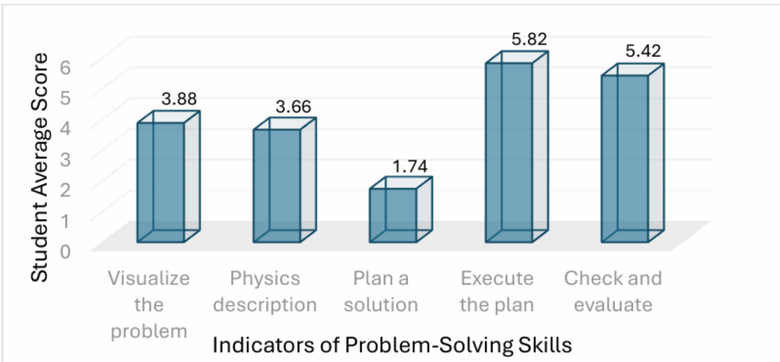
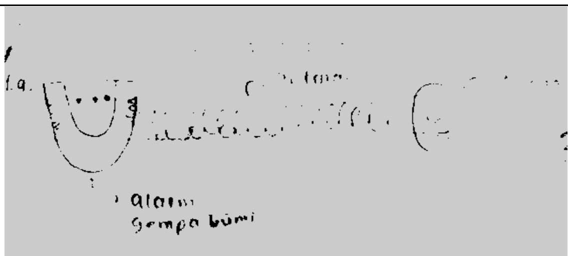
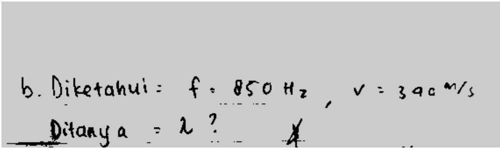
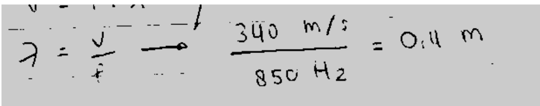
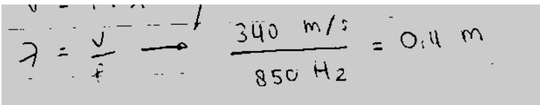
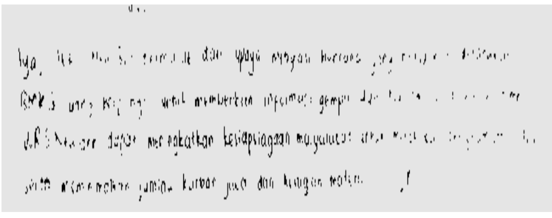


Figure 7. Graph of the average of students on each indicator of problem-solving skills

Table 5. The result of the written test of physics problem-solving skills by students

Indicator of Physics Problem-Solving Skills	Result of the Written Test of Physics Problem-Solving Skills by Students	
Visualize the problem		Based on the results of the written test of problem-solving skills in physics, it was found that in the visualize the problem indicator, students were able to draw diagrams

Indicator of Physics Problem-Solving Skills	Result of the Written Test of Physics Problem-Solving Skills by Students	
		correctly. However, they were still lacking in providing information such as the direction of wave propagation, wavelength, source sound, and listener
Physics description		In the physics indicator description, most students are accustomed to writing down the known, unknown, and answer parts, but some still forget to write down one of the parts or are incomplete in including the information obtained.
Plan a solution		Indicator plan a solution shows the lowest results, most students have not written down the formula or concept used and directly entered the variable values into the equation.
Execute the plan		To execute the plan, some students have completely written down the calculation steps. However, there are also those who are still lacking or skip certain steps certain steps.
Check and evaluate		Meanwhile, on the indicator check and evaluate, the majority of students were able to draw conclusions based on their

Indicator of Physics Problem-Solving Skills	Result of the Written Test of Physics Problem-Solving Skills by Students
	calculations and write them down correctly.

Table 6. Student questionnaire results

Indicator	Statements	Answers STS	TS	S	SS
Learning Physics	I feel able to understand physics material that is associated with daily life.	1.9% (2)	17.6% (19)	57.4% (62)	23.1% (25)
	Learning physics related to daily life encourages me to find solutions as a problem-solving solution to problems in the physics material presented.	0.9% (1)	19.4% (21)	53.7% (58)	25.9% (28)
	Learning physics that is associated with daily life makes me motivated in studying physics material.	1.9% (2)	12.0% (13)	61.1% (66)	25.0% (27)
	Average	**2%**	**16%**	**57%**	**25%**
Problem-solving skills	I feel able to visualize problems by drawing, diagramming, or graphing a problem in physics.	14.8% (16)	54.6% (59)	24.1% (26)	6.5% (7)
	I feel able to describe a problem by writing down the known and asked variables of a problem in physics.	31.5% (34)	55.6% (60)	11.1% (12)	1.9% (2)
	I feel that I am able to plan a solution by determining equations and systematically arranging steps to solve a problem in physics.	58.3% (63)	23.1% (25)	16.7% (18)	1.9% (2)
	I feel able to use solutions by substituting, calculating, and solving the physics equations of a problem in physics material.	55.6% (60)	25.0% (27)	16.7% (18)	2.8% (3)
	I feel able to evaluate the solution by examining the final result and giving a conclusion from a problem in physics.	57.4% (62)	20.4% (22)	19.4% (21)	2.8% (3)
	Average	**44%**	**36%**	**18%**	**3%**
E-book	Learning with digital book teaching media increased my interest and motivation in learning physics material.	0.9% (1)	14.8% (16)	56.5% (61)	27.8% (30)

Indicator	Statements	Answers			
		STS	TS	S	SS
	Learning with digital book teaching media helps me visualize abstract physics concepts.	0.9% (1)	15.7% (17)	63.0% (68)	20.4% (22)
	Average	**1%**	**15%**	**60%**	**24%**

Discussion

Validity and reliability of questions instruments based on student test result

Validity and reliability of questions instruments based on student test results to determine the validity and reliability of the problem-solving skills instrument, an analysis was conducted using the Rasch model with the help of Winstep software (Ikhsan, 2023). Rasch analysis was used because it provides a more objective picture of the quality of the items, including the extent to which each item can measure students' abilities consistently and in accordance with the expected measurement model. In addition, this approach also allows researchers to identify the unidimensionality of the instrument, namely the extent to which all items measure the same construct of ability, namely problem-solving skills (Ridwan et al., 2023). Figure 3 represents the testing of five instruments on 108 grade XI MIPA students using modern item response theory (IRT) through the Rasch model, which was analyzed using the Winstep program. The unidimensionality of the instrument can be seen from the quantitative analysis using output table 23 in the Winstep program.

In order for an instrument to be analyzed accurately, it must meet the unidimensionality requirement, which means that all items measure a single construct. Unidimensionality requires the existence of a common factor that explains the correlation between items. If the data shows evidence of multiple dimensions, as indicated by high residual eigen values, then the key assumption of a one-factor model such as the Rasch model has been violated. This violation will undermine the validity of the test and cause estimates of student ability or item difficulty to be inaccurate and unreliable (Isnaini et al., 2025).

Based on the results in Figure 3, unidimensionality is seen in the raw explained by measure located in the observed column, with a result of 51.6%. In addition, there is a second criterion that unexplained variance in the1stcontrast in the eigenvalue value is not greater than 2.0 because the existence of an eigen value above 2 can be interpreted as evidence of multidimensionality in the test structure. In Figure 2, the unexplained variance in the1st to 5th contrasts are, respectively, 4.3579, 2.9032, 2.3840, 1.8959, and 1.7021. For the unexplained variance in the1stand2ndcontrast eigenvalues is 4.3579 and 2.9032, which exceeds the unidimensionality criterion, in other words, multidimensionality. This indicates a small possibility of other subdimensions in the instrument (for example, differences in problem-solving skills). However, because the proportion of variance explained (51.6%) is well above the 20% threshold, the instrument can still be considered unidimensional in general. Nevertheless, since most of the variance (around 66.8%) is explained by the main model, it can be concluded that this problem-solving skills test instrument is sufficiently unidimensional and suitable for further analysis.

Problem-solving skills are a latent construct, meaning that this ability cannot be measured directly, but is estimated through students' answers to test items (Isnaini et al., 2025). Therefore, to ensure that each item in the instrument is truly capable of measuring problem-solving skills in a valid and consistent manner, this analysis was conducted with reference to three main parameters, namely Outfit Mean Square (MNSQ) and Outfit Z-Standard (ZSTD), and Point-Measure Correlation (Pt-Measure Corr). The MNSQ and ZSTD value requirements are as follows: a) 0.5< MNSQ outfit value < 2.0; b) -0.2< ZSTD outfit value <+2.0; and c) 0.32 < outfit Pt Mean Corr 0.8 logit (Simamora et al., 2022).

Based on the results of the Rasch model analysis, the item separation value of 3.76 with a reliability of 0.93 indicates that the items have excellent and consistent separation capabilities. Meanwhile, the person separation of 1.61 with a reliability of 0.72 indicates that there is sufficient variation in the abilities of the students. The average outfit MNSQ value of 0.86 is within the ideal range (0.5-1.5), so that in general the items are categorized as fitting the Rasch model. The ZSTD Outfit value with an average of -0.17 is still within acceptable limits (-2.0 to +2.0), indicating no significant deviation from the model. However, some numbers, 2.3 and 9, show MNSQ values above the ideal limit and therefore need to be revised. The Pt Measure Corr values range from 0.15 to 0.73, with most items meeting the eligibility criteria (0.32 to 0.80). This indicates that most of the items are able to differentiate students based on their problem-solving abilities. Overall, this instrument is considered valid and reliable for measuring problem-solving skills.

Problem-solving skills of students by gender

Based on Figure 5, it can be seen that in general, the problem-solving abilities of female and male students are relatively balanced. Most of the DIF values are around zero, which indicates that the items are fair and do not show gender bias. These findings indicate that the test instrument is able to measure problem-solving abilities objectively in both groups of students. However, there are several items that show a significant difference in DIF values, namely I15 (indicator check and evaluate in question number 1) and I52 (indicator physics description in question number 5), which tend to be higher for female students, making these two items easier for the female group and relatively difficult for males. According to Hidayah et al. (2024), females tend to show more intense and emotional responses than males. They tend to take more complete and detailed notes, and females also have higher accuracy and precision. This is related to the physics description indicator and the check and evaluate indicator, which require students to describe what is known and what is asked in the question and to review the results obtained and conclude the final results based on the analysis and physics concepts used. Thus, the accuracy and precision possessed by female students can support their performance on these two indicators.

Meanwhile, in item I43 (plan a solution indicator in question number 4), the DIF value is higher for male students, which means that the question is easier for males and more challenging for females. According to Simatupang et al. (2020), males tend to focus on intellectual, abstract, and objective matters. This is in line with the indicator plan a solution, which requires students to systematically develop steps to solve problems based on relevant physics concepts. Thus, the more prominent logical and structured thinking skills of male students can support the process of planning solutions in solving physics problems.

This difference is likely due to the context and style of the questions. Questions that require verbal analysis or descriptive reasoning tend to be easier for women to solve, while questions involving visual and technical aspects are easier for men to understand. This is in line with research conducted by Davita & Pujiastuti (2020), which states that differences in thinking patterns between men and women are influenced by differences in brain structure and hormonal factors. These structural differences are reflected in the way each individual performs an activity.

The result of student's test

Based on the results of the problem-solving skills test, the categories of student scores are shown in Figure 4. The graph shows that most students, both female and male, are in the low category with scores ≤40. The number of female students in the low category reached around 60, while there were 37 male students. Only a small number of students are in the medium category (41< score ≤ 70), namely 5 female and 6 male students, while no students reached the high category (10< score ≤ 100) (Qotrunnada & Prahani, 2022).

The average problem-solving skills based on five main indicators can be seen in Figure 5. The indicator "execute the plan" received a high score of 1.16, followed by "check and evaluate" with a score of 1.08. This shows that most students are quite capable of implementing the steps to solve problems and checking their work. However, the indicator "plan a solution" received a low score of 0.34, which means that students still have difficulty in systematically designing problem-solving strategies and selecting the appropriate physics formulas or concepts.

Meanwhile, the indicators for visualizing the problem (0.77) and describing physics (0.73) were in the moderate category. This indicates that students were quite capable of understand the problem and describe the general physics situation, but are still not optimal in identifying important variables and the relationships between concepts.

Based on the results of the student response questionnaire in Table 5, it can be seen that the physics learning indicators related to everyday life show a very positive trend. This is evident in the average percentage of students who agreed and strongly agreed, which was 57% and 25%, respectively. This means that most students feel that contextual physics learning can improve their understanding and motivation in learning.

For the problem-solving skills indicator, the results show greater variation. The average for strongly disagree and disagree responses reached 44% and 36%. This indicates that most students still find it difficult to develop physics problem-solving skills, such as describing, describing variables, planning, solving equations, and evaluating. Thus, even though students understand physics concepts contextually, their application in the form of problem solving remains a challenge.

Meanwhile, for the digital book media indicator, the results show a positive response with an average of 60% of students agreeing and 24% strongly agreeing. This shows that the use of digital book media in physics learning is considered effective in increasing interest and motivation, as well as helping students visualize abstract physics concepts (Anggaryani, 2022).

Results of interviews with physics teachers

Based on interviews with high school physics teachers, it was found that the physics learning process has implemented the Problem Based Learning (PBL) model, with routine activities beginning with open-ended questions. However, teachers said that most students still tend to memorize formulas without understanding the application of physics concepts in everyday life, so their conceptual understanding still needs to be improved. In terms of problem-solving skills, teachers use test instruments and provide argumentative essay questions and projects that require higher-order thinking skills. Teachers act as facilitators who guide the students' investigation process as needed in order to train students' independence and problem-solving skills.

Regarding digital books, teachers consider e-books to be effective in helping students understand abstract concepts because they contain interactive elements and can be accessed at any time. However, the obstacles faced are limited devices and uneven internet coverage. To ensure the quality of learning, teachers choose e-books that are relevant to the learning objectives and encourage students' problem-solving skills. This is in line with research conducted by Kholiq (2020), which explains that digital books can help students visualize abstract physics concepts and increase their motivation and independence in learning. Research conducted by Kinasih et al. (2023) shows that students' physics problem-solving skills are still low and physics learning tends to be teacher-centered with suboptimal use of digital media. However, this study did not analyze differences in problem-solving skills based on gender using the Rasch model, so it did not provide a comprehensive picture of the variations in abilities among students. Based on this, this study attempts to fill this gap by analyzing students' physics problem-solving skills based on gender using the Rasch model as the basis for developing a 3D digital book-assisted Problem-Based Learning (PBL) model on sound wave material.

CONCLUSION

Fundamental Finding: Based on the study's findings, it can be concluded that the physics problem-solving skills of high school students generally remain in the low category. This condition is primarily attributed to current physics learning practices that are still teacher-centered and oriented toward procedural problem-solving, with the implementation of the Problem-Based Learning (PBL) model and the use of digital books being limited only to introductory phases. Analysis reviewed from a gender perspective shows that the overall abilities of male and female students are relatively balanced, though females excel in descriptive and evaluative aspects, while males are stronger in solution planning. **Implication**: Consequently, the findings underscore the urgent need for a pedagogical shift towards student-centered strategies to meet the global mandate for Quality Education (SDG 4), particularly Target 4.4 concerning relevant skills acquisition. The Problem-Based Learning (PBL) model assisted by 3D digital books is found to have significant potential as an empirical basis for developing learning strategies that are more interactive and contextual, thereby improving students' essential physics problem-solving skills. **Limitation**: However, this study is limited by the imbalance in the number of male and female samples and the scope being restricted to profile analysis without direct application of the model. **Future Research**: Therefore, further research is strongly recommended to conduct a test of effectiveness (experimental design) of the proposed PBL model assisted by digital books on physics topics, utilizing a balanced and representative sample.

AUTHOR CONTRIBUTIONS

Dhea Wanda Irani contributed to the conceptual framework, research design, and supervision of the study. **Elvia Reza Lutfiani** was responsible for developing the research methodology, conducting data analysis, and interpreting the results. **Siska Agustin Sha Hareni** contributed to data collection, data curation, and preparation of research materials. **Nofri Hidayatin** was involved in literature review, sourcing references, and supporting the data analysis process. **Nurul Muawiyan** contributed to manuscript drafting, editing, and visualization of research findings. **Binar Kurnia Prahani** contributed to the conceptualization, and validation of the research design. **Hanandita Veda Saphira** contributed to the supervision, and final review of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors state that no financial or personal conflicts of interest exist that may have affected the content or findings of this research.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors declare that no artificial intelligence (AI) tools or other digital writing assistants were used in the preparation, analysis, or writing of this manuscript. All stages of the research process, including data analysis, interpretation, and manuscript writing, were conducted solely by the authors. The authors take full responsibility for the originality, accuracy, and integrity of the content presented in this article.

REFERENCES

Ahmad, N. Q., Arthur, R., Rahayu, W., & Rahmadhani, E. (2025). Pengembangan instrumen kemampuan pemecahan masalah matematika siswa menggunakan model Rasch. *Juring (Journal for Research in Mathematics Learning)*, *8*(1), 061. https://doi.org/10.24014/juring.v8i1.34022

Alkautsar, I., & Anggaryani, M. (2022). Mobile learning "Asmeralda" for teaching static fluid at senior high schools. *Berkala Ilmiah Pendidikan Fisika, 10*(2), 179. https://doi.org/10.20527/bipf.v10i2.13341

Andani, T. (2022). Analisis validasi media pembelajaran e-book berbasis Flip pdf Professional pada materi gelombang bunyi di SMA. *Jurnal Kumparan Fisika, 4*(3), 213–220. https://doi.org/10.33369/jkf.4.3.213-220

Annisa, D., & Haryadi, R. (2023). Meta-analisis pengaruh model pembelajaran problem based learning terhadap pemecahan masalah siswa pada materi fluida statis. *INKUIRI: Jurnal Pendidikan IPA*, *12*(2), 139. https://doi.org/10.20961/inkuiri.v12i2.72952

Asrizal, A., N, A., Ahzari, S., & Helma, H. (2025). Interactive multimedia sound and light waves integrated STEM to develop concept understanding and literacy skills of students. *Journal of Turkish Science Education, 22*(1), 18–32. https://doi.org/10.36681/tused.2025.002

Asyhari, A., & Sifa'i, M. (2021). Problem-based learning to improve problem-solving skill: Is it effective enough? *Indonesian Journal of Science and Mathematics Education*, *4*(1), 78–88. https://doi.org/10.24042/ijsme.v4i1.8674

Ardianti, B., Buhungo, T. J., Mohamad , W. M., & Odja, A. H. (2025). Pengaruh penerapan model PBL menggunakan media kit untuk meningkatkan kemampuan pemecahan masalah siswa. *OPTIKA: Jurnal Pendidikan Fisika, 9*(2), 238-250. https://doi.org/10.37478/optika.v9i2.6550

Cindikia, M., Achmadi, H. R., Prahani, B. K., & Mahtari, S. (2020). Profile of students' problem solving skills and the implementation of assisted guided inquiry model in senior high school. *Studies in Learning and Teaching, 1*(1), 52–62. https://doi.org/10.46627/silet.v1i1.22

Davita, P. W. C., & Pujiastuti, H. (2020). Analisis kemampuan pemecahan masalah matematika ditinjau dari gender. *Kreano, Jurnal Matematika Kreatif-Inovatif, 11*(1), 110–117. https://doi.org/10.15294/kreano.v11i1.23601

Dwikoranto, Dzulkiflih, Lintangesukmanjaya, R. T., Putra, D. A., & Bergsma, L. N. (2025). Problem-based learning assisted by Cre-ASI (Creative Assessment With Solving Instrument) to improve students' creative thinking skills. *Jurnal Pendidikan IPA Indonesia, 14*(3), 480–495. https://doi.org/10.15294/jpii.v14i3.25606

Dwiyanti, N., & Perdana, R. (2024). Pengembangan media pembelajaran fisika berbantuan

3D aplication Scratch untuk meningkatkan physics identity peserta didik pada topik gelombang bunyi. *DIFFRACTION: Journal for Physics Education and Applied Physics, 6*(1), 20–29. https://doi.org/10.37058/diffraction.v6i1.9399

Ghofur, A., Jatmiko, B., & Sanjaya, I. G. M. (2023). Profile of high school students' problem-solving skills and the application of problem-based learning: A preliminary study. *Studies in Learning and Teaching, 4*(3), 522–536. https://doi.org/10.46627/silet.v4i3.317

Haris, A., & Mahir. (2025). The influence of problem-solving-based physics learning models on students' critical thinking ability and learning independence on the achievement of SDG 4. *International Journal of Learning, Teaching and Educational Research, 24*(8), 1076–1091. https://doi.org/10.26803/ijlter.24.8.48

Henra, K., Budayasa, I. K., & Ismail. (2025). Exploring metacognitive strategies in feminine female high school students: a qualitative study in statistical problem solving. *Perspektivy Nauki i Obrazovania, 73*(1), 336–348. https://doi.org/10.32744/pse.2025.1.22

Isnaini, F., Maria Silitonga , H. T., Syarif Hidayatullah, M. M., Sirait, J., & Afrizon, R. (2025). Diagnosing students' problem-solving challenges in rotational dynamics using two-tier AR flashcard tests. *Jurnal Inovasi Pendidikan IPA, 11*(2), 402–417. https://doi.org/10.21831/jipi.v11i2.80461 .

Kholiq, A. (2020). Development of B D F-AR 2 (Physics Digital Book Based Augmented Reality) to train students' scientific literacy on global warming material. *Berkala Ilmiah Pendidikan Fisika, 8*(1), 50. https://doi.org/10.20527/bipf.v8i1.7881

Kinasih, R. A., Prahani, B. K., Wibowo, F. C., & Costu, B. (2023). Profile of students' physics problem solving skills and implementation PBL model assisted by 3D digital module to improve problem solving skills. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 9*(2), 245–256. https://doi.org/10.21009/1.09207

Mashurin, A. H., Mubarok, H., & Prahani, B. K. (2021). Profile of guided discovery learning implementation assisted by virtual lab and students' problem-solving skills on gas kinetic theory. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 7*(2), 131–144. https://doi.org/10.21009/1.07205

Meisaroh, S., Achmadi, H. R., & Prahani, B. K. (2020). Profile of students' problem solving skills and implementation free inquiry model in senior high school. *Berkala Ilmiah Pendidikan Fisika, 8*(2), 59. https://doi.org/10.20527/bipf.v8i2.8230

Muliana, Fonna, M., & Nufus, H. (2024). Pengaruh penerapan Problem Based Learning (PBL) terhadap keterampilan abad 21. *Ar-Riyadhiyyat: Jurnal Pendidikan Matematika, 5*(1), 22–30. https://doi.org/10.47766/arriyadhiyyat.v5i1.2900

Muñoz Alvarez, G., Greca, I. M., & Arriassecq, I. (2025). Problem-based learning as a strategy for teaching physics in technical–professional higher education: A case study in Chile. *Education Sciences, 15*(8), 1–20. https://doi.org/10.3390/educsci15080941

Musengimana, T., Yadav, L. L., Uwamahoro, J., & Nizeyimana, G. (2025). Instructional strategies for enhancing students' problem-solving skills in physics: A systematic review. *Discover Education, 4*(1). https://doi.org/10.1007/s44217-025-00733-x

Neswary, S. B. A., & Prahani, B. K. (2022). Profile of students' physics critical thinking skills and application of problem based learning models assisted by digital books in physics learning in high school. *Jurnal Penelitian Pendidikan IPA, 8*(2), 781–789. https://doi.org/10.29303/jppipa.v8i2.1444

Ningrum Widiya Tika, H. (2024). Investigasi kemampuan bernalar ilmiah siswa melalui implementasi model problem based learning materi fisika fluida statis. *JPF (Jurnal Pendidikan Fisika) FKIP UM Metro, 12*(1), 68–80. http://dx.doi.org/10.24127/jpf.v12i1.9433

Nisa, K., Suprapto, N., Amiruddin, M. Z., Sari, E. P. D. N., & Athiah, B. D. (2024). Ethnoscience-Quizizz test to measure problem-solving skills: A Rasch analysis. *International Journal of Evaluation and Research in Education, 13*(6), 4247–4255. https://doi.org/10.11591/ijere.v13i6.28075

Pradana, P. W., & Supahar. (2025). Assessment instrument of graph representations on sound wave topic: Development and measurement implementation. *Knowledge Management and E-Learning, 17* (2), 352–371. https://doi.org/10.34105/j.kmel.2025.17.016

Prahani, B. K., Pristianti, M. C., Jatmiko, B., Amelia, T., & Wibowo, F. C. (2022). Digital learning research in the last 30 years: Important role of interactive learning in physics. *TEM Journal, 11*(3), 1357–1363. https://doi.org/10.18421/TEM113-46

Prahani, B. K., Rizki, I. A., Nisa, K., Citra, N. F., Alhusni, H. Z., & Wibowo, F. C. (2022). Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject. *Journal of Technology and Science Education, 12*(2), 379–396. https://doi.org/10.3926/jotse.1590

Pristianti, M. C., & Prahani, B. K. (2022). Profile of students' physics problem solving skills and problem based learning implementation supported by website on gas kinetic theory. *Jurnal Pendidikan Progresif, 12*(1), 375–393. https://doi.org/10.23960/jpp.v12.i1.202229

Rachmawati, O. Q., Prahani, B. K., & Mubarok, H. (2022). Profile of students' physics problem-solving skills and implementation of Quizizz-based Team Games Tournament (QTGT) method in physics learning technology. *Jipf (Jurnal Ilmu Pendidikan Fisika, 7*(1), 82–93. https://dx.doi.org/10.26737/jipf.v7i1.2479

Qotrunnada, N. A., & Prahani, B. K. (2022). Profile of PBL model assisted by digital books to improve problem solving ability of high school students on dynamic fluids. *Jurnal Penelitian Pendidikan IPA, 8*(3), 1175–1183. https://doi.org/10.29303/jppipa.v8i3.1451

Ridwan, I. M., Kaniawati, I., Suhandi, A., Ramalis, T. R., Rizal, R., & Sujarwanto, E. (2023). Tes kemampuan pemecahan masalah pada tema perubahan iklim: Analisis Rasch model. *Diffraction, 5*(1), 37–46. https://doi.org/10.37058/diffraction.v5i1.7738

Sa'adah, S. I., & Ikhsan, J. (2023). Validity and reliability test of the learning independence questionnaire instrument in using electronic modules. *Jurnal Penelitian Pendidikan IPA, 9*(12), 11173–11180. https://doi.org/10.29303/jppipa.v9i12.4466

Hutasoit, S. A. (2021). Pembelajaran Teacher Centered Learning (TCL) dan Project Based Learning (PBL) dalam pengembangan kinerja ilmiah dan peninjauan karakter siswa. *Jurnal Pendidikan Indonesia (Japendi), 2*(10), 1775–1799. https://doi.org/10.59141/japendi.v2i10.294

Saphira, H. V., Rizki, I. A., Zakhiyah, I., Saharani, S. P., & Jauhariyah, M. N. R. (2022). 21st century skills research trends over the last 10 years: Bibliometric review and analysis. *Pedagogia Jurnal Ilmu Pendidikan, 20*(01), 21–33. https://doi.org/10.17509/pdgia.v20i1.45263

Sari, I. P. M., Jatmiko, B., & Suprapto, N. (2023). Students' physics problem-solving skills in daily life context: Between confession and fact. *Jurnal Penelitian Pendidikan IPA, 9*(1), 231–241. https://doi.org/10.29303/jppipa.v9i1.2561

Satipa, D. A., Susilawati, S., Hikmawati, H., & Gunada, I. W. (2024). Pengaruh model problem based learning berbantuan simulasi PhET terhadap kemampuan pemecahan masalah siswa. *Jurnal Ilmiah Profesi Pendidikan, 9*(4), 2712–2720. https://doi.org/10.29303/jipp.v9i4.2668

Septikasari, A. N., Maison, M., & Nazarudin, N. (2021). Interactive e-book for physics learning: Analysis of students' characters and conceptual understanding. *Indonesian Journal of Science and Mathematics Education, 4*(1), 25–36. https://doi.org/10.24042/ijsme.v4i1.7664

Hidayah, S., Farizal, M., Sholiha, M., & Khairi, A. K. U. (2024). Analisis kemampuan pemecahan masalah matematis siswa ditinjau dari perbedaan gender. *Algoritma : Jurnal Matematika, Ilmu Pengetahuan Alam, Kebumian dan Angkasa, 2*(5), 139–154. https://doi.org/10.62383/algoritma.v2i5.178

Silaban, Y. F. H., & Jumadi, J. (2022). Concept understanding profile of high school students on doppler effect and sound intensity levels. *Momentum: Physics Education Journal, 6*(1), 51–58. https://doi.org/10.21067/mpej.v6i1.5664

Simatupang, R., Napitupulu, E., & Asmin, A. (2020). Analisis kemampuan pemecahan masalah matematis dan self-efficacy siswa pada pembelajaran problem based learning. *Paradikma: Jurnal Pendidikan Matematika, 13*(1), 29–39. https://doi.org/10.24114/paradikma.v13i1.22944

Sunarti, T., Suprapto, N., Hidaayatullaah, H. N., Suliyanah, Admoko, S., & Jauhariyah, M. N. R. (2025). Evaluating student responses to ethnophysics learning: Improving scientific literacy and problem-solving skills using a PLS-SEM approach. *Multidisciplinary Science Journal, 7*(10), 2025454. https://doi.org/10.31893/multiscience.2025454

Simamora, N. N., Astalini, A., Darmaji, D. (2022). Analisis Kebutuhan Mahasiswa terhadap E-modul Fisika Matematika. Jurnal Pendidikan MIPA, 12(1), 1–7. https://doi.org/10.37630/jpm.v12i1.520

Viyanti, Shintya, R. E., Rosidin, U., Suyatna, A., & Farawahidah, N. (2025). Analysis of project-based problem-solving skills of optical equipment materials with heller and heller steps. *Jurnal Pendidikan IPA Indonesia, 14*(2), 241–250. https://doi.org/10.15294/jpii.v14i2.23810

Zakaria, A., Wahyuni, I. S., Satriawan, M., Saputra, O., & Habibbulloh, M. (2023). Pengembangan media pembelajaran ARDI (AR-Digital Book) berbasis augmented reality 3D animated pada materi induksi elektromagnetik. *IPF: Inovasi Pendidikan Fisika, 12*(2), 54–64. https://doi.org/10.26740/ipf.v12n2.p54-64

Dhea Wanda Irani
Bachelor of Physics Education, Universitas Negeri Surabaya
Ketintang, Gayungan District, Surabaya, East Java 60231
Email: dhea.22057@mhs.unesa.ac.id

Elvia Reza Lutfiani
Bachelor of Physics Education, Universitas Negeri Surabaya
Ketintang, Gayungan District, Surabaya, East Java 60231
Email: elviareza.22020@mhs.unesa.ac.id

Siska Agustin Sha Hareni
Bachelor of Physics Education,Universitas Negeri Surabaya
Ketintang, Gayungan District, Surabaya, East Java 60231
Email: siska.22072@mhs.unesa.ac.id

Nofri Hidayatin
Bachelor of Physics Education, Universitas Negeri Surabaya
Ketintang, Gayungan District, Surabaya, East Java 60231
Email: nofrihidayatin.22016@mhs.unesa.ac.id

Nurul Muawiyan
Bachelor of Physics Education, Universitas Negeri Surabaya
Ketintang, Gayungan District, Surabaya, East Java 60231
Email: nurul.22097@mhs.unesa.ac.id

Binar Kurnia Prahani
Postgraduate Physics Education, Universitas Negeri Surabaya
Ketintang, Gayungan District, Surabaya, East Java 60231
Email: binarprahani@unesa.ac.id

HananditaVeda Saphira
Digital Technologies for Learning, University of Wollongong
Northfields Ave, Wollongong NSW 2500, Australia
Email: hvs346@uowmail.edu.au