Development of Problem-Based Learning Integrated STEM E-Student Worksheet to Foster Students' Scientific Literacy Competence

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Abstract *– This study aims to develop a STEM-integrated Problem-Based Learning (PBL) E-Student Worksheet that is suitable for use in teaching and effective in fostering students' scientific literacy competence, as well as to analyze students' responses to the use of the E-Worksheet. The research adopts a Research and Development (R&D) approach using the ADDIE development model. The stages conducted in the study include: 1) Analyze, 2) Design, 3) Development, 4) Implementation, and 5) Evaluation. Data collection techniques employed include interviews, questionnaires, tests, and documentation. Data were analyzed using test instrument validation analysis, feasibility analysis, and effectiveness analysis of the E-Student Worksheet. The results of the study indicate that the STEM-integrated PBL-based E-Worksheet on the topic of sound waves is suitable for use in learning, with a material feasibility test score of 89.77%, a media feasibility test score of 90.17%, and a readability test score of 86.89%. The STEM-integrated PBL-based E-Worksheets was also found to be effective in fostering students' scientific literacy competence. On the indicator of explaining scientific phenomena, a score of 83.64% was achieved; on the indicator of evaluating and designing scientific investigations, a score of 75.76% was achieved; and on the indicator of interpreting data and scientific evidence, a score of 80.00% was achieved. Furthermore, the STEM-integrated PBL-based E-Student Worksheet received positive feedback from students, with a response rate of 79.59%.*

Keywords*: E-Student Worksheet; Problem-Based Learning; STEM; Scientific Literacy Competence*

INTRODUCTION

In the 21st century, the development of information and communication technology (ICT) has advanced rapidly (Anwar, 2022). 21st-century skills encourage students to be creative, innovative, critical thinkers, collaborative, and technologically literate (Jayadi et al., 2020). The Framework for 21st Century Skills outlines 16 essential skills for 21st-century learning, categorized into three major groups: foundational literacies, competencies, and character qualities. Foundational literacies consist of six literacy skills: numerical literacy, financial literacy, ICT literacy, language and literature literacy, cultural and civic literacy, and scientific literacy.

Scientific literacy is a critical thinking skill that connects science and technology to everyday life (Stiff et al., 2023). According to the Programme for International Student Assessment (PISA) 2015, four aspects are considered in evaluating scientific literacy: context, knowledge, competence, and attitude (Rusilowati & Astuti, 2019). However, based on data from the Organisation for Economic Cooperation and Development (OECD), Indonesia's scientific literacy score in PISA 2022 decreased from 396 in 2018 to 383 (Cormann, 2023). This indicates that Indonesia's scientific literacy remains low.

The low level of scientific literacy, particularly in the competence aspect, is also evident among students studying physics on the topic of sound waves. Research by Sari (2021) revealed that students' scientific literacy competence on sound wave material was categorized as poor, with a percentage of 42.95%. Additionally, a study by Irwan et

al. (2019) at SMA Negeri 2 Bulukumba found that students' scientific literacy competence on sound wave material remained low.

The low level of scientific literacy competence is also observed among students at SMA Negeri 1 Jatilawang. Based on observations, students' scientific literacy competence in learning physics is categorized as low. The causes of this issue include the use of learning media that primarily rely on printed worksheets (LKS or LKPD) that are less engaging, monotonous, non-contextual, and lack interactivity. These worksheets fail to facilitate students' scientific literacy competence. Furthermore, the teaching methods employed are predominantly lecture-based and rely on problem-solving exercises in teaching modules. The teaching approach has not been optimized and does not incorporate contextual learning that integrates science, processes, technology, and mathematics to help students solve real-world problems. This leads to low student motivation in physics learning.

To address these issues, it is necessary to use contextual physics learning media that leverage technology and train students' scientific literacy competence. Learning media serve as intermediaries between teachers and students in the learning process, aiming to stimulate student motivation for effective learning and achieving educational success (Hasan et al., 2021). With the use of appropriate learning media, the learning process becomes more effective and efficient (Nurfadhillah, 2021). One such technology-based learning medium is electronic student worksheets.

E-Student Worksheets is a digital student worksheet containing activities such as analyzing and problem-solving (Harahap et al., 2022). The use of E-Student Worksheets can make the teaching and learning process more engaging, enjoyable, and interactive, thereby enhancing students' enthusiasm for learning (Puspita & Dewi, 2021; Ningsih et al., 2023). The E-Student Worksheets developed in this research is based on the Problem-Based Learning (PBL) model. A PBL-based E-Student Worksheets incorporates real-world problems as a context for students to learn problem-solving skills (Purba & Purba, 2023). The development of PBL-based E-Student Worksheets has been widely implemented. For instance, a study by Sinuraya & Frisnoiry (2023) demonstrated that PBL-based E-Student Worksheets effectively improved students' mathematical problem-solving skills at SMA Swasta Katolik Budi Murni 2 Medan. To ensure direct student engagement in discovering concepts and fostering meaningful learning, PBL-based E-Student Worksheets can be integrated with the STEM approach (Sari et al., 2023).

The Science, Technology, Engineering, and Mathematics (STEM) approach integrates four disciplines—science, technology, engineering, and mathematics—to enhance students' problem-solving skills (Fransiska & Sidabutar, 2022). The goal of STEM education is to train students in applying basic STEM knowledge, such as scientific and technological literacy, to develop and apply these skills in addressing real-world problems (Mu'minah & Aripin, 2019). Research by Syaifudin (2022) shows that the use of STEM-based E-Student Worksheets fosters students' scientific literacy competence in Dynamic Electricity topics for classes XII IPA 6, XII IPA 7, and XII IPA 8 at SMA Negeri 1 Purbalingga, with effectiveness percentages of 77%, 87%, and 91%, respectively, categorized as effective and highly effective. Similarly, Astuti et al. (2023) affirm that the implementation of the

STEM approach can enhance students' scientific literacy.

Based on the explanation above, the researcher conducted a study titled "Development of STEM-Integrated Problem-Based Learning E-Student Worksheets to Foster Students' Scientific Literacy Competence." The STEM-integrated PBL-based E-Student Worksheets can assist students in their development by promoting a shift in mindset during the learning process, equipping them with relevant and competitive skills aligned with 21st-century competencies (Hanipah, 2023).

RESEARCH METHODS

The research method employed in this study is Research and Development (R&D) using the Analyze, Design, Development, Implementation, and Evaluation (ADDIE) development model. The instructional design scheme of the ADDIE model, as outlined by Branch and cited by Hidayat & Nizar (2021), is illustrated in Figure 1.

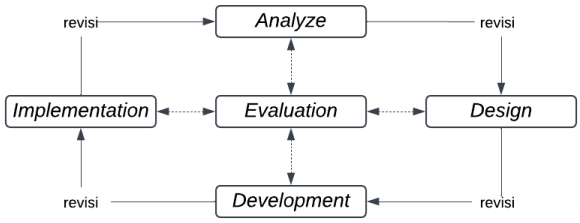

Figure 1. ADDIE model

This research was conducted at SMA Negeri 1 Jatilawang, located in Jatilawang Subdistrict, Banyumas Regency, Central Java, over six months. The subjects of the study were 33 students from Class XI-A at SMA Negeri 1 Jatilawang. Data collection techniques included interviews, questionnaires, test instruments, and documentation. The data analysis techniques used in the development of the STEM-integrated PBL-based E-Student Worksheets focused on the feasibility analysis and effectiveness analysis of the E-Student Worksheets. The description of the ADDIE development model stages is as follows:

Analyze Stage

This stage involves identifying needs or issues for product development. The researcher conducted a literature review and observations, including interviews with physics teachers at SMA Negeri 1 Jatilawang.

Design Stage

At this stage, the researcher designed the STEM-integrated PBL-based E-Student Worksheets. Steps in the design stage include: Determining the media; Selecting the material; Designing the layout or interface, and; Creating the initial draft.

Development Stage

The development stage involved several steps: Validation by media and content experts; A small-scale trial to identify shortcomings in the E-Student Worksheets.

Implementation Stage

In the implementation stage, the following activities were conducted: A large-scale trial; Posttest assessments.

Evaluation Stage

The evaluation stage is the final step in developing the E-Student Worksheets using the ADDIE approach. This stage aims to refine and assess the feasibility, effectiveness, and feedback on the developed STEM-integrated PBL-based E-Student Worksheets.

RESULTS AND DISCUSSION

Results

This research produced a product in the form of a STEM-integrated PBL-based E-Student Worksheets that is feasible, effective, and received positive feedback from students. The results are categorized into several stages, as described below:

1. Analyze Stage

In the analysis stage, needs or problems relevant to product development were identified, including learning objectives, instructional models, and the learning media used in the teaching process. Based on observations, the learning media at SMA Negeri 1 Jatilawang primarily consisted of printed worksheets (LKPD), PowerPoint presentations, and printed Student Worksheets. The use of printed LKPDs was found to be less effective, necessitating the development of more appropriate technology-based learning media (Ningrum et al., 2024).

The use of technology at SMA Negeri 1 Jatilawang was also found to be suboptimal, as teachers had not implemented contextual learning that integrates science and technology. Contextual learning is necessary to enable students to explore learning experiences that connect instructional content with real-world contexts relevant to everyday life (Fitri & Juliani, 2024).

Moreover, the teaching method employed by teachers relied predominantly on lectures. This method led to monotonous learning processes that did not actively involve students, resulting in poor conceptual understanding among them (Nurisnaeni, 2022).

Thus, there is a need for learning media and instructional models that can effectively train students' scientific literacy competence in physics education.

2. Design Stage

The design stage involved creating the blueprint for the E-Student Worksheets product being developed. The design process included the following steps:

a. Determination of Media

The suitable medium selected for this research was E-Student Worksheets, developed using the Problem-Based Learning (PBL) model integrated with STEM aspects.

b. Selection of Learning Material

The learning material chosen for the E-Student Worksheets was the sound wave resonance topic from the Class XI "Kurikulum Merdeka" curriculum. The Learning Outcomes (Capaian Pembelajaran - CP) for this material included the ability of students, by the end of phase F, to understand and explain resonance phenomena and calculate the speed of sound waves in the air.

c. Layout Design

The layout design aimed to organize the content to be included in the E-Student Worksheets. The content comprised: Concept maps, Description of the E-Student Worksheets, Instructions for using the E-Student Worksheets, Learning Outcomes (CP) and Learning Objectives Flow (ATP), Steps in the PBL model, and Details of learning activities.

The design process also involved formatting aspects such as font size, font type, media dimensions, line spacing, and color combinations.

d. E-LKPD Design

The E-Student Worksheets structure was designed in alignment with the learning objectives using Canva software. The design consisted of three sections: the introductory section, the main content, and the closing section.

This section included the cover page, preface, table of contents, description,

concept map, user instructions, learning outcomes and objectives, introduction, and features in the E-Student Worksheets. The cover page of the E-Student Worksheets contained the title of the material, class level, author, logo, and an image representing the material. An example of the cover page design is shown in Figure 2.

Figure 2. Cover Design of E-Student Worksheets

The content section of the E-Student Worksheets was designed to align with the Problem-Based Learning (PBL) model integrated with STEM aspects. The learning material focused on the subtopic of sound wave resonance. Additionally, the E-Student Worksheets incorporated various supporting features aimed at enhancing students' interest in learning.

These supporting features included interactive elements, multimedia integration, problem-solving activities, and real-world examples to contextualize the material. The design emphasized an engaging and interactive learning experience, motivating students to actively participate in the learning process.

The detailed content design of the E-Student Worksheets is illustrated in Figure 3.

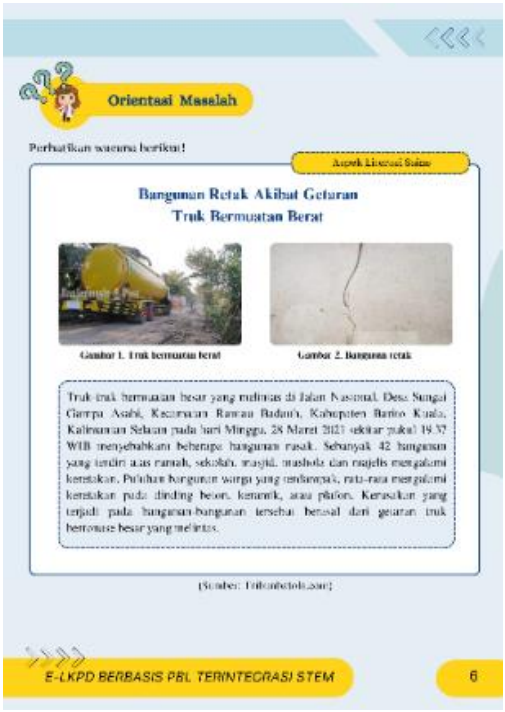

Figure 3. Content Design of E-Student Worksheets

The closing section of the E-Student Worksheets contains the bibliography and the author's biography. The layout of the closing section of the E-Student Worksheets can be seen in Figure 4.

Figure 4. Final Design of E-Student Worksheets

3. Development Stage

In the development stage, the E-Student Worksheets that had been created was validated by subject matter experts and media experts. Validation by experts aimed to assess the feasibility of the STEM-integrated PBL-based E-Student Worksheets for use as a learning medium. Following validation, the product underwent revisions and a small-scale trial.

a. Validation by Subject Matter Experts

The results of the STEM-integrated PBL-based E-Student Worksheets validation by subject matter experts are presented in Table 1.

Table 1. Results of E-Student Worksheets Material Validation

No	Code of Validators	Percentage (%)		V-Aiken's	
		Score	Criteria	Score	Criteria
1	DS-01	91,30	Very Feasible	0,87	Valid
2	DS-02	86,30			
3	DS-03	77,50			
4	GR-01	97,50			
5	GR-02	96,25			
Average		**89,77**			

In the validation test of the STEM-integrated PBL-based E-Student Worksheets by subject matter experts, several aspects were evaluated to ensure the material in the E-Student Worksheets is valid and suitable for use in the learning process. These aspects include **content**, **presentation**, and **language quality**. The results of the material validation test for each aspect of the E-Student Worksheets are presented in Table 2.

Table 2. Hasil Validasi Materi E-LKPD untuk Setiap Aspek Penilaian

No	Aspek Penilaian	V-Aiken's	Kriteria
1	Isi	0,86	Valid
2	Kebahasaan	0,87	Valid
3	Penyajian	0,89	Valid

b. Validation by Media Experts

The results of the feasibility test of the STEM-integrated PBL-based E-Student Worksheets by media experts are presented in Table 3.

Table 3. Hasil Validasi Media E-Student Worksheets

No	Code of Validators	Percentage (%)		V-Aiken's	
		Score	Criteria	Score	Criteria
1	DS-01	94,50	Very Feasible	0,88	Valid
2	DS-02	90,90			
3	DS-03	72,70			
4	GR-04	96,40			
5	GR-05	96,36			
Rata-rata		**90,17**			

In the validation test of the STEM-integrated PBL-based E-Student Worksheets by media experts, several aspects were evaluated. These aspects include **size**, **cover design**, and **content design**. The analysis of the media validation test results for each aspect of the E-Student Worksheets is presented in Table 4.

Table 4. Results of Media Expert Validation for Each Assessment Aspect

No	Assessment Aspects	V-aiken's	Criteria
1	Size	0,93	Valid
2	Cover Design	0,85	Valid
3	Content Design	0,89	Valid

c. Feasibility Test Revisions

Revisions to the material feasibility and media feasibility were made after the STEM-integrated PBL-based E-Student Worksheets were validated by subject matter and media experts.

d. Analysis of Small-Scale Trial Results

A small-scale trial was conducted after the E-Student Worksheets were validated by the validators and revised according to their suggestions. The trial involved readability testing of the E-Student Worksheets and test instruments integrated with aspects of scientific literacy competence, administered to Class XII students.

The readability test of the E-Student Worksheets was conducted by distributing readability questionnaires to students. The purpose of the readability test was to determine the readability level of the developed E-Student Worksheets. The results of the readability test analysis are presented in Table 5.

Table 5. Results of Readability Test Analysis for E-Student Worksheets

Readability Aspects	Percentage (%)	Criteria
Structure of E-Student Worksheets	87,11	Very Good
Language	86,67	Very Good
Presentation	87,00	Very Good
Average	86,89	Very Good

The next stage involved testing the assessment test instrument. Before implementation, the test instrument was validated by expert validators to determine its feasibility.

After the test instrument was validated and revised, a small-scale trial was conducted. The trial involved 30 students from Class XII at SMA Negeri 1 Semarang. The results of the trial were then analyzed to determine the validity, reliability, difficulty level, and discriminatory power of the test items.

The validity of each test item was analyzed using the product-moment correlation formula with the assistance of Microsoft Excel. The calculated rxy values were compared against the critical r-value from the product-moment table at a 5% significance level. If $r_{xy} > r_{table}$, the item was deemed valid. The calculations and validity criteria of the test items are presented in Table 6.

Table 6. Data on Item Validity Test Results

Number of Item	Description
1, 2, 4, 5, 6, 7, 9, 10, 11, 14, 15, 16, 17, 18, 19, 20, 21	Valid
3, 8, 12, 13	Tidak Valid

Based on Table 6, 17 questions were deemed valid, while 4 questions were invalid. The invalid questions could not be used in the large-scale test as they were difficult for students to understand and contained ambiguous interpretations. If these questions are to be used in the large-scale test, they must first be revised. On the other hand, the valid questions could be directly used as test instruments to measure students' scientific literacy competence.

After the validity test, the next step was the reliability test. Reliability was analyzed using the Cronbach's Alpha formula with the assistance of Microsoft Excel. The results indicated a reliability value of 0.80, categorized as high. A reliability score of ≥0.60 signifies that the test items are reliable (Sugiyono, 2019).

The subsequent steps involved analyzing the difficulty level and discriminatory power of the questions. The calculations and criteria for the difficulty level and discriminatory power are presented in Table 7 and Table 8, respectively.

Table 7. Data on Difficulty Index Results

Criteria	Number of Item
Difficult	3, 8, 11, 12, 13,
Intermidiate	1, 2, 5, 6, 8, 10, 14, 16, 20, 21
Easy	4, 7, 9, 15, 17, 18, 19

Table 8. Data on Discriminatory Power Results

Criteria	Number of Item
Baik	1, 5, 7, 14, 16, 18
Cukup	2, 4, 10, 11, 15, 20
Jelek	3, 6, 8, 9,12, 13,17, 19, 21

After conducting the analysis, including tests for validity, reliability, difficulty level, and discriminatory power, a total of 15 questions were deemed suitable for use as assessment tools.

4. Implementation Stage

In the implementation stage, the researcher implemented the STEM-integrated PBL-based E-Student Worksheets product and the validated assessment instruments. The purpose of this stage was to evaluate the effectiveness of the STEM-integrated PBL-based E-Student Worksheets in fostering students' scientific literacy competence.

The effectiveness of the E-Student Worksheets product was determined based on students' learning outcomes, which were measured using the assessment instruments. The results of the learning outcomes assessment are presented in Table 9.

Table 9. Results of Student Learning Assessment

Score	Number of Students	Category
47	1	Incomplete
60	1	Incomplete
67	4	Incomplete
73	9	Complete
80	5	Complete
87	5	Complete
93	7	Complete
100	1	Complete

Based on the analysis, the results of the test analysis for each indicator in the competence aspect of scientific literacy skills are presented in Figure 5.

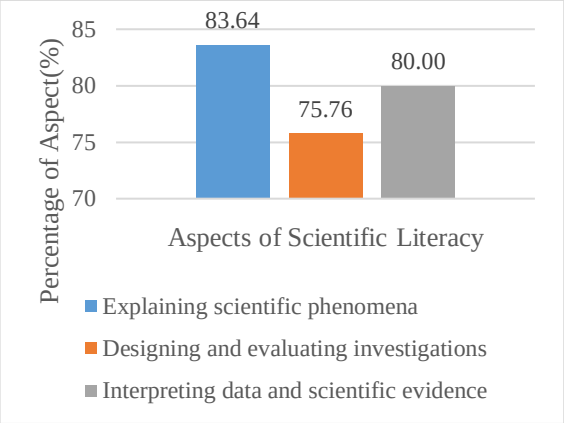

Figure 5. Graph of Test Analysis Results for Each Indicator in the Competence Aspect of Scientific Literacy Skills

5. Evaluation Stage

The evaluation stage is the final phase in the development of the STEM-integrated PBL-based E-Student Worksheets using the ADDIE approach. This stage aimed to refine and assess the feasibility, effectiveness, and feedback on the developed E-Student Worksheets. Evaluation was also conducted throughout the four previous ADDIE development stages. This process, known as formative evaluation, was designed for revision purposes.

The final evaluation in the ADDIE model, referred to as summative evaluation, was conducted using a student response questionnaire after the E-Student Worksheets was implemented. The purpose of the student response questionnaire was to gather feedback on their experience using the E-Student Worksheets.

The student responses were analyzed using a percentage formula. The results of the student response questionnaire analysis for the E-Student Worksheets are presented in Table 10.

Table 10. Results of Student Response Questionnaire Analysis on the Use of E-Student Worksheets

No	Student Response Indicators	Percentage (%)	Criteria
1	Content Quality	74,55	Positive
2	Appearance	84,12	Very Positive
3	Language	83,64	Very Positive
4	Benefits of the STEM Approach and Scientific Literacy in E-Student Worksheets	76,06	Positive
	Average	**79,59**	Positive

Discussion

The discussion of the STEM-integrated PBL-based E-Student Worksheets will be elaborated in the following sections.

1. Feasibility of STEM-Integrated PBL-Based E-Student Worksheets

The feasibility of the STEM-integrated PBL-based E-Student Worksheets was measured through material feasibility tests, media feasibility tests, and readability tests. The material and media feasibility tests were conducted by five subject matter experts and five media experts.

a. Material Feasibility

The purpose of the material feasibility test was to ensure that the content in the E-Student Worksheets is appropriate for use. The results of the material validation analysis for the E-Student Worksheets are shown in Table 1. Validation conducted by five validators using percentage analysis yielded an average score of 89.77%. According to Wardani et al. (2021), E-Student Worksheets content is deemed feasible if it scores above 60%. Additionally, the material feasibility of the E-Student Worksheets was analyzed using the V-Aiken's formula, which resulted in a score of 0.87, categorized as valid. In V-Aiken's analysis, the feasibility criteria are considered met if $v_{result} > v_{table}$. Based on this analysis, the content in the STEM-integrated PBL-based E-Student Worksheets was deemed feasible for use.

The material feasibility test evaluated several aspects, including content feasibility, presentation feasibility, and language quality feasibility. The results for each aspect of the material feasibility test are presented in Table 2. Based on Table 2, the V-Aiken's analysis for each aspect indicates that the material feasibility criteria were categorized as highly valid.

b. Media Feasibility

The purpose of the media feasibility test was to ensure that the STEM-integrated PBL-based E-Student Worksheets is suitable for use as a learning medium. This test was conducted by media experts proficient in the field. The results of the media feasibility validation are presented in Table 3.

Based on Table 3, the media feasibility validation conducted by five validators using percentage analysis yielded an average score of 90.17%. According to Wardani et al. (2021), the E-Student Worksheets is considered feasible if it scores above 60%. Furthermore, the media feasibility was also analyzed using the V-Aiken's formula, which yielded a score of 0.88, categorized as valid. In V-Aiken's analysis, the feasibility criteria are deemed met if $v_{result} > v_{table}$. Based on the percentage analysis and V-Aiken's results, the STEM-integrated PBL-based E-Student Worksheets was deemed feasible as a learning medium.

The media feasibility test evaluated several aspects, including size feasibility, cover design feasibility, and content design feasibility. The analysis results for each aspect of media feasibility are presented in Table 4. Based on these results, the media feasibility validation using V-Aiken's analysis for each aspect was categorized as highly valid.

c. Readability Test

The readability test for the E-Student Worksheets was conducted by distributing a readability questionnaire to students. The purpose of this test was to determine the readability level of the developed E-Student Worksheets. The readability test results are presented in Table 5.

Based on Table 5, the structure aspect of the E-Student Worksheets scored 87.11%, categorized as very good. The language aspect scored 86.67%, categorized as good. The presentation aspect scored 87.00%, categorized as very good. The average score for the readability analysis of the STEM-integrated PBL-based E-Student Worksheets was **86.89%**, categorized as very good. According to Pratama & Saregar (2019), an E-Student Worksheets is considered feasible if it scores **≥61%**. Therefore, the developed E-LKPD product was deemed suitable for advancement to the large-scale trial stage.

2. Effectiveness of STEM-Integrated PBL-Based E-Student Worksheets in Enhancing Students' Scientific Literacy Competence

The effectiveness of the STEM-integrated PBL-based E-Student Worksheets in fostering students' scientific literacy competence was obtained from the results of students' learning activities after using the E-Student Worksheets. Effectiveness was measured using test instruments containing aspects of scientific literacy competence integrated with STEM. Before the test items were implemented to students, they were first validated by expert validators. The validated and revised test items were then trialed on a small scale for analysis. After conducting analyses, including validity, reliability, difficulty level, and discriminatory power tests, 15 test items were deemed appropriate for data collection. These test items were then implemented on a large scale with 33 students of Class XI-A at SMA Negeri 1 Jatilawang.

The test items were administered after students used the E-Student Worksheets in the learning process, aiming to measure the effectiveness of the E-Student Worksheets in fostering students' scientific literacy competence. Test results were considered satisfactory if scores exceeded the Minimum Passing Criteria (KKM) of 70.

The results of the scientific literacy test for Class XI-A students at SMA Negeri 1 Jatilawang after using the E-Student Worksheets are presented in Table 9. The data in Table 9 were analyzed using a percentage formula to determine classical completeness. The calculation showed a classical completeness value of 81.81%. Based on effectiveness criteria, a value of 81.81% indicates effectiveness because more than 60% of students met the minimum passing criteria (Nasiroh et al., 2020). Based on this, it can be stated that the developed E-Student Worksheets has a positive impact on students' scientific literacy competence.

The aspect of scientific literacy assessed in this study is the competence aspect, which consists of three indicators: explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting data and scientific evidence. The results of the test analysis for each indicator in the competence aspect of scientific literacy are shown in Figure 2.

Based on Figure 2, the results of the scientific literacy skills test in the competence aspect are as follows: the indicator of explaining scientific phenomena achieved a percentage of 83.64%, categorized as effective; the indicator of evaluating and designing investigations achieved a percentage of 75.76%, categorized as effective; and the indicator of interpreting data and scientific evidence achieved a percentage of 80.00%, categorized as effective. Overall, the average result of the students' scientific literacy skills test was 79.8%, categorized as effective.

3. Student Responses to the Use of E-LKPD

The student response questionnaire aimed to gather students' feedback after using the STEM-integrated PBL-based E-Student Worksheets during the previously conducted learning activities. The results of the student response analysis are presented in Table 10. The average percentage of student responses to the use of the STEM-integrated PBL-based E-Student Worksheets was 90.55%, categorized as very positive.

The student response aspects consisted of four assessment aspects: content quality, appearance, language, and the usefulness of the E-Student Worksheets.

Student responses to the content quality of the E-Student Worksheets received a percentage of 74.55%, categorized as positive. This was because the material presented in the E-Student Worksheets was concise and easy for students to understand. Additionally, the instructions for using the E-Student Worksheets were clear and easy to follow.

Student responses to the appearance of the E-Student Worksheets received a percentage of 84.12%, categorized as very positive. This was attributed to the E-Student Worksheet's visually appealing design, including its use of colors, images, and cover. The font used was clear and easy to read, and the steps in the E-Student Worksheets were clearly displayed and easy for students to follow.

Student responses to the language used in the E-Student Worksheets received a percentage of 83.64%, categorized as very positive. This was due to the straightforward and easy-to-understand language used in the E-Student Worksheets content.

Student responses to the usefulness of the STEM approach and scientific literacy in the E-Student Worksheets received a percentage of 76.06%, categorized as positive. This was because the use of the STEM-integrated E-Student Worksheets made it easier for students to understand the concept of sound wave resonance. Furthermore, the addition of practice questions in the E-Student Worksheets greatly supported students' conceptual understanding.

CONCLUSION

Based on the results and discussion presented, the STEM-integrated PBL-based E-Student Worksheets is feasible for use in learning, with a material feasibility test percentage of 89.77%, media feasibility test percentage of 90.17%, and readability test percentage of 86.89%. These results categorize all validation outcomes as highly feasible.

The STEM-integrated PBL-based E-Student Worksheets is also effective in fostering students' scientific literacy competence. The scientific literacy competence indicators achieved the following scores:

- Explaining scientific phenomena: 83.64%,
- Evaluating and designing scientific investigations: 75.76%,

- Interpreting data and scientific evidence: 80.00%.

In addition, the use of the STEM-integrated PBL-based E-Student Worksheets received positive feedback from students, with a response rate of 79.59%.

Based on the research findings, it is suggested that future research develops the STEM-integrated PBL-based E-Student Worksheets for other topics and expands its focus to other aspects of scientific literacy. These may include content, context, and attitude aspects of scientific literacy, not just the competence aspect.

REFERENCES

Anwar, A. (2022). Media Sosial Sebagai Inovasi Pada Model PjBL dalam Implementasi Kurikulum Merdeka. *Jurnal UPI*, *19*(2), 237–250.

Astuti, W., Sulastri, Syukri, M., & Halim, A. (2023). Implementasi Pendekatan Science , Technology , Engineering , and Mathematics untuk Meningkatkan Kemampuan Literasi Sains dan Kreativitas Siswa. *Jurnal Pendidikan Sains Indonesia*, *11*(1), 25–39.

Cormann, M. (2023). *PISA 2022 Results The State of Learning ad Equity in Education: Vol. I* (Issue 2). OEDC.

Fitri, Y. S., & Juliani, S. (2024). Upaya Peningkatan Kemampuan Numerasi Siswa Melalui Pembelajaran Kontekstual dengan Bantuan Game Sederha. *Jurnal Pendidikan Dan Riset Ilmu Sains*, *03*, 118–127.

Fransiska, N. R., & Sidabutar, H. (2022). Student workshet the development based on stem (sciene, technology, engineering and mathematics) based construct 2 assisted lkpd on excretion system materials …. *Educenter: Jurnal Ilmiah …*, *1*(7), 701–713. https://jurnal.arkainstitute.co.id/index.php/educenter/article/view/262%0Ahttps://jurnal.arkainstitute.co.id/index.php/educenter/article/download/262/208

Hanipah, S. (2023). Analisis Kurikulum Merdeka Belajar Dalam Memfasilitasi Pembelajaran Abad Ke-21 Pada Siswa Menengah Atas. *Jurnal Bintang Pendidikan Indonesia (JUBPI)*, *1*(2).

Harahap, K. R. P., Sani, R. A., & Simamora, J. A. (2022). Development of Worksheet Based on Science , Techonology , Engineering and Mathematics (STEM) To Improve Creative Thinking Ability on Substance Pressure Materials. *Indonesian Science Education Research (ISER)*, *4*(2), 20–28.

Hasan, M., Milawati, Darodjat, Khairani, H., & Tahrim, T. (2021). Media Pembelajaran. In *Tahta Media Group*.

Hidayat, F., & Nizar, M. (2021). Model ADDIE (Analysis, Design, Development, Implementation, and Evaluation) dalam Pembelajaran Pendidikan Agama Islam. *Jurnal Inovasi Pendidikan Agama Islam*, 28–37.

Irwan, A. P., Usman, & Amin, B. D. (2019). Analisis Kemampuan Literasi Sains Peserta Didik. *Jurnal Sains Dan Pendidikan Fisika (JSPF)*, *15*(3), 17–24.

Mu'minah, I. H., & Aripin, I. (2019). Implementasi Stem Dalam Pembelajaran Abad 21. *Prosiding Seminar Nasional Pendidikan*, *1*(2012), 1496. https://prosiding.unma.ac.id/index.php/semnasfkip/article/view/219

Ningrum, R. A., Qomaria, N., Hadi, W. P., Ahied, M., & Sutarja, M. C. (2024). KELAYAKAN E-LKPD BERBASIS LITERASI SAINS MATERI GETARAN DAN. *Jurnal Natural Science Educational Research*, *7*(1), 121–128.

Ningsih, S., Hala, Y., & Usman. (2023). Menerapkan E-LKPD Interaktif Berbasis Liveworksheet untuk Meningkatkan Hasil Belajar dan Keatifan Peserta Didik Kelas VII SMP Negeri 3 Sinja. *Pemikiran Dan*

Pengembangan Pembelajaran, *5*(3), 1–6.

Nurisnaeni. (2022). Peningkatan Penguasaan Konsep Dan Aktivitas Belajar Siswa Menggunakan Model Pembelajaran Kooperatif Tipe Tgt (Times Games Tournament) Pada Materi Sistem Saraf Di Sma Yabujah Indramayu Tahun 2020 / 2021. *Jurnal Sinau*, *8*, 180–206.

Purba, M., & Purba, G. (2023). Pengembangan Lembar Kerja Peserta Didik Berbasis Problem Based Learning Unpetuk Meningkatkan Kemampuan Penalaran Matematis Siswa. *Jurnal Riset Rumpun Ilmu Pendidikan*, *2*(1), 84–98.

Rusilowati, A., & Astuti, B. (2019). *Pengembangan Tes Literasi Sains*.

Sari, M. W., Wati, I. K., Nugraheni, F. S. A., & Suciati, S. (2023). Development of Ethno-STEM-based Science Learning Tools. *Journal Intellectual Sufism Research (JISR)*, *5*(2), 95–101. https://doi.org/10.52032/jisr.v5i2.143

Sari, N. N. (2021). *Analisis Kemampuan Literasi Sains pada Aspek Pengetahuan dan Proses Sains Siswa pada Materi Gelombang Bunyi*.

Sinuraya, R. G., & Frisnoiry, S. (2023). Development of Problem Based Learning (PBL) Electronic Student Worksheets (E-LKPD) to Improve Students' Mathematical Problem Solving Ability. *Formosa Journal of Multidisciplinary Research*, *2*(1), 107–124.https://doi.org/10.55927/fjmr.v2i1.2690

Syaifudin, M. (2022). Efektivitas e-lkpd berbasis stem untuk menumbuhkan ketermapilan liteasi numerasi dan sains dalam pembelajaran listrik dinamis di SMA Negeri 1 Purbalingga. *Jurnal Riset Penididikan Indoensia*, *2*(2), 211–220.