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Development of Student Worksheets Based on Engineering Design Process to Enhancing Student's Scientific Literacy in Middle School Students

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Abstract

Scientific literacy is the ability to actively participate in discussions and understanding issues related to science and scientific ideas, serving as a form of participation as an informed citizen. The objective of this research is to examine the validity, practicality, and effectiveness of a student worksheets based on the engineering design process (EDP). The research type and design fall under research and development (R&D) and have been developed using the ADDIE research design through the steps of Analyze, Design, Develop, Implement, and Evaluate. Data collection included validation and student response questionnaires, implementation sheets, and scientific literacy tests to assess validity, practicality, and effectiveness. The validation questionnaire is used to measure validity, the student response questionnaire is used to determine student responses, the implementation sheet is used to assess the feasibility of the learning process, and the science literacy test is used to assess the improvement in students' scientific literacy. The validity analysis yielded a result of 90%, categorizing the EDP-based student worksheets as very valid. The practicality score of 86% demonstrates that the worksheets are highly practical for use in learning environments. Additionally, the effectiveness, measured through an N-gain value of 0.76, indicates a significant improvement in students' scientific literacy. The student response questionnaire results, with an 84% score, reflect a very positive reception from students. These findings collectively confirm that the EDP-based student worksheets are valid, practical, and effective tools for enhancing scientific literacy among junior high school students. These results suggest that EDP-based worksheets can be a valuable tool for fostering scientific literacy among junior high school students, equipping them with the skills to engage in scientific discussions and make informed decisions as active citizens.

Keywords: student worksheets, scientific literacy, engineering design process

INTRODUCTION

Science learning is an educational process that focuses on the exploration and understanding of natural knowledge, covering various phenomena and processes that occur in the surrounding environment, as well as how humans study, manage, and utilize them wisely (Meryastiti et al., 2022). Through science learning, students are not only invited to understand basic concepts but are also given the opportunity to explore the impact of science in everyday life (Wen et al., 2020). This aims to equip them with the ability to face and solve various real challenges in the future (Pratiwi et al., 2019). One of the essential skills that students must have to apply science concepts correctly and appropriately is

scientific literacy, namely the ability to understand and use scientific knowledge in the context of everyday life critically and responsibly (Suparya et al., 2022; Sutiani et al., 2021; Jufrida et al., 2019).

According to Organisation for Economic Co-operation and Development (2019) scientific literacy, it is the ability to participate in discussions and understanding of issues related to science and scientific ideas, as a form of participation as an informed citizen. Students need to have scientific literacy skills in their learning process as a provision to face challenges in the global era (Pratiwi et al., 2019). With the inclusion of scientific literacy in the science learning process, it is expected to develop the necessary skills in students, so that they can later solve problems related to scientific phenomena using rational ideas and concepts.

The Organisation for Economic Co-operation and Development (2019), Indonesia ranked 73rd out of 79 countries in the 2018 Programme for International Student Assessment (PISA) in literacy, mathematics, and science. The country's science literacy score was significantly below the OECD average, highlighting the pressing need for substantial improvements in science education. Despite efforts, Indonesia has consistently ranked low in global science literacy from 2000 to 2018, as reported by PISA. This underscores the ongoing challenges faced by the Indonesian education system and the significant gap in science education compared to other OECD countries (Fuadi et al., 2020).

Providing quality teaching materials is a basic need to support the success of the student learning and teaching process (Izzatunnisa et al., 2019). One of the teaching materials that plays an important role in supporting learning activities is the Student Worksheet. Student Worksheets not only function as learning support but also as a tool designed to encourage students to be active in understanding concepts and applying them. However, many teachers do not fully understand the potential and strategic function of Student Worksheets. They tend to think of Student Worksheets as just a collection of material summaries and practice questions (Aristiadi et al., 2018). The results of the interview showed that although Student Worksheets are still often used in the teaching and learning process in schools, their use is limited to general types of Student Worksheets. This type of Student Worksheet does not support the development of students' science literacy skills because it only contains passive material and practice questions and minimal investigative questions (Ellianawati et al., 2024). As a result, Student Worksheets are less able to stimulate students to think critically, find creative ideas, or formulate concepts independently in solving problems (Bakri et al., 2020). Student Worksheets in schools tend to be used only as homework, so they do not provide optimal contribution in motivating students to actively participate in the learning process in the classroom (Syamsidar et al., 2021). This condition emphasizes the need to develop more innovative and interactive Student Worksheets, which not only present learning materials but are also designed to inspire students in developing their science literacy skills through a more creative and exploratory approach (Kahar et al., 2021; Suryawati et al., 2020).

Teachers can use EDP-based student worksheets in teaching to create new and innovative activities in designing learning methods for students, enabling them to practice their science literacy skills through these activities (Widiyanti et al., 2021). The EDP-based student worksheets are designed to emphasize inquiry and problem-solving by engaging students in the engineering design process, which includes identifying problems, brainstorming solutions, designing prototypes, and evaluating outcomes. This approach contrasts with traditional worksheets that primarily focus on rote practice and passive learning. The use of the EDP approach is a strategy that involves students in solving everyday life problems and gives them the opportunity to systematically explain scientific phenomena (Putra et al., 2023). By applying the EDP approach, students are trained to follow a series of steps that start with defining a problem and end with developing solutions to enhance their knowledge. The relationship between science literacy skills and the Engineering Design Process is not limited to science alone but can also provide benefits in various academic fields. It is evident that quality education is driven by the application of science accompanied by technology and engineering in discovering important ideas for student development (Ramadhani et al., 2020).

Based on the problem description above, an innovation was created to develop teaching materials in the form of EDP-based student worksheets with the hope of improving the quality of learning, boosting students' learning enthusiasm, and enhancing students' scientific literacy skills in the science learning process.

METHODS

This research employs the Research and Development method utilizing the ADDIE development model. It was conducted at Public Junior High School 2 Panti during the first semester of the academic year 2023/2024, with the research trial subjects being 30 students of class VII C. The developed product is an instructional material in Physics subject, specifically a student worksheet based on the Engineering Design Process (EDP) for the first semester of junior high school class VII. The product development involves steps conducted using the ADDIE approach, namely Analyze, Design, Develop, Implement, and Evaluate. These stages are as follows:

1. Analysis, the stage where the researcher conducts needs analysis as the basis for product development. This stage consists of three types of analyses: needs analysis, student characteristic analysis, and curriculum analysis.
2. Design, is a stage where the researcher designs the framework of the student worksheets based on the selection of materials, competencies to be covered, learning strategies, forms, and assessment methods.
3. Development is the stage of creating or actualizing the content that has been previously designed. At this stage, validation steps by relevant validators are necessary to produce a better product.
4. Implementation, is the stage of testing the product applied to the learning process in schools to assess the extent of the influence of student worksheets on teaching and learning activities.
5. Evaluation, researchers evaluate each stage from analysis, design to product development to assess the implementation results, then draw conclusions whether the product requires improvement or already meets the desired criteria.

The data collection techniques employed in this research consist of validation questionnaires, implementation sheets, tests, and student responses. Validation questionnaires were distributed to three validators to assess the validity level of the developed product. Implementation sheets were completed by three observers to determine the implementation of the product during the learning process. There were two tests administered, namely the pretest (before implementing the product) and posttest (after implementing the product), which included science literacy indicators. The purpose of these tests was to measure the extent to which the product could enhance students' science literacy. The final data collection technique was the student response questionnaire, which aimed to assess the effectiveness and students' responses after using the product.

The data obtained from the instruments used will then be processed using formulas according to their needs. To analyze the data from the three validators, the following formulas are used.

$$Expert\ validation\ = \frac{Empirical\ total\ score}{Maksimum\ total\ score}\ \text{x}\ 100\ \% \quad (1)$$

The practicality of the Student Worksheets is measured through observations by three observers via an implementation sheet. The assessment of implementation is measured based on whether or not the core activities using EDP-based student worksheets are implemented in the learning process. The results obtained will then be analyzed using the following formula.

$$Practicality\ = \frac{Total\ score}{Maksimum\ score}\ \text{x}\ 100\ \% \quad (2)$$

The effectiveness of EDP-based student worksheets as teaching materials to enhance scientific literacy is measured using a science literacy test and student response questionnaires. The test scores obtained will then be analyzed using the N-gain test to determine the extent of improvement. The formula used to determine the N-gain value is as follows.

$$< g > = \frac{(S\ post{-}test){-}(S\ pre{-}test)}{S\ max{-}(S\ pre{-}test)} \quad (3)$$

The last instrument is the student response questionnaire which contains three assessment indicators: interest, motivation, and response. The assessment results of these three indicators are then used to measure the effectiveness of the EDP-based student worksheets. The student response questionnaire is analyzed using the following formula.

$$Point = \frac{Total\ score}{Maksimum\ score} \text{ x } 100\ \% \quad (4)$$

RESULTS AND DISCUSSION

Based on the data obtained from needs analysis conducted at Public Junior High School 2 Panti with 30 student respondents, a draft of EDP-based student worksheets containing physics material for grade VII odd semester was prepared. The preparation of EDP-based student worksheets begins by determining the cover that includes the material title, school level target, images related to the material, and the name of the compiler. FIGURE 1 is the cover image of the developed worksheets:

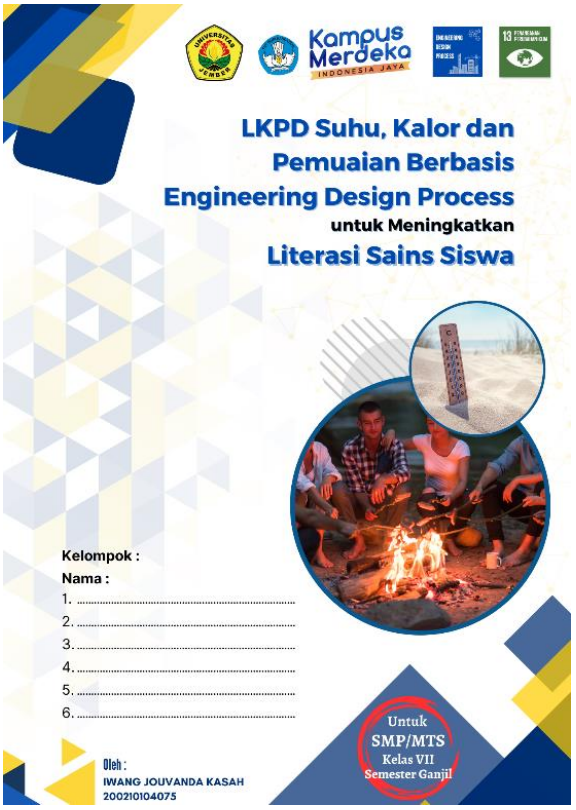

FIGURE 1. Cover Student worksheets

The next step is to create the content of the student worksheets, starting from the usage instructions, learning objectives and goals, as well as exercise questions relevant to the material. The content of the student worksheets is tailored to the indicators of scientific literacy and is also integrated with the engineering design process approach, which consists of several steps: problem, define, learn, plan, try, test, and decide. Examples of the EDP steps can be seen in FIGURE 2 and FIGURE 3.

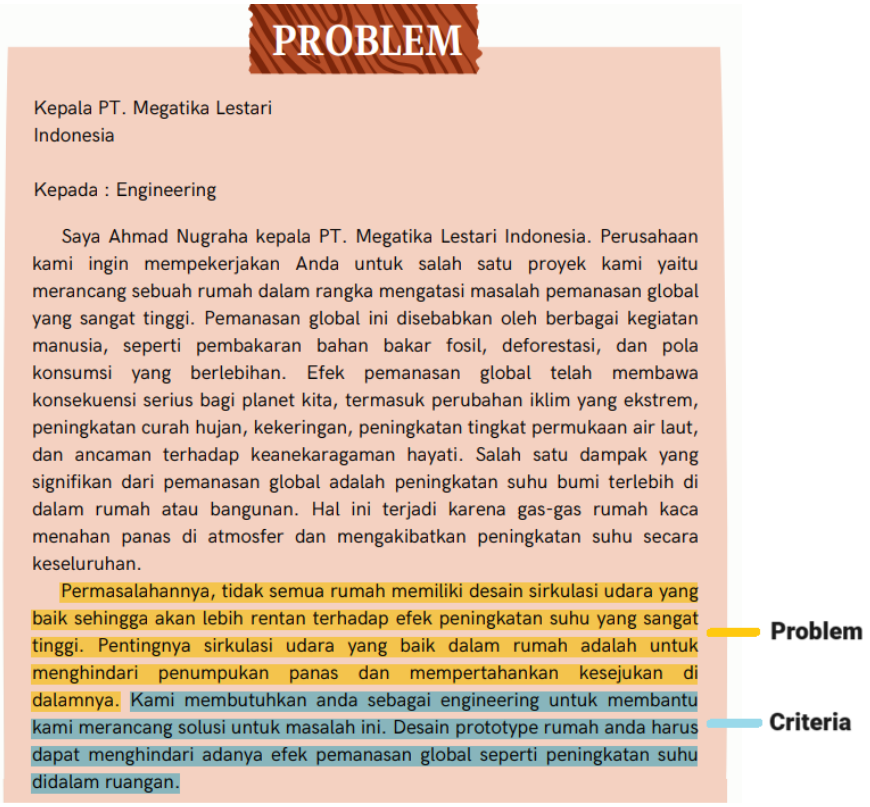

FIGURE 2. Contents of the Student worksheet

FIGURE 3. Examples of student activities

After the process of developing EDP-based worksheets is completed, the next step is to validate the product. Product validation is submitted to three validators consisting of two science teachers and one junior high school science teacher with the aim of assessing the validity and suitability of the developed product as a teaching material. The results of the validation of EDP-based student worksheets can be seen in TABLE 1.

TABLE 1. The results of the validation analysis of EDP-based student worksheets

No.	Aspect of Assessment	Percentage Validator (%)			Percentage (%)	Category
		1	2	3		
1	Graphic Aspect	83	83	100	89	Very Valid
2	Language Aspect	90	90	100	93	Very Valid
3	Content Aspect	90	85	90	88	Very Valid
Average		**88**	**86**	**97**	**90**	**Very Valid**

In the validation stage, there were inputs from all three validators regarding the design of background color, text, and arrangement of material composition. The evaluation, in the form of suggestions from the validators regarding the developed product, serves as a reference for product improvement, ensuring that when implemented, it becomes a usable product that encourages students to learn. The validation assessment results from all three validators yielded a total average score of 90%. Therefore, with these results, the product can be considered valid with minor revisions and can be utilized in teaching activities. A product is deemed valid if it meets the validity criteria of both the construct and content aspects, as well as supports consistent learning and components within the instructional material (Novitasari et al., 2022).

After the completion of product development, the supporting devices and instruments have been validated and declared valid. The next step is to conduct a field trial of the development product, namely the EDP-based student worksheets, to measure its effectiveness and practicality in learning. The development product is tested during six sessions of learning. The practicality analysis of the product is measured through assessment activities conducted during the learning process, as detailed in TABLE 2 according to students' activities based on EDP.

TABLE 2. The results of the practicality analysis of EDP-based student worksheets

No	Assessment Activity	Observer		
		1	2	3
1.	Students understand the worksheet instructions	50	100	100
2.	Students understand the problem section	83	92	83
3.	Students work on the define section	75	100	75
4.	Students work on the learn section (activities 1,2,3,4,5)	90	85	80
5.	Students work on the plan section	100	75	100
6.	Students fill in the completion stage	75	83	100
7.	Students work on the try and test section	75	100	75
8.	Students conduct the experiment	92	75	83
9.	Students work on the decide section	100	100	75
10.	Students present the results of the worksheet	100	75	75
Average		**84**	**88**	**85**
Total Average			**86**	
Category			**Very Practical**	

The implementation of learning in five meetings obtained an average percentage score of 86%. Based on this percentage score, it can be interpreted that learning using EDP-based student worksheets falls into the category of very practical when implemented. However, some activities showed practicality levels below 80%, such as understanding student worksheets instructions, working on defining, working on planning, working on the completion stage, working on trying and testing, conducting practical work, working on deciding, and presenting the results of the work. These activities were less implemented due to the lack of student response and confidence when given instructions to carry out these activities. However, all activities implementing EDP-based student worksheets in each

meeting could proceed well with an overall average score of 86%, categorized as very practical. This is in line with the opinion of Nesri & Kristanto (2020) that EDP-based student worksheets can be considered highly practical if it achieves a learning implementation percentage within the range of 80%-100%. Therefore, with a practicality value of 86% for the EDP-based student worksheets, it can be said that EDP-based student worksheets is highly practical to be implemented and used by students and teachers in learning.

The effectiveness test of scientific literacy was conducted before and after the implementation of the development product. Students filled the question given based on the indicator of scientific literacy. The results of the effectiveness analysis can be seen in TABLE 3.

TABLE 3. The results of the effectiveness test of EDP- based student worksheets

Component	VII C Class		*N-gain <g>*	Category
	Pre-test	***Post-test***		
Number of Student	30	30		
Lowest Value	30	54	0.76	High
Highest Value	72	100		

The effectiveness test results of the Worksheet show that the N-gain value of students after completing the pretest and posttest is 0.76, categorized as high. Based on this data, it can be concluded that the use of EDP-based student worksheets can improve students' scientific literacy in the subject of temperature, heat, and expansion. The effectiveness data for each science literacy indicator can be seen in TABLE 4.

TABLE 4. Results of the analysis of science literacy indicators.

No	Indicator Science Literacy	Average Pre-Test	Average Post-Test	*N-gain*	Category
1.	Applying knowledge in relevant contexts in life	5.18	8.90	0.77	High
2.	Identifying scientific issues	4.18	8.64	0.77	High
3.	Explaining scientific phenomena	3.87	7.60	0.61	Medium
4.	Using scientific evidence	3.13	8.77	0.82	High

The results of the analysis of each science literacy indicator indicate that three out of four indicators are in the high category, namely the indicator of applying knowledge in relevant life contexts at 0.77; identifying scientific issues at 0.77, and using scientific evidence at 0.82. The indicator with the lowest value is the indicator of explaining scientific phenomena with a value of 0.61, categorized as moderate. TABLE 3 shows that the result of the N-gain analysis is 0.76, which according to Hake (1998), an N-gain value of (<g>) $\geq$ 0.70 falls into the high category. Therefore, it can be said that there is an improvement in students' science literacy on the subject of temperature, heat, and expansion using EDP-based student worksheets, with the improvement falling into the high category. The high N-gain value of students is obtained from completing tasks and exercises in EDP-based student worksheets, which integrate science literacy indicators with EDP steps and are tailored to students' learning achievements.

Students will be able to solve a problem systematically through the application of EDP so that it can also affect the improvement of students' literacy, creative and critical abilities (Khamhaengpol et al., 2021; Lin et al., 2021; Syukri et al., 2023). The application of EDP in learning will encourage students to be more active in solving problems because in the EDP approach, students are invited to become engineers who must solve problems with solutions based on scientific facts (Nusyirwan et al., 2021). This is in line with the results of research conducted by Ramadhani et al. (2022) which concluded that the use of Student Worksheets based on the Engineering Design Process (EDP) can improve students' understanding of learning materials. Therefore, it can be concluded that student worksheets are effective to be applied in teaching and learning activities.

In addition to the pretest-posttest effectiveness analysis, the effectiveness was also analyzed based on the students' questionnaire responses regarding the use of worksheets in learning. There are indicators used to create the student response questionnaire, namely the interest indicator with 6

questions, material indicator with 6 questions, and language indicator with 3 questions. The analysis of student responses can be seen in TABLE 5.

TABLE 5. The result of student response analysis

No.	Aspect	Percentage (%)	Category
1.	Interest	84	Very Good
2.	Material	83	Very Good
3.	Language	84	Very Good
Average Student Response		**84**	**Very Good**

TABLE 5 shows the percentage of student responses after using EDP-based student worksheets in learning with a total of 30 students. It can be observed that the student response has an average value of 84% with a category of excellent. Each indicator also has a value with a very high category, namely the interest indicator at 84%, material indicator at 83%, and language indicator at 84%. Dusalan & Sowanto (2023) stated that the student response questionnaire serves as feedback in learning, so if it obtains a high average, the development product used is considered effective. Student Worksheets are effective teaching materials in improving students' cognitive abilities (Indrasari et al., 2022). This is supported by the research of Tukan et al. (2020), who stated that student worksheets is classified as an effective teaching material based on the results of student response questionnaires with a very good category.

CONCLUSION

The EDP-based student worksheets developed has been validated for use as a teaching material in learning. This is based on the validity analysis results of the student worksheets conducted by three validators, with a validity value of 90% categorized as highly valid. The practicality analysis resulted in an average of 86%, categorized as highly practical. The effectiveness of EDP-based student worksheets has an N-gain value of 0.76, categorized as high. Students' responses to the use of EDP-based student worksheets in learning received very positive responses with a percentage of 84%. These results underscore the value of EDP-based worksheets in promoting active learning and enhancing scientific literacy in junior high school settings, offering a promising approach for broader application in science education.

Based on the research findings, the researcher provides the following recommendations: (1) Further studies should explore the implementation of the EDP approach with different subject materials to assess its broader applicability; and (2) Greater attention should be given to students' comprehension and acceptance during the learning process to ensure effective engagement and learning outcomes.

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