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Framework of Problem-Based Learning Activities with STEM Approach: Utilizing Plastic Waste with Ecobrick Method in Improving Students' Ecological Literacy to Solve Environmental Problems

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ABSTRACT: Plastic is a difficult chemical to degrade or decompose naturally, taking hundreds or even thousands of years for nature to break down plastic. However, the reality is that plastic is widely used in various human needs, from food packaging materials to automotive materials. One way to overcome plastic waste is through eco-brick or utilizing waste with plastic bottle media. Ecobrick is one creative effort to manage plastic waste into useful objects and reduce pollution and toxins caused by plastic waste. Teaching about eco-brick issues can be used as teaching material to improve students' ecological literacy. Ecological literacy is a state in which individuals have good knowledge and attitudes about the environment and are capable of taking actions that positively impact the environment. However, the ecological literacy of students could be a lot higher. One of the reasons for this is that the teaching methods used so far have yet to bring out their ecological capabilities. Therefore, this study will apply problem-based learning (PBL) with a STEM approach. PBL is a learning approach involving a specific syntax combining STEM disciplines of Science, Technology, Engineering, and Mathematics. This approach can improve students' ecological literacy in solving environmental problems.

KEYWORDS: Environmental Problems, Ecobrick, Learning Activities, PBL-STEM, Plastic Waste, Students' Ecological Literacy.

INTRODUCTION

Waste is a part of something that is not used, not liked, or must be disposed of, which generally comes from human activities. Human activities that pollute the environment by disposing of waste indiscriminately can reduce environmental cleanliness (Azwar (1979)). Waste management is a problem that this nation has yet to solve. According to the Director-General of Waste, Hazardous Waste, and B3 (Hazardous and Toxic Materials) Management from the Ministry of Environment and Forestry, Tuti Hendrawati Mintarsih, the total amount of waste in Indonesia in 2019 will reach 68 million tons. Plastic waste is estimated to reach 9.52 million tons, or 14 percent of the total waste. Based on data from Jenna Jambeck (2018), a waste researcher from the University of Georgia, Indonesia is ranked second in the world as a producer of plastic waste, reaching 187.2 million tons, after China, which reaches 262.9 million tons. Moreover, plastic waste in Indonesia has become the primary source of waste weight accumulation, mainly since plastic decomposes in about 1 millennium or around 1000 years.

Plastic is a chemical material that is difficult to degrade or decompose by nature, requiring hundreds or even thousands of years for nature to break it down. However, plastic is widely used in various human life needs, ranging from food packaging to automotive materials. Plastic is made from petrochemical substances. These chemical substances are not suitable for returning to the ecology around us. Scientific research shows that these chemical substances are toxic to humans. Scattered, burned, or disposed of plastic decomposes into toxic chemicals. Over time, these chemicals dissolve into soil, water, and air, which plants and animals absorb. Ultimately, these substances can cause congenital disabilities, hormonal imbalances, and cancer (Pavani & Rajeswari, 2014).

Plastic waste is the most commonly disposed of waste by humans because many people use plastic for their daily needs. The disposal of plastic waste into water and soil is also rampant, further exacerbating environmental damage because plastic waste is made of inorganic materials. If plastic waste is carried into rivers or oceans, it will cause damage to the ecosystem in the area. One way to tackle plastic waste is through the eco-brick method or using waste with plastic bottles as the medium. Ecobrick comes from eco and brick, an environmentally friendly alternative to conventional bricks in building construction. Therefore, eco-bricks are plastic bottles that are densely filled with non-biodegradable waste, namely plastic (Ecobricks.org, 2015).

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Ecobrick is one creative effort to manage plastic waste into valuable items, reducing the pollution and toxins caused by plastic waste. The technique is simple and easy to implement; hence it can quickly spread through social networks (communities, villages, and schools). Eco-brick aims to reduce plastic waste and recycle it using plastic bottles as a medium to create something useful. A shift towards a student-centered learning paradigm is one way to improve the quality of education. This paradigm can be implemented in problem-based learning, where students are placed as the subject of learning. Such an education system can foster enjoyable and comfortable learning experiences for students.

Lestari and Yudhanegara (2015) stated that problem-based learning (PBL) presents students with real problems to develop their own knowledge, inquiry, and high-level skills, become independent, and increase their knowledge, inquiry, and high-level skills self-confidence. The real problem that society is currently facing is related to plastic waste. Therefore, educators must be able to increase students' ecological literacy in solving environmental problems through learning. Educators use problem-based learning with a STEM approach for utilizing plastic waste with the eco-brick method to increase students' ecological literacy in solving environmental problems. STEM education is learning between two or more STEM components, one STEM component, and other disciplines. According to Tan (2003), problem-based learning (PBL) is an innovation in learning because, in PBL, students' thinking abilities are truly optimized through systematic group or teamwork so that students can empower, hone, test, and develop their thinking abilities continuously (Rusman, 2018).

Research conducted by the Hannover Research Institute (2011) shows that the primary goal of STEM Education is an effort to demonstrate holistic knowledge between STEM subjects. Integration in the STEM learning system can be successful if all aspects of STEM are present in every learning process for each subject (Nida'ul Khairiyah, 2019). STEM (Science, Technology, Engineering, and Mathematics) is an essential issue in education today (Becker & Park, 2011; Kuenzi, 2008). STEM education integrates science, technology, engineering, and mathematics learning and is recommended to help students develop the 21st-century skills needed for success (Beers, 2011). STEM can be developed by linking it to the environment, creating a learning experience that brings real-world situations into the classroom (Subramaniam et al., 2012). This means that through the STEM approach, students are not just memorizing concepts but understanding and applying scientific concepts to everyday life. Combining problem-based learning with STEM elements can be highly beneficial in preparing students to face challenges, especially regarding environmental issues.

Goldman (2009) and Ibrahim (2016) state that the increasing environmental damage is caused by the lack of ecological intelligence possessed by individuals in a particular area, leading to a lack of sensitivity to signs of environmental damage (Gardner, 2006: Gould 7 Hosey, 2006). Therefore, ecological education is needed to reflect critically on this situation. If education is conducted using the transfer of knowledge process, it will only result in students having knowledge about the environment but needing more awareness and concern for it (Muhaimin, 2015). Parwati's research shows that STEM learning can develop creativity and ecological literacy, which are essential for facing the challenges of the 21st century (Parwati, 2015). PBL-STEM learning is an approach that integrates the Problem-Based Learning model with the STEM approach (Afriana et al., 2016). STEM disciplines are closely related to each other. Science requires mathematics as a tool for data processing, while technology is the application of science itself (Torlakson, 2014). Learning science also requires an engineering design process, which is knowing how to operate or design a procedure to solve a problem.

Implementing problem-based learning with a STEM approach can encourage students to utilize their environment as a source of learning. Real environmental problems can directly increase the development of ecological literacy among students. Ecological literacy is a state where individuals have good knowledge and attitudes about the environment and can take positive actions for the environment. Individuals with ecological literacy know that the environment must be preserved and cared for because it functions as a place of residence, a food source, and a place to develop life (Wahid, 2016). Students can develop ecological awareness from the problems they face in their daily lives. By combining problem-based learning with the STEM approach, in this paper, we will learn the framework of problem-based learning activities with the STEM approach: utilizing plastic waste with the eco-brick method to increase students' ecological literacy in solving environmental problems.

The main objectives of this study are: (1) to describe the problem-based learning activities with the STEM approach in utilizing plastic waste with the eco-brick method to increase students' ecological literacy in solving environmental problems, (2) to describe the framework of its development, (3) to describe the process of problem-based learning with STEM approach in increasing students'

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ecological literacy in solving environmental problems, (4) to explain how problem-based learning can increase students' ecological literacy in solving environmental problems.

METHOD

This study's research type is the Research and Development (R&D) method. According to Borg & Gall (1983), as cited in Wisata, Basuki et al. (2019), R&D is a process to develop or validate products used in education and learning. R&D is a research method used to produce a specific product and test its effectiveness of the product. The research design in this study follows the steps of research and development according to Borg and Gall (1983), which include (1) needs analysis (research and information collecting), (2) planning, (3) developing preliminary product/prototype, (4) preliminary field testing, (5) primary product revision, (6) main field test, (7) operational product revision, (8) operational field testing, (9) final product revision, and (10) dissemination and implementation. This aligns with Astutik & Praharani's (2018) opinion that development research is used for product development and effectiveness. The study was conducted at SDN Wates 2, Magersari sub-district, Mojokerto City. The subjects in this study were 28 fifth-grade students in class 5A.

RESULTS

A. Learning Syntax of Problem-Based Learning with STEM Approach

The framework of the problem-based learning model integrated with the STEM approach aims to explore how the problem-based learning model integrated with STEM (Science, Technology, Engineering, and Mathematics) approach can enhance students' ecological literacy in solving environmental problems. The framework of this research is developed based on the syntax in (Masluchah et al, 2022). Understanding the issues arising from open problems is the first step in the framework. Then, problem-solving strategies are developed by collecting information from literature and library reviews. The following is the presented problem regarding using eco-brick materials in making bookshelves.

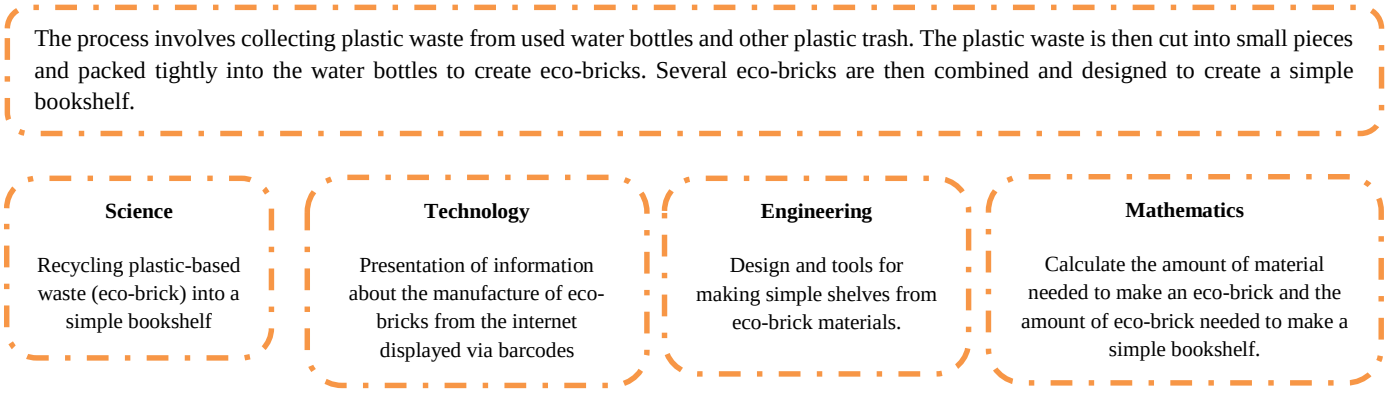

Fig. 1. The STEM problem is making a simple bookshelf from eco-bricks.

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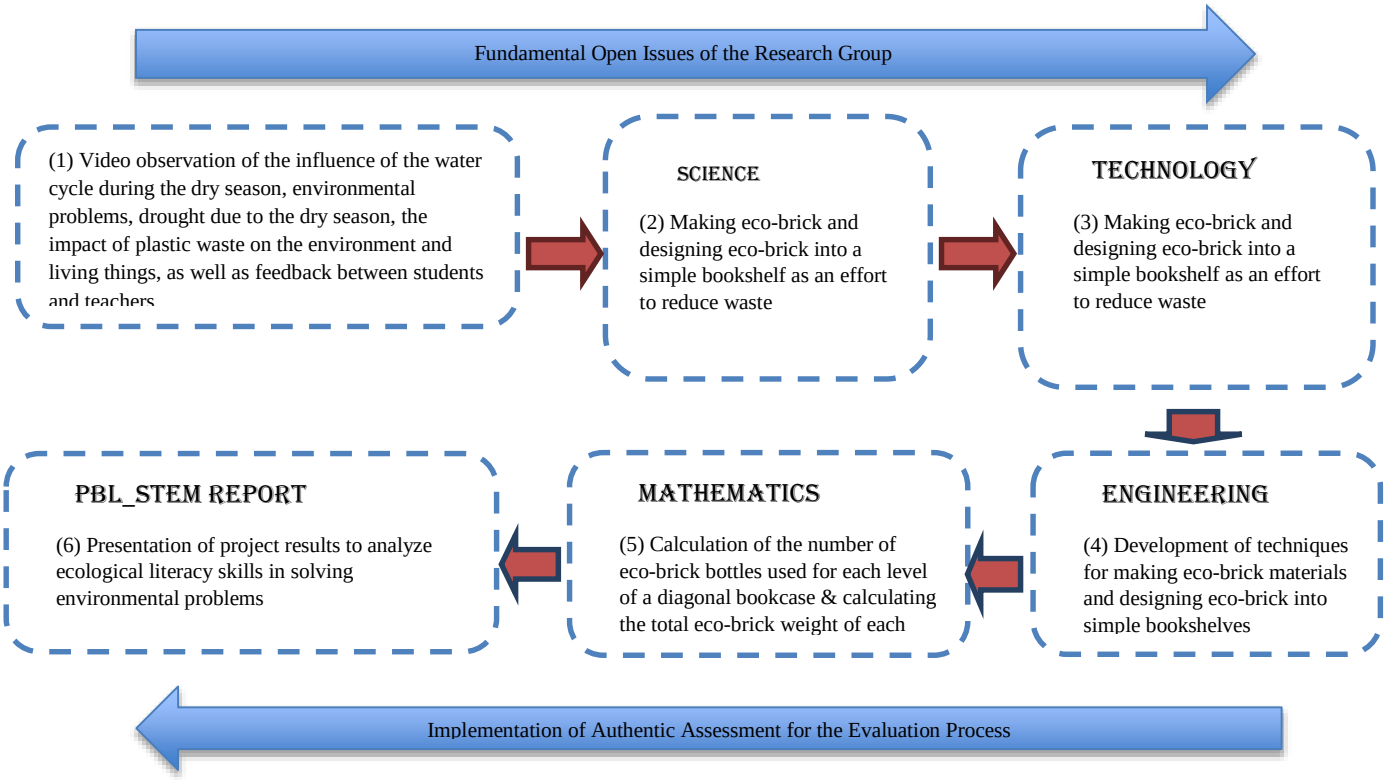

Fig. 2. The PBL-STEM framework utilizes eco-bricks to make simple bookshelves

The problem-based learning framework integrated with STEM in this research comprises several steps. The first step is observing videos about the influence of the water cycle during the dry season, environmental issues, drought caused by the dry season, the impact of plastic waste on the environment and living creatures, and feedback between students and teachers. The second step is making eco-bricks and designing them into a simple bookshelf to reduce waste. The next step is confirming students' needs in the research process through classroom learning. The fourth step is implementing eco-bricks designed into a simple bookshelf. The fifth step is testing the research product. The final step is the problem-based learning report, which includes reporting the research results and the students' ecological literacy in solving environmental problems. More systematically, the framework for integrating problem-based learning with the STEM approach is presented in Figure 2.

Achievements and Learning Objectives of PBL-STEM

The expected learning outcome is for students to be able to solve the problem of utilizing eco-brick material in designing a simple bookshelf. The purpose of problem-based learning with a STEM approach is to develop knowledge and skills in various disciplines in the fields of science, technology, engineering, and mathematics, including:

a. In the science aspect, students are expected to:
- Utilizing inorganic waste into useful objects
- Recycling plastic waste into environmentally friendly eco-brick materials
- Making and designing eco-brick materials into a simple bookshelf

b. On the technological aspect, students are expected to:
- Utilizing the internet network and browsing materials from various sources
- Studying videos about making eco-bricks
- Using barcodes as a source of technical information for making eco-bricks.

c. On the technical aspect (engineering), students are expected to:
- Applying eco-brick material to design a simple bookshelf model according to the available eco-brick material
- Testing the ability of the simple bookshelf when given a load.

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d. In terms of mathematics, students are expected to:

- Weigh the materials used in making eco brick.
- Calculate the number of eco-brick bottles needed in each branch of the bookshelf required in the simple bookshelf.
- Calculate the cost used in making eco brick
- Calculate the amount of material needed to make eco brick
- Compare the costs required by each group in making eco brick.

Elements of utilizing plastic waste with the eco-brick method

a. Aspects of science (science) in the problem

The problem of plastic waste is never-ending. Plastic waste is the primary source of waste accumulation in Indonesia, especially since plastic is a waste that is difficult to decompose within 1000 years. Disposing of plastic by burning it also causes other problems, such as air pollution.

Seeing the severity of the plastic waste problem, Ecobrick is a method to minimize plastic waste by filling plastic bottles with clean inorganic waste until the bottle is entirely complete and compact. Eco-brick aims to reduce and recycle plastic waste using plastic bottles as a helpful medium.

(a) (b) (c) (d)

Fig. 3. (a) Ecobricks, (b) (c) Simple Bookshelf Model from Ecobrick, (d) The Process of Implementing Ecobrick int the Bookshelf tiers are simple

b. Technoloy aspects (technology) in the problem

Processing waste at school is a challenge in itself for school communities. Therefore, simple and appropriate technologies are needed to process waste. For example, they are implementing incinerators, recycling, and composting technologies. One technology that is easy for students to do is recycling. Recycle or reuse used items such as plastic bottles, food cans, paper, and cardboard. Ecobrick is part of recycling plastic bottles tightly filled with non-biological waste. With internet technology facilities, students can search for information about making eco-bricks. Here are some sources of information that are used:

https://www.youtube.com/watch?v=2EGeIRY739Q
https://www.youtube.com/watch?v=dliJHzmDQo8
https://www.youtube.com/watch?v=9jYR_tG5JM0
https://www.youtube.com/watch?v=lAbu0znJ1W8

The sources of barcode information used as literacy sources are:

Fig. 4. Barcodes containing references to making eco-bricks

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c. Technical aspects (engineering) in the problem

A technique is needed to quickly and tightly pack plastic waste into bottles to create eco-bricks. Therefore, it is necessary to calculate the weight of the plastic waste inside the eco brick. If the bottle is not tightly filled with plastic waste, it will result in an unbalanced and unsightly bookshelf. In designing a simple bookshelf, applying good, comfortable, and safe eco-bricks is necessary according to the formed pattern.

Fig. 5. The process of making eco-bricks.

d. Aspects of mathematics (mathematics) in the problem

The mathematical aspects in this research include a) Weighing the materials used in making eco-bricks, b) Calculating the number of eco-brick bottles needed in each branch of the simple bookshelf, c) Calculating the cost of making eco-bricks, d) Calculating the amount of material needed to make eco-bricks, e) Comparing the costs required by each group in making eco-bricks.

Fig. 6. Weighing the weight of the eco brick

Fig. 6. The process of assembling eco-brick into a bookshelf is simple.

Problem-Based Learning Framework with STEM Approach: Utilizing Plastic Waste with Ecobrick Method in Enhancing Students' Ecological Literacy in Solving Environmental Problems

In this section, we will discuss the stages of the Problem-Based Learning model with the STEM approach in detail; five steps will describe the Problem-Based Learning model with the STEM approach on utilizing plastic waste with the eco-brick method in enhancing students' ecological literacy in solving environmental problems.

1. The first syntax is student orientation to the problem (STEM analysis: Science). Further details will be explained in Table 1. A more detailed explanation of stage 1 can be seen in Table 1.

Table 1. PBL-STEM Learning Activities in Syntax 1.

Syntax 1	Learning activities
Student Orientation to the Problem (STEM Analysis: Science)	a. Students, along with their teacher, observe a video about the influence of the water cycle during the dry seasonhttps://www.youtube.com/watch?v=2EGeIRY739Q
	b. Students and teachers provide feedback regarding the observed video.

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	c. Students, with guidance from the teacher, analyze and understand the influence of the water cycle on living creatures.
	d. Students, along with their teacher, conduct observations in the school environment.
	e. After the observation, students are asked to mention the influence of the water cycle on living creatures and environmental problems in the school environment.
	f. Students, along with their teacher, watch a video about environmental problems g. https://www.youtube.com/watch?v=dliJHzmDQo8
	h. Students and teachers provide feedback regarding the observed video (students mention seven environmental problems)
	i. Students and their teacher observe a video about drought caused by the dry season. j. https://www.youtube.com/watch?v=9jYR_tG5JM0
	k. Students and their teacher observe a video about drought caused by the dry season. l. https://www.youtube.com/watch?v=9jYR_tG5JM0
	m. Students read Theme 8 book about the influence of the water cycle on living creatures

2. The second syntax is organizing students in learning (STEM analysis: Science). Further details about stage 2 can be seen in Table 2.

Table 2. PBL-STEM Learning Activities in Syntax 2

Syntax 2	Learning Activities
Organizing Students in Learning (STEM Analysis: Science)	a. Students work on worksheets provided by the teacher in groups.
	b. In groups, students observe pictures of drought (Critical Thinking)
	c. The students discuss in groups about: 1. What they see in the picture 2. The consequences of the prolonged dry season 3. Factors that affect the decrease in groundwater availability 4. Activities that can be done to ensure groundwater availability 5. Environmental problems in Indonesia. (Problem-solving)
	d. The students present the results of their group discussion in front of the class.
	e. Students from other groups give feedback on the group's presentation in front of the class
	f. Students observe a video about the impact of plastic waste on the environment and living creatures https://www.youtube.com/watch?v=lAbu0znJ1W8
	g. Students and teacher provide feedback on the observed video (students are able to mention efforts to reduce plastic waste)

(a) (b)

Fig. 7. (a) Students working on LKPD (student worksheets), (b) Students watching a video

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3. The third syntax is guiding independent or group investigations of students (STEM Analysis: Technology)
   A more detailed explanation regarding stage 1 can be found in Table 3.

Table 3. The PBL-STEM learning activities in syntax 3

Syntax 3	Learning Activities
Guiding students' independent and group investigations (STEM Analysis: Technology)	Students use their mobile phones to scan a barcode to search for references on making eco-bricks to preserve the soil. (Digital literacy, problem solving)
	Students discuss preparing the tools and materials for making eco-bricks according to the barcode references provided by the teacher. (Communication, Critical Thinking, Collaboration)

Fig. 8. Students scanning the barcode

4. The fourth syntax is Developing and Presenting the Works (STEM Analysis: Engineering) is "A more detailed explanation of stage 1 can be found in Table 4.

Table 4. The PBL-STEM learning activities in syntax 4.

Syntax 4	Learning Activities
Developing and presenting the works (STEM Analysis: Engineering)	Students work together in groups to create eco-brick works. (Problem-solving)
	Students present the method of making eco-bricks. (Integrity, Problem-Solving)

5. The fifth syntax is to analyze and evaluate problem-solving processes (STEM Analysis: Mathematics)
   A more detailed explanation regarding stage 1 can be seen in Table 5.

Table 5. The PBL-STEM learning activities in syntax 5

Syntax 5	Learning Activities
The analysis and evaluation of problem-solving processes (STEM Analysis: Mathematics) in student worksheets (LKPD)	Students work in groups to weigh the materials used in making eco-bricks (Critical Thinking, Collaboration)
	Each group calculates the number of eco-bricks needed for each level of the shelf (Critical Thinking, Collaboration)
	Students work in groups to calculate the weight of eco-bricks for each level of the shelf (Critical Thinking, Collaboration)
	Each group calculates the total number of eco-bricks needed to make a simple bookshelf (number of bottles and their weight) (Communication, Collaboration)
	Each group calculates the total number of eco-bricks needed to make a simple bookshelf (number of bottles and their weight) (Communication, Collaboration)
	Students complete an evaluation test on the impact of the water cycle on living creatures and environmental issues.

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Fig. 10. Students are working on PBL-STEM worksheets and calculating the number of eco-bricks in each level of the bookshelf.

The framework of assessment instruments for students' ecological literacy abilities

Table 6. The framework of assessment instruments for sudents' ecological abilities

No	The components of ecological literacy	Indicator	Strategy
1.	Implications	● We have a respectful attitude towards the environment, value the environment, and take responsibility for environmental issues. ● They actively participate and have the confidence to contribute to improving and maintaining the environment.	● It creates rules that can cultivate an environmentally conscious character, such as prohibiting students from littering. ● Involving students in activities to clean up the school environment.
2.	Ecological knowledge	● The ability to apply ecological concepts, particularly concepts related to individuals, ecosystems, populations, and natural cycles	● Providing various learning resources on ecology. ● Implementing student-centred learning approaches by the topic
3.	Social and political knowledge	● Understanding that economic, social, political, and ecological activities are interdependent. ● Understanding that human cultural activities affect the environment	● Providing examples to students of the relationship between ecology and society, such as how the amount of waste in the sea affects the livelihood of fishermen. ● Assigning tasks to students to find other examples related to the relationship between ecological situations and human social life.
4.	Environmental issues knowledge	● Understanding various environmental issues influenced by economic, social, political, and other issues ● Understanding the quality of water, air, and soil and the use of land for wildlife habitat and human populations	● Explaining to students current environmental problems or issues, such as the excessive impact of plastic waste on the environment ● Socializing students with engaging media about maintaining the quality of water, soil, and air
5.	Cognitive abilities	● Ability to identify and analyze environmental problems using various sources	● Providing various literature on environmental issues ● Assigning students to find environmental problems related to various media and sources

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6.	Responsible Behavior towards the Environment	• Actively participating in solving and maintaining the environment • Developing an eco-friendly lifestyle	• Training students to recycle waste into valuable objects (eco-brick) • Educating students to sort waste by type

Framework for Assessing Environmental Problem-Solving Skills

Table 7. Framework for assessing environmental problem-solving skills

No	Observation Aspect	Indicator
1.	Exploring and Understanding	Identifying environmental problems.
2.	Representing and formulating	Connecting available information to generate new information.
3.	Planning and executing	Planning solutions for environmental problems.
4.	Monitoring and reflection	Planning forms of monitoring or supervision.

Follow-up Development of Learning Devices

For the learning device development stage, the Borg and Gall development model will be used, which includes ten steps: needs analysis (research and information collecting), planning, development of preliminary product/prototype, preliminary field testing, primary product revision, main field testing, operational product revision, operational field testing, final product revision, and dissemination and implementation.

The first needs analysis step will be conducted through a literature review and field study. The literature review examines relevant literature and research findings on developing problem-based learning devices with a STEM approach to improving students' ecological literacy in solving environmental problems. A field study will be conducted to gather information on the necessity of the learning device.

The second stage involves planning by formulating objectives, determining the learning sequence, and selecting the learning materials to be presented in the syllabus, lesson plans, teaching materials, student activity sheets, and evaluation. The third stage involves developing the initial product/prototype of problem-based learning devices with a STEM approach to improving students' ecological literacy in solving environmental problems, which includes the syllabus, lesson plans, teaching materials, student activity sheets, and evaluation questions.

The fourth stage involves conducting preliminary field testing to validate the initial product/prototype I and the research instruments used to check for validity, practicality, and effectiveness. The validated research instruments include the syllabus, implementation plan for problem-based learning with a STEM approach, teaching materials, student activity sheets, evaluation questions, and questionnaires. The validation results include content validity, format validity, language validity, as well as practicality. The fifth stage involves revising the preliminary field testing results based on feedback from the validator. The improved results become prototype II.

The sixth stage is the main field test, which involves assessing the practicality and effectiveness of the product. The assessment of the product's practicality includes the implementation of the learning, student activities, teacher assessment of the learning syllabus, lesson plans, teaching materials, evaluation questions, and student responses to the materials and learning process.

The sixth stage is the preliminary field test of the product, which involves assessing the practicality and effectiveness of the product. The practicality assessment includes evaluating the implementation of the learning, student activities, and teacher assessment of the syllabus, lesson plans, learning materials, and evaluation questions, as well as student responses to the materials and learning process. The product's effectiveness can be seen by improving students' ecological literacy skills in solving environmental problems from meeting 1 to meeting 3. The seventh stage is the product revision stage, which involves improving the problem-based learning tool with a STEM approach to improving students' ecological literacy in solving environmental problems. The eighth stage is the large-scale field test stage, which involves testing the effectiveness and adaptability of the product design. This test involves potential product users, and the field test results are a developed design model ready to be implemented, both in terms of substance and methodology. The ninth stage is the final product revision stage, which involves refining the developed product to ensure its

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effectiveness. The tenth stage is the dissemination and production stage, which involves disseminating the product through scientific forums or mass media. Product distribution should only be done after a quality control process.

DISCUSSION

Developing a framework for problem-based learning with a STEM approach for using plastic waste with the eco-brick method to improve students' ecological literacy in solving environmental problems can guide further research. There are at least two research activities that can be conducted further, namely: (1) developing problem-based learning materials with a STEM approach using the Borg and Gall development model, (2) analyzing the implementation of problem-based learning materials with a STEM approach for the utilization of plastic waste with the eco-brick method in improving the ecological literacy of students in solving environmental problems. STEM can be developed by linking it to the environment, creating a learning experience that brings real-world situations into the classroom (Subramaniam et al., 2012). This means that through the STEM approach, students are not just memorizing concepts but understanding and applying scientific concepts to everyday life (Kuenzi, 2008). Shows that STEM learning can develop creativity and literacy, which are essential for facing the challenges of the 21st century (Parwati, 2015).

CONCLUSION

The results of this study have described the syntax of problem-based learning integrated with the STEM approach. The main result is the activity framework of problem-based learning with a STEM approach for utilizing plastic waste with the eco-brick method in improving students' ecological literacy in solving environmental problems. This research result includes the development of an observation instrument framework for each student related to students' ecological literacy and their ability to solve environmental problems.

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