Tadris: Jurnal Keguruan dan Ilmu Tarbiyah 8 (2): 315-325 (2023)
DOI: 10.24042/tadris.v8i2.16823

TADRIS: JURNAL KEGURUAN DAN ILMU TARBIYAH
(Tadris: Journal of Education and Teacher Training)
P-ISSN: 2301-7562 | E-ISSN: 2579-7964
ejournal.radenintan.ac.id/index.php/tadris/index

Developing STEM Electronic Student Worksheet with Problem-Based Learning to Enhance Communication Skills

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Article History:
Received: May 17th, 2023
Revised: June 16th, 2023
Accepted: November 14th, 2023
Published: December 30th, 2023

Keywords:
Communication skills,
Problem-based learning,
STEM,
Worksheets

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Abstract: This research aimed to develop STEM-integrated Problem-Based Learning e-worksheets to enhance students' communication skills. The research methodology employed was research and development (R&D). The development process followed the instructional design model ADDIE, which consists of five stages: analysis, design, development, implementation, and evaluation. Upon conducting research and analysis, the results indicated high satisfaction with the validity of the STEM-integrated problem-based e-worksheets in terms of content and construct. The average content aspect percentage was 88%, while the construct aspect percentage was 87%. The effectiveness of the e-worksheets was demonstrated through N-gain results and paired t-tests, revealing a notable improvement in communication skills. In conclusion, the developed Problem-Based Learning e-worksheets integrated with STEM effectively enhanced students' communication skills. These findings hold significant value for the learning process, particularly in enhancing students' communication skills and providing teachers of physics with additional e-worksheets as valuable learning resources. It is expected that further development of these e-worksheets will contribute significantly to enhancing students' overall communication skills.

INTRODUCTION

In the era of digitalization, Indonesia has become well-acquainted with the paradigm of the fourth industrial revolution. The advent of the Internet of Things, in conjunction with advancements in scientific data applications and the exponential proliferation of artificial intelligence, robotics, cloud computing, 3D printing, and nanotechnology, collectively epitomize the distinctive attributes of this fourth industrial revolution (Ghufron, 2018). In this contemporary era, it has become exceedingly important for students to attain proficiency in skills that characterize the 21st century, primarily focusing on information technology (Mishra & Mehta, 2016; Subekti et al., 2018). The 21st-century skills that challenge learners today include critical thinking, problem-solving, creativity, innovation, communication, and collaboration (Bele Sole & Made Anggraini, 2018; Farisi, 2016; Sagala et al., 2019). One of the skills being extensively studied for enhancement is communication skills. Communication skills are a crucial endeavour towards achieving ideal information literacy for students at the secondary school level.

Hosnan, (2014) asserts that to compete effectively in the 21st century, learners must possess communication skills that can influence every aspect of life (Khlaisang & Koraneekij, 2019). Communication is essential when

confronting 21st-century learning (Valtonen et al., 2017). Effective communication throughout the learning process will train students to think critically. Learners must be proficient in oral and written communication to foster positive and mutually beneficial relationships between educators and students in the educational environment (Khoiruddin, 2012).

Indonesia has made numerous efforts to enhance the quality of education through research-based models, strategies, approaches, and the utilization of trending media. These efforts have proven successful in elevating the standard of education in other countries (Boesdorfer, 2019; Hidayat & Rostikawati, 2018; Mulyadi et al., 2014; Sagala et al., 2019). However, based on the preliminary study conducted in one of the high schools in Lampung Province, involving the distribution of questionnaire surveys via Google Forms to 27 educators and 42 students, the results indicate that many students still encounter difficulties in their learning activities. Approximately 78.5% of the students express their fondness for physics, yet 57.2% of them find physics lessons challenging, especially regarding sound waves. Furthermore, 50% of the teachers still rely on printed teaching materials, and 75% have not yet incorporated problem-based STEM-integrated worksheets into their teaching practices.

Among the many concepts in physics that pose challenges for students, sound waves are among the most difficult to comprehend. Consequently, students must comprehensively understand the principles and theories underlying them to facilitate their future progress in this domain. Online learning has become commonplace and is considered an alternative learning solution, especially after the COVID-19 pandemic that has affected the country. Teachers and fellow students can still interact without face-to-face meetings (Daniel, 2020; Redhana, 2019). One way to innovate the learning process for the current situation is by creating various learning resources, such as books, modules, or student worksheets, and developing them in electronic formats, which can provide a solution (Apriyanto et al., 2019; Sholeha et al., 2019).

This research variable, such as developing e-worksheets using a scientific approach, has been extensively investigated (Apriyanto et al., 2019). The competence of teachers in creating e-worksheets with an emphasis on representation has been a subject of study (Aruan et al., 2017). The relationship between high-order thinking skills, representation, and concepts (Tajudin & Chinnappan, 2016), The development of assessment for communication and collaboration skills based on Problem-Based Learning (Noviana et al., 2019), learning using the STEM approach for 21st-century skills (Stohlmann et al., 2012), and the implementation of learning with appropriate technology to cultivate a culture of utilizing renewable energy (Laliyo et al., 2014).

Despite the abundance of research and presented facts, it is evident that there is still a gap. To bridge the divide between factual knowledge and ideal educational expectations, educators must possess the ability to develop appropriate and inventive teaching methods. This is crucial for addressing and resolving learning difficulties, particularly in physics education (Nugroho & Ruwanto, 2017; Stohlmann et al., 2012; Winayawati et al., 2012). The difference between this research and previous studies lies in developing e-worksheets based on Problem-Based Learning integrated with STEM, aiming to enhance students' communication skills. The fusion of problem-based learning with the STEM (Science, Technology, Engineering, and Mathematics) approach in physics education is highly feasible. Problem-based learning integrated with STEM can facilitate students' abilities to critically

analyze and effectively solve problems (Ismail et al., 2016). As a result, students develop problem-solving attitudes and skills within themselves (Paramartha et al., 2020). The knowledge applied in problem-solving aligns with the development of communication competence, enabling students to comprehend questions, elucidate scientific phenomena, draw conclusions based on empirical evidence (Ismail et al., 2016) and resolve academic issues (Putri et al., 2018).

METHOD

Research Design

Research and Development (R&D) is employed in this developmental research. The development design adheres to the ADDIE instructional development model, encompassing five stages: analysis, design, development, implementation, and evaluation (Branch, 2009). The development process of the e-worksheet is based on the ADDIE instructional development model developed by Branch (2009), which comprises five consecutive steps, namely (1) Analysis, (2) design, (3) development, (4) implementation, and (5) evaluation. The developmental stage model is based on its suitability for the required research design to produce e-worksheet that effectively enhances students' communication skills.

In Analysis stage, the researcher conducts preliminary investigations to assess the initial conditions and challenges faced in the field, along with potential strategies that can be employed to address these issues. Initial research data is gathered through the distribution of questionnaires to a sample comprising 47 high school students and 27 physics teachers from Lampung Province. The findings and analysis of these needs serve as the foundation for formulating further actions.

In the design stage, the e-worksheet developed is problem-based and utilizes the STEM approach to enhance communication skills. The e-worksheet is developed using software that can be accessed online. The e-worksheet will contain content including user instructions, engaging learning materials, relevant sample questions, and their solutions. It will also feature images/videos related to sound wave phenomena, material summaries, and interactive quizzes with accompanying feedback.

The development stage involves the actualization of the product design. The aim is to ensure that the developed product is ready for implementation in an educational setting, enabling feedback and further suggestions to refine the product before field testing (Lumbantobing et al., 2019). The initial product produced will undergo a feasibility test first. This validation aims to assess the suitability of the product created and its implementation in the learning process. The validation in this research encompasses content and construct validation.

In the implementation stage, the developed and revised e-worksheet product will be field-tested using an experimental method, specifically the one-group pretest-posttest design. Jack R & Wallen (2009) used a design where one class is employed as the experimental group, with the dependent variable assessed through a pretest administered before the treatment and a posttest conducted after the treatment.

The evaluation stage occurs after the analysis, design, development, and implementation stages. The evaluation results are used as feedback to improve the product obtained from internal evaluation. The evaluation stage includes several activities, including problem analysis, design refinement, validation by content and construct experts, and student response assessment. The primary goal of this evaluation stage is to ensure the level of student communication skills proficiency. The research procedure is illustrated in Figure 1.

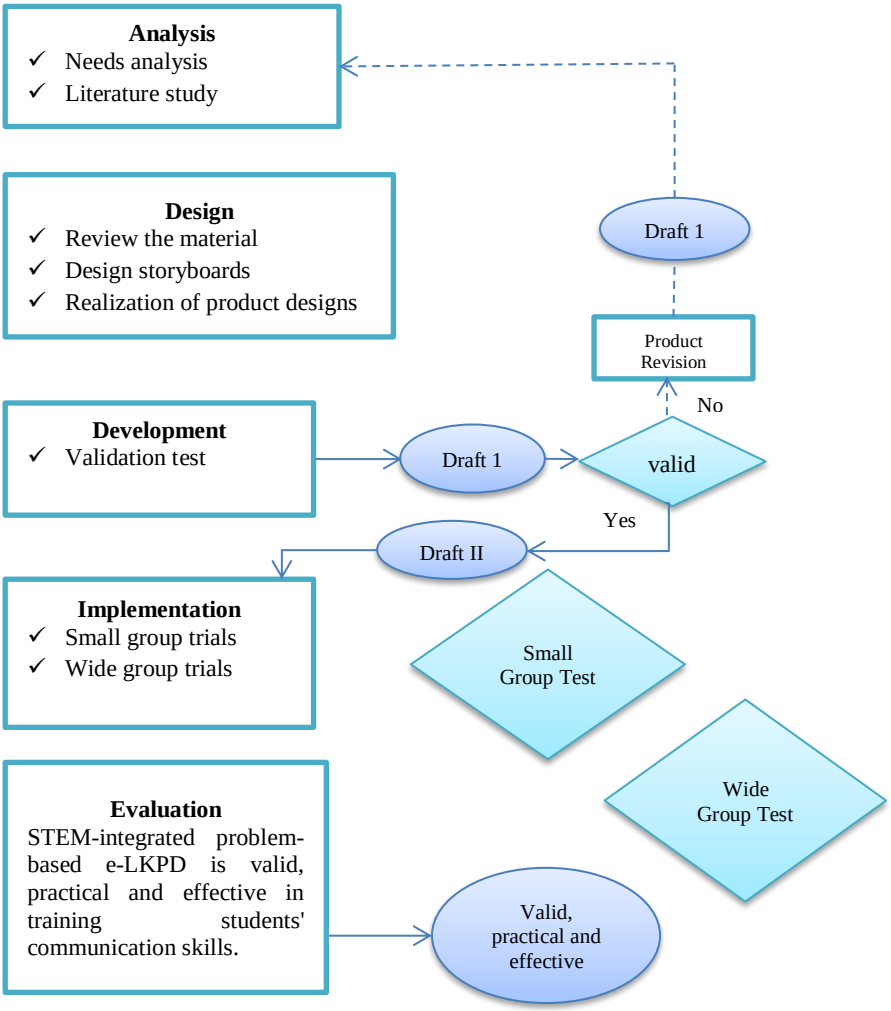

Figure 1. Research Design.

Data Collection

The collected data comprises information gathered from three main sources: the needs analysis, assessments of product validity (including content and construct validity, as well as practicality measured through feasibility, readability, and student responses), and data on product effectiveness obtained from self-assessment questionnaires focusing on communication skill enhancements.

Data Analysis

The data analysis process involves a structured approach encompassing various stages. Initially, a preliminary analysis offers an overarching understanding of the collected data. Subsequently, a meticulous examination of the product design data is conducted, delving into its intricacies. Following this, an in-depth scrutiny of the instruments utilized takes place, emphasizing their validity and reliability. Finally, the analysis extends to the field trial data, encompassing detailed evaluations through both small-group and large-group analyses. Each stage contributes significantly to comprehending and interpreting the research outcomes comprehensively.

RESULT AND DISCUSSION

The outcome of this developmental research is problem-based e-worksheets with a STEM approach designed to enhance students' communication skills. Data regarding the validity of the e-worksheet development were obtained

during the analysis, design, and development stages. In contrast, data regarding practicality and effectiveness were acquired during the implementation and evaluation stages.

Analysis

The analysis stage involved reviewing literature and field research to identify the needs and challenges teachers and students face. Literature study results were obtained by examining several articles to find information on high-quality teaching materials for enhancing communication skills. The field study was conducted through questionnaires distributed to 47 high school students and 27 physics teachers in Lampung Province, resulting in a summary of the student's needs, as presented in Table 2.

Table 2. Summary of Student Needs Analysis.

No	Statement	Student Responses
1	The students enjoy learning physics.	The percentage shows that 79.4% of the students enjoy physics lessons, while 20.6% do not enjoy physics.
2	The factors contributing to the enjoyment of learning physics.	The top three factors for liking physics lessons, with the highest percentages, are 35% due to the subject matter, 22% because of the teaching materials, and 19% because of the teacher.
3	Challenging topics in learning physics.	The material considered difficult in physics is the sound wave topic, with a percentage of 42.6%.
4	The physics learning process already incorporates problem-based learning media.	Learning still rarely utilizes problem-based learning media, with a percentage of 36.3%.
5	The learning process utilizes group discussion and presentation methods.	35.3% of students state that the learning process involves discussions often, while 33.3% state it is rare.
6	The learning process employs experimental methods.	36.3% of the learning process already employs experimental methods.
7	The tools and materials most commonly used in learning.	80.2% of students agree that the teaching material frequently used by teachers is books.
8	The learning process already uses electronic or online-based teaching materials.	43.6% of students state that teachers already use electronic/online-based teaching materials.
9	Satisfaction with the physics learning process at school.	The highest percentage of students, 44%, feel neutral, 39% are satisfied, 10% are unsatisfied, and 6% are very satisfied.
10	Activeness in the process of learning physics in class.	Regarding student engagement in the physics learning process, 54.5% feel average, 36.6% feel active, 5% feel very active, and 4% are not active.

Based on the summary of needs analysis in Table 2, there is a need for teaching materials that not only contain physics content but also encourage active student engagement and develop good communication skills. Therefore, the researcher has developed teaching materials as problem-based e-worksheets integrated with STEM. These electronic teaching materials are presented in an attractive format, including STEM learning steps, various instructional videos, and quizzes.

In this e-worksheet, students will find physics content, problem-solving steps, and electronically displayed experiments.

Design

The e-worksheet design follows a problem-based approach and was created using Canva. Its format comprises sections including introduction, content, and conclusion. The introduction covers the title page, foreword, table of contents, instructions for usage, learning objectives, outcomes, indicators, and objectives. The content section includes three distinct worksheets (Worksheet 1, Worksheet 2, and Worksheet 3) with activities aligned to

stages of problem-based learning. Each worksheet incorporates STEM-based laboratory activities aimed at improving students' communication skills. The concluding section includes a summary, evaluation, references, and author's profile. These activities are designed for both online and offline usage, intending to enhance students' communication skills. Post-design, the e-worksheet is converted into PDF format and integrated into the Canva application to incorporate engaging physics learning videos and simulations.

Figure 2. Product Design.

Development

In the development stage, the designed product is then prepared for both content and construct validation. The results of the validation of the developed product can be seen in Table 3 and 4.

Table 3. Results of the Construct Expert Validation Assessment.

No	Evaluation Aspects	Percentage
1	Originality	88%
2	Language	84%
3	Design	85%
4	The Colouring System of the Images/Animations	91%
	Average	**87%**

Table 4. Results of the Content Expert Validation Assessment.

No	Evaluation Aspects	Percentage
1	Syntax	85%
2	Social System	92%
3	Principles of Reactions	90%
4	Support System	87%
5	Instructional and Accompanying Impacts	85%
	Average	**88%**

Based on the assessment by the subject matter expert, it is evident that the percentage score for suitability falls into the "highly suitable" category. Therefore, problem-based e-Worksheets with a STEM approach can be used. The assessment by content experts in Table 4 reveals that the first aspect, related to

syntax, obtained a suitability percentage of 85%. In the second aspect, concerning the social system aspect, it received a suitability percentage of 92%; in the third aspect, related to reaction principles, it obtained a suitability percentage of 90%. Meanwhile, the fourth aspect regarding support system assessment received a score of 87%, and the fifth aspect concerning instructional and accompanying impacts received a score of 85%. The average assessment by content expert validators is a suitability percentage of 88%. Based on the assessment results of the content experts, it is evident that the percentage score falls into the "highly suitable" category. Therefore, the problem-based e-worksheets with a STEM approach can be used for sound wave topics.

Implementation

Table 5 displays an analysis of posttest scores for both the experimental and control groups. The data illustrates that the experimental group attained higher posttest scores in comparison to the control group. Within the experimental group, the scores ranged from 75 as the lowest to 88 as the highest, totaling 1710 with an average of 81. Conversely, the control group's scores ranged from 70 as the lowest to 85 as the highest, totaling 1628 with an average of 78. The average N-Gain score, reflecting an improvement of 0.81, falls within the "good" category.

Table 5. Summary of Posttest Scores in the Experimental and Control Groups.

Class	Highest Score	Lowest Score	$\sum X_i$	Average
Experiment	88	75	1710	81
Control	85	70	1628	78

Table 6. Descriptive Statistics.

Class	N	Mean	St. Dev	Minimum	Maximum
Experiment	21	80.8571	2.00713	74.00	85.00
Control	21	78.0000	2.73861	73.00	85.00

According to Table 6, both the control and experimental groups consist of 21 respondents each. The mean value for the control group is 78.000, whereas for the experimental group, it is 80.857. The standard deviation for the experimental group is 2.007, whereas for the control group, it is 2.738. The maximum value for both the control and experimental groups is 85, with the minimum value being 73 for the control group and 74 for the experimental group.

Table 7. The Result of the One-Sample Kolmogorov-Smirnov Test for Normality.

		Control	Experimental
N		21	21
Normal Parameters[a]	Mean	78.0000	80.8571
	Std. Deviation	2.73861	2.00713
Most Extreme Differences	Absolute	.167	.386
	Positive	.119	.281
	Negative	-.167	-.386
Kolmogorov-Smirnov Z		.764	1.767
Asymp. Sig. (2-tailed)		.604	.004

a. Test distribution is Normal.

Table 8. Test of Homogeneity of Variances.

Result			
Levene Statistic	df1	df2	Sig.
3.307	1	40	.076

Table 9. Results of the Independent Samples T-Test.

		Levene's Test for Equality of Variances		**T-test for Equality of Means**						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Result	Equal variances assumed	3.307	.076	-3.856	40	.000	-2.85714	.74093	-4.35462	-1.35966
	Equal variances not assumed			-3.856	36.675	.000	-2.85714	.74093	-4.35886	-1.35542

According to Table 7, the control class demonstrates a Kolmogorov-Smirnov value of 0.764, while the experimental class exhibits a Kolmogorov-Smirnov value of 1.767. The significance obtained from the data is > 0.05. Hence, it can be inferred that, based on Kolmogorov-Smirnov, the regression model complies with the assumption of normality, signifying that the data conforms to a normal distribution. In Table 8, both groups showcase a significance value of 0.364, where the obtained significance through the data is (p) > 0.05. Thus, it can be deduced that each data group originates from a population with consistent variance (homogeneity). As per Table 9, the significance value registers as 0.000, with the obtained significance from the data being (p) < 0.05. Therefore, it can be inferred that the independent variable (X) exerts influence over the dependent variable (Y), indicating acceptance of the hypothesis.

Evaluation

Upon implementing the suggested product improvements, a reevaluation process was conducted to assess the efficacy of the refined product. Soliciting feedback from teachers and students revealed positive perceptions regarding the product's quality and appeal, indicating the successful development of the e-worksheet. These collective enhancements culminated in the final product, showcasing substantive improvements and affirming the overall effectiveness of the e-worksheet development. Notably, this was corroborated by the N-gain results and paired t-tests, underscoring tangible advancements in communication skills.

The conducted developmental process underscores the pivotal role of worksheets as an invaluable tool in facilitating active learning support and stimulating interest in scientific education and assessment (Lee, 2014). Worksheets, emerging as a cornerstone in educational tools, actively engage students throughout the teaching and learning journey, emphasizing the necessity to tailor their design according to students' needs. Moreover, these worksheets intricately integrate visual elements, such as images, complementing textual content. The researcher's endeavor in crafting electronic worksheets symbolizes an innovative stride in furnishing learning

materials attuned to contemporary educational requisites. The Problem-Based Learning Worksheets, integrated with STEM principles, focused on exploring sound waves to augment students' communication abilities and gauge the feasibility and receptiveness of the developed product among students.

Content validation by experts showcased an impressive average score of 87%, signifying a highly suitable rating. Concurrently, subject-matter experts evaluated the e-worksheet's content, resulting in an overall average percentage of 88%, also deemed highly appropriate. These e-worksheets encompass an array of interactive and captivating elements, including discussion columns, images, videos, animations, and diverse color schemes. These multifaceted features captivate student attention and combat disengagement, fostering an immersive learning environment. This echoes findings from Asrori & Suparman's (2020) research, emphasizing that e-worksheets, enriched with videos, images, and engaging animations, induce a sense of enjoyment in learning, thereby influencing learning outcomes. Additionally, the developed e-worksheet incorporates a virtual laboratory, enabling students to conduct online experiments and participate in activities that amplify their communication proficiencies.

CONCLUSION

Based on the research findings and discussions, it is evident that the problem-based e-worksheet, integrating STEM principles with sound waves, fulfills stringent validity criteria. This developed e-worksheet stands as a highly valid product, scoring an average percentage of 88% for content and 87% for construct validity. Moreover, its effectiveness is substantiated by the N-gain results and paired t-tests, unmistakably showcasing an enhancement in students' communication skills. This confirms the potency of the problem-based e-worksheet integrated with STEM in fostering improved communication skills among students. For future research endeavors, delving deeper into the longitudinal effects of utilizing problem-based e-worksheets integrated with STEM could provide valuable insights into sustained skill development.

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