An Innovative STEM-Based Worksheet to Enhance Scientific Literacy at Senior High School

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Abstract. The students are willing to engage in science, they are required to have scientific literacy. However, Indonesian students still score far behind other countries. So this study aims to improve students' scientific literacy skills by applying STEM-based student worksheets in Physics learning. The sample consists of 23 students at senior high school. The sample was determined through a purposive sampling technique. The quantitative was applied as a research approach. The type of research was quasi-experimental using a one-group pretest-posttest design. The research instrument is a scientific literacy test with the validated subjects. Student literacy scores on pre-test and post-test after the STEM-based worksheet were 33.7 and 78.89. This approach succeeds in enhancing each of the scientific literacy indicators with a score of 0.40 for indicators explaining scientific phenomena, 0.37 for the indicator evaluating and designing scientific research, and 0.32 for indicators interpreting data and scientific evidence with the medium category as well. The results showed an improvement in students' scientific literacy skills after the application of STEM-based student worksheets achieved an N-gain score of 0.70 with a high category. These findings have implications for educators to increase student involvement in learning activities with the STEM approach.

Keywords:STEM-based learning, Science literacy, Students' worksheet.

1 Introduction

Innovation in education continues to improve the quality of learning. The quality of learning is valued well when learning is effective. Effectiveness of learning refers to the usefulness, performance, and ability of an activity to complete a task according to a specific purpose and a good result[1]. According to [2] it is essential for students to have the knowledge of science as a supply to face the challenges of the 21st century. Because scientific knowledge can build a new generation that has strong scientific thinking and attitude that can effectively disseminate research and scientific findings to the general public.

Based on PISA 2018 data, the literacy rate of Indonesian students in science is lower than the average of the Organization for Economic Cooperation and Development (OECD) countries [3]. In 2019, Indonesia ranked 70th out of 78

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countries in the PISA scientific literacy rating, which is held every three years by OECD [3]. Furthermore, the results show that Indonesian students' literacy is limited to remembering and recognizing simple facts, but they are unable to communicate and narrate scientific material or apply complex and abstract concepts in everyday life.

PISA 2018 also argues that a person who has scientific literacy is one who is willing to engage in science and technology that is required to have the first three competencies namely the ability to explain scientific phenomena by recognizing, offering, and evaluating explanations to share natural phenomenon and technology, both the competencies of evaluation and designing scientific research that is to describe and evaluate scientific research and offer ways to deal with scientific questions, as well as the third is to interpret scientific data and evidence by analyzing and evaluating data, claims and arguments can be a variety of repetitions and draw scientific conclusions accurately [4].In other words, those who have good scientific literacy ability can have the ability to understand and analyze scientific and technological phenomena, evaluate and guide scientific research, interpret and summarize data, and maintain a solid foundation in scientific knowledge.

All competences necessitate knowledge, much as indicators that explain technical and scientific events require understanding of scientific content, or content knowledge. Beyond content knowledge, the second and third competencies call for procedural knowledge that forms the basis of a range of approaches and practices to develop scientific knowledge as well as epistemic knowledge, or an awareness of the general practical motivations behind scientific research, the veracity of the claims made, and the definitions of terms like theory, hypothesis, and data. [4].

Related to [5] mentions the learning strategy in the 21st century, science learning became a more student-centered approach. Thus it can be done by learning through scientific literacy training. Academic success is demonstrated when students understand what they are learning and have the ability to apply and solve various problems that arise in everyday life, so learning scientific literacy is important for students to understand expansion. Scientific literacy can be used as a reference for the evolution of science learning because scientific literacy was well evaluated in developing science learning methods in the 21st century. Moreover, scientific literacy is also an important aspect to be mastered by students because it influences the learning process of science in schools [6].

Enhancement of students' scientific literacy skills has been done previously with a variety of learning approaches and models. One approach that can enhance scientific literacy is the STEM approach [7]. [8] mentions one way to improve science literature is student-centric active learning through the application of the STEM approach. The approach requires students to simultaneously have the knowledge and skills to solve a problem and train students to apply their knowledge as a solution to environmental problems using technology. This is in line with the results of a study conducted by [7] that concluded blended learning with a STEM approach can improve scientific literacy with a very high category of 86.53%.

The integration of science, technology, engineering, and mathematics into the STEM approach improves students' scientific literacy. At every step of science, learning encourages students to think critically and find solutions, so that they not only understand science concepts but can also use their knowledge to solve problems [9]. [10] also stated that learning with a STEM approach can improve student literacy and understanding of concepts as this approach contains learning steps that accommodate literacy skills during the learning process. Teachers also help students gather information to solve problems. STEM education is an educational method that

integrates science, technology, engineering, and mathematics with an emphasis on problem-solving in both real-world and professional contexts. [11].

In the learning process, STEM can be used as a stage or step in the students' worksheet that can be applied to improve the various abilities, skills, and understanding of students. This is in line with the results of previous research that students with the STEM approach are effective in improving the self-efficiency of pupils [12], the skills of the science process, the scientific attitude of students [13], and critical thinking skills [14]. In accordance with those facts, the researchers are interested in implementing a STEM-based students' worksheet to improve scientific literacy.

2 Method

This study used quantitative research techniques with quasi-experimental research, and it had a pre-experimental design with a single group pretest–posttest. The study was conducted in a Banda Aceh senior high school. Twenty-three seniors from Banda Aceh's senior high school make up the study's sample. A test of scientific literacy is the research tool. Two stages comprise the test data collection technique: the pre-test is used to determine the science literacy skills prior to receiving treatment, and the post-test is used to determine the science literacy skills improvement following treatment using the students' worksheet and a STEM-based approach.

The implementation of a STEM-based worksheet is implemented in five stages. The first step is defining the problem. At this stage, students are given the opportunity to read the worksheet and determine what problems are discussed in the given discourse. They are also given the chance to discuss the issues discussed with group friends. The second is gathering information. In this phase, students are required to gather information on how to complete a given project based on the discourse of the problem initiated. Besides, the students are also allowed to ask and use any media to collect information, such as books and the internet. The third is generating the solution, at this stage the students start discussing how to complete the project, namely designing the solar charger product, defining the tools and materials, and determining the steps of work in the creation of the project. The fourth is implementing the best solution. At this stage, students start working on the project tasks according to the planning they have made before with the members of the group. Participants can ask their teachers about their problems while working on the project and write down the problems experienced in the columns provided in the worksheet. The five is evaluating the solution and reflecting at the final stage each group presents the results of the product already made in front of the classroom. Students also discussed the pros and cons of completing assigned project tasks, and other members of the group also responded to teachers by providing input for assigned projects.

Analysis of students' scientific literacy is measured by looking at the N-gain or normalized gain calculated as presented at Table 1.

Table 1. Gain index category

Gain Score	Category
$g \geq 0{,}70$	High
$0{,}30 \leq g < 0{,}70$	Medium
$g < 0{,}30$	Low

3 Results and Discussion

STEM approaches applied through STEM-based worksheets can improve students' literacy, creativity, and activity, in accordance with [8] which states that one way to improve scientific literacy is student-centered active learning that is through the application of the STEM approach. This learning requires students to simultaneously have knowledge and skills to solve a problem and train students to apply their knowledge as a solution to environmental problems using technology. So students have new science by solving problems scientifically related to everyday life.

This is also in line with research by [16] that suggests that STEM-based students' worksheets provide interesting and relevant activities for students. This can be done by using real-world contexts, case studies, experiments, or projects that interest students. Thus, the development of STEM-based worksheets can help students develop the skills and abilities needed in today's digital age, such as critical, creative, and collaborative thinking skills, as well as skills in science, technology, and mathematics.

The STEM measures available in the worksheet have the potential to improve the student's literacy of science. This step is able to improve the problem-solving skills of students because they are required to be able to identify problems in everyday life in a discourse related to scientific phenomena on alternative energy matter. This step is potentially improving students' scientific literacy on indicators explaining scientific phenomena. This is in line with [17] which states that the application of learning based on an integrated STEM project makes students more skilled in identifying as well as explaining the phenomena scientifically of the problem presented.

Next to the second STEM step is to gather information related to the problem. At this stage, students are required to find as much information as they can from various sources in order to be able to add information to complete the product to be made. Besides, students' understanding of the physical concepts of renewable energy is also increasing so that students can create creative and innovative products according to the given problem. The research [17] mentioned that there is an improvement in the indicator interpreting data and scientific evidence occurs because students have been trained during the learning process in how to find information and conduct research. [10] also stated that student scientific literacy can be enhanced with STEM-based learning as this approach contains learning steps that help students in gathering information to solve a problem.

The third STEM step is to produce a scientific solution. At this stage, students are required to design products that can be applied in scientific life, determine tools and materials as well as steps of manufacture of products according to previously collected information. The students' scientific literacy can be enhanced by following this step on indicators to evaluate and design scientific research. This is in line with [18] statement that STEM is potentially effective in enhancing students' creativity and scientific collaboration in designing a product.

STEM's fourth step is to implement the best solution. In this phase, students are required to create products according to the design and other requirements that have

been specified in advance. In addition, the students are also instructed to write down the constraints during the manufacture of the product so that students can evaluate the product after testing in groups and can produce the best product. During this stage, there is an opportunity to enhance the competence of scientific literacy by refining the indicators used for the evaluation and design of scientific research. According to [19] that stated that STEM can support students in communicating the results of solutions, sketches, and plans of manufacture according to the concepts of the material that have been established.

The last step of STEM is evaluation and reflection. At this stage, students are able to present a product that has been made after testing so that students can explain the product that was made, from preparation, and creation to completion of the product. Besides, at this stage other groups along with teachers give input about the products that have been made, and then students get the results of the input in the form of reports. In this phase, there exists the potential to enhance scientific literacy skills on indicators to evaluate and design scientific research. This is in line with the results of a study by [9] which states that at every step of learning STEM encourages students to find solutions, so that they not only understand science concepts but can also use their knowledge to solve problems.

In this study, the improvement of scientific literacy capabilities of 23 pupils at senior high school was determined from achieving N-gain scores by applying a STEM-based worksheet. According to the pretest and posttest data, the result showed an improvement of students' scientific literacy competency. The N-Gain score analysis of 0.70 shows that the student's scientific literacy is increased in the highest category. This is demonstrated by the results of the study that the average student post-test scores are higher in comparison to the students' pre-test scores. To see the improvement in science literature of the student using the N-gain test, compare the pretest and posttest scores that were presented in Table 2.

Table 2. Data on students' scientific literacy skills

Test Type	N	Min	Max	$\bar{x}$
Pre Test	23	12,5	50	33,7
Post Test	23	37,5	100	79,89
N-gain				0,70
N-gain %				70%

Based on the data in table 2, the average value of the pretest was 33.7. After receiving STEM-based learning treatment, there was a 70% improvement in scientific literacy with an average post-test score of 79.89 and was in the high improvement category. The results of this study are in line with [20] who obtained an N-gain score of 0.68 with a medium category, this is due to the STEM influence in learning so it can improve scientific literacy.In addition, N-gain score of each indicator of scientific literacy based on the results of pretest and posttest students was presented at Fig. 1

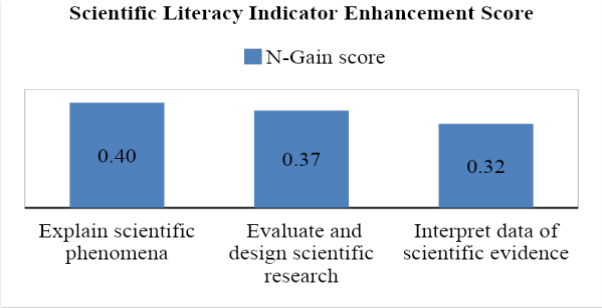

Fig. 1. N-gain score for each scientific literacy indicator

On the basis of Fig. 1, the N-gain increase score is obtained for the indicator explaining scientific phenomena by 0.40 with a medium category, for the indicator evaluating and designing scientific research the N -gain score of 0.37 with the medium category, and for indicators interpreting data and evidence obtaining the scientific score of N - gain by 0.32 with the average category. Then it can be concluded that the indicators describing science phenomena obtain the highest N - gain score of 0,40 after applying the STEM-based students' worksheet, whereas the lowest value of the result N - gain is an indicator interpreting the data of scientific evidence of literacy of science with a scale of 0.32.

The highest-increased scientific literacy indicator describes a scientific phenomenon with an N-gain score of 0.40 and belongs to a moderate category. It shows that after using the worksheet, students are able to solve issues related to explaining scientific phenomena on alternative energy materials. In addition, students are also able to identify the problem given by searching for additional information from various available sources. As a result, it can be applied in everyday life. This is in line with the results of the [17] study which also obtained the result of the percentage increase in N-gain on the indicator explaining scientific phenomena with a moderate category of 36%. It shows students seeking solutions and answers to existing problems, as well as re-reading the lesson material while learning or independently.

The lowest improvement in scientific literacy indicators is the interpretation of scientific evidence data of science literature with a score of 0.32. This is due to the lack of students' ability to mention data related to scientific phenomena as well as students' lack of ability to complete the test of scientific literacy because they are not accustomed to learning that trains the ability to literate science. This is in line with [17] who argue that the low increase in scientific literacy is due to the less trained students in developing science literature skills during the process of learning activities.

4 Conclusion

The findings suggest that the implementation of STEM-based student worksheets involves five stages in the worksheet resolution process: problem definition, information collection, solution generation, best solution implementation, solution evaluation, and reflection. The STEM phases on the worksheet serve as a practical step in the production process for alternative energy materials products. Every STEM level is designed to help students develop their scientific literacy in their physics classes.

Students' scientific literacy can be enhanced by doing STEM-based worksheets, with an average N-gain score of 0.70 in high categories. This demonstrates how raising pupils' scientific literacy can benefit from the STEM approach. Additionally, using STEM-based worksheets can improve students' scientific literacy as indicated by three different metrics. The three indicators that belong into the middle group are measured indicators, which include describing scientific phenomena, assessing and planning scientific research, and scientifically analyzing evidence data. The findings suggested that teachers use STEM-based worksheets to improve their pupils' scientific literacy. It is strongly advised that students engage in engaging learning activities through the use of the STEM method and student-centered learning.

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