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STEM-PBL integrative electronic module: Is that effective in improving students' critical thinking skills?

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Abstract: The aim of this research is to develop an electronic module that integrates STEM and PBL projects to improve students' critical thinking skills. Development research conducted using the ADDIE model. The research was conducted at Muhammadiyah 2 Junior High School (JHS) of Batu. Product trials were carried out involving 25 class VII students. The data collection instrument was carried out using a questionnaire given to media experts, material experts, teachers and students to test the feasibility and practicality of the media, as well as the pretest-posttest to measure students' critical thinking skills. The results of the study show four things: 1) the E-Module learning media is in the very feasible category with a weighting percentage of eligibility, namely 77.5% by media experts and 98% by material experts. 2) E-Module learning media is included in the very practical category by science teachers with a percentage of 97%, and the practical category by students with a percentage of 79%. 3) The results of the implementation show that students are very enthusiastic in participating in learning activities using the E-Module, seen from the percentage of aspects of interest in the media which reaches 86%. 4) E-Module learning media has a significant effect so that it has the potential to improve students' critical thinking skills (Sig = 0.000). Thus, the E-Module with the STEM approach based on the PBL Model can be used in learning environmental pollution material by students.

Keywords: Critical thinking skills, environmental pollution, E-Modul, STEM, PBL

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INTRODUCTION

The rapid development of technology has had an impact on the implementation of learning at almost all levels of school. For this reason, mastery of 21st-century skills is something that students need to have (Husamah et al., 2015; Alifah, 2021). There are many abilities that a person must master to be skilled in 21st-century life, including the ability to use communication tools, various social media, critical thinking skills, and problem-solving. This aims to enable someone to obtain information and use it in solving everyday problems. Therefore, the role of the teacher as a facilitator is vital in presenting creative and innovative learning so that it can attract students' interest in learning. Some of the efforts made by teachers are creating learning devices and interactive media according to students' learning needs. Interactive media in the form of e-modules (electronic modules) have been widely developed to support learning innovation. Electronic modules were developed to make it easier to implement lesson plans using developing technology to adapt to current learning needs (Negara et al., 2019; Mijaya et al., 2021).

The development of electronic modules is carried out by paying attention to the principles of stimulating student interest in learning, flexibility, and suitability to the needs and contexts faced by students daily. Therefore, the development of electronic modules needs to be adapted and integrated with the learning model used on a particular topic being discussed. Some electronic modules that are developed often skip this and focus more on how to present interesting things in terms of technological application (Nia et al., 2022; Laili et al., 2019). One learning model that is suitable for implementing electronic modules is the problem-based learning (PBL) model (Mayasari et al., 2016; Ningsih, 2020).

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Several researchers report that PBL can improve students' critical thinking skills and is relevant to the needs of 21st-century learning (Dharma et al., 2019; Noviar & Hastuti, 2015).

The PBL implementation emphasizes student activity in solving problems while the teacher becomes a facilitator (Antika, 2014; Sani, 2020). However, in reality, many PBL implementations are still not in harmony when applied in the classroom. Sometimes teachers are still trapped in the pseudo-PBL implementation where the teacher's role is still more dominant (Tyas, 2017; Firmansyah, 2019). This happens because the learning tools created do not integrate with PBL syntax (Junaidi, 2020; Hakim et al., 2016). In addition, teachers sometimes experience difficulties in developing integrated learning tools such as modules (Tyas, 2017; Salama et al., 2021). Some researchers also state that students are not affiliated with learning because the apperception and problem orientation given to students are not contextual enough to students' lives. As a result, student participation and interest in learning are minimal, giving the impression of being passive and affecting the learning process (Mediakarya et al., 2020; Yasdar & Muliyadi, 2018; Pratiwi & Wahyuni, 2019).

In 21st-century learning, many researchers believe that problem contextualization in PBL can be integrated with the Science, Technology, Engineering, and Mathematics (STEM) thinking framework. According to experts, a systematic approach carried out in a multidisciplinary manner is believed to be able to develop students' critical thinking abilities. The STEM approach has become very important due to technological developments in various sectors that require a person to have these abilities or the demands of 21st-century life (Winarni et al., 2016). Several characteristics of STEM that are considered relevant to 21st-century learning are the chosen problem focus. In this case, STEM only focuses on how theory relates to the context of everyday problems. For example, with STEM students not only learn about the theory of decomposition carried out by microbes, but also how to solve problems using this theory. This learning aims to train students' hard skills and soft skills so that they have 21st-century skills.

The STEM approach and PBL model can enable students to acquire the 21st-century knowledge needed today, especially critical thinking skills (Mulyani, 2019; Oktavia, 2019; Prismasari et al., 2019; Yustina et al., 2019). With these various considerations, it is necessary to develop a more systematic STEM-based PBL. One thing that can be done is to develop modules and lesson plans that can improve students' critical thinking skills (Redhana, 2019; Mariyatun, 2022). This research aims to develop a PBL-based electronic module with a STEM framework.

METHOD

This development research uses the analysis, design, development, implementation, and evaluation (ADDIE) model as in Figure 1. The analysis stage is carried out by collecting as much information as possible about what is needed in developing learning media and knowing the needs of students or teachers in learning interaction.

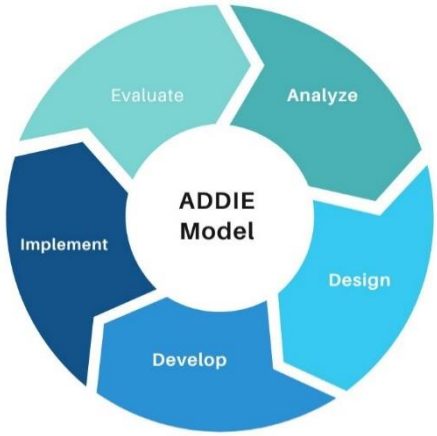

Figure 1. ADDIE model procedure

The results of the analysis are outlined in a design that includes learning materials and instruments. Furthermore, at this stage, the researcher makes a product development plan that is tailored to the needs of students and teachers. The four steps taken in the planning stage include determining

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competencies and indicators, designing the initial draft of the e-module, identifying materials, selecting assessment strategies, and testing instruments. The development of this module uses web-based tools, not just a one-way module. It allows for two-way interaction between teachers and students in the learning process.

The resulting initial draft of the e-module was then developed by carrying out a series of tests and expert assessments. In this research, we involved several experts, including material experts, media experts, and language experts. Only drafts that have met the assessment standards will be tested at the product implementation stage. At the product testing stage, we involve teachers and students to measure the practicality of the media. Implementation is carried out by teachers and students by filling out questionnaires and the influence of media in improving critical thinking skills, using PBL with STEM in its implementation.

The evaluation stage is the final stage of the development steps carried out. From the results of the student response questionnaire and interviews with educators, the product being developed will be evaluated for improvement if there are still deficiencies in the e-module learning media. Research and development will be carried out in September-October 2022 on a limited basis. The subject of this trial was carried out to determine the effect of the product in improving critical thinking skills, validity, and response to the media by several experts and students. The data analysis technique uses a questionnaire to measure feasibility and practicality with 5 expert validation assessment scores in Table 1 so that you can calculate the percentage with 5 categories in Table 2 and Table 3 to measure critical thinking abilities.

Table 1. Expert validation assessment score

Description	Score
Excellent	5
Good	4
Moderate	3
Low	2
Very low	1

Table 2. Criteria of validation percentage

Persentase (%)	Categories
0 – 20	Very unworthy
21 – 40	Unworthy
41 – 60	Quite decent
61 – 80	Decent
81 – 100	Very decent

Table 3. N-gain score categorization of critical thinking abilities

Range	Categories
0.70 – 1.00	High
0.31 – 0.69	Moderate
0.00 – 0.30	Low

RESULTS AND DISCUSSION

The results of the analysis, as an initial stage of development, show that teachers need learning media that can be accessed in both directions. This is done to increase student involvement in the learning process. Furthermore, the results of interviews with students also showed the same thing, namely involvement in the learning process. In this case, students feel very happy if the learning process involves them actively. On the other hand, the characteristics of students with an average age of 13 years (gen Z) have a good understanding and skills in using digital technology. Some researchers believe that the current generation Z is a digital native group where they are accustomed to using technology, especially digital-based ones.

The results of this analysis become a reference for researchers to develop e-modules by emphasizing two-way activities between teachers and students. Therefore, the e-module development carried out is based on website use. There are three main applications used in this research, namely *Weebly*, *Canva*, and *Wordwall*. This media is equipped with material summaries, images, videos, and

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articles that can be accessed by students. The STEM framework used as a value in this module lies in the use of contextual problems around students. This framework is combined with a problem-based model to stimulate students' critical thinking skills in solving problems. Furthermore, the problem raised in this e-module is water pollution that occurs in Batu City (Figure 2).

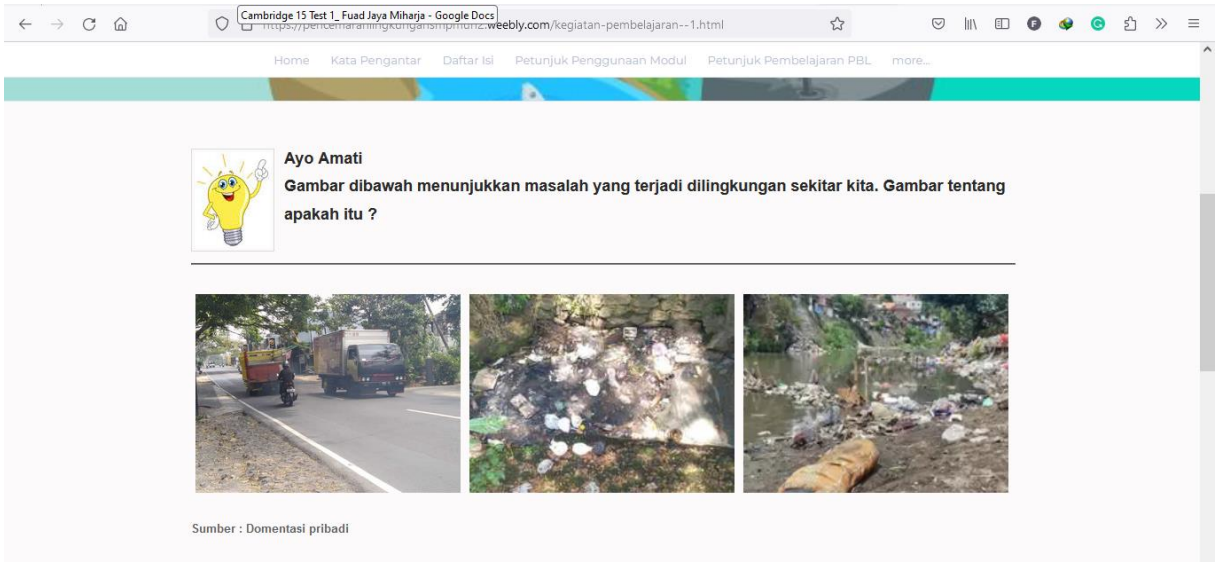

Figure 2. Orientation to water pollution problems in e-modules with the STEM framework

Implementation of the STEM framework in the development of integrated e-modules in the PBL model used. In this case, students carry out two practicums which are directed through electronic modules, starting from the problem of diaper waste in rivers and fruit and vegetable peel waste. Students have been able to produce useful products, namely flower pots from diaper waste and eco enzymes from fruit and vegetable peel waste. The STEM aspect in solving these problems is described in Table 4.

Table 4. The STEM component through the students' project

Component	Description
Science	▪ **Product 1**. Processing diaper waste into flower pots a) Bacterial growth and development b) Antiseptic and sterilization concept c) The role of sunlight in the pot drying process ▪ **Product 2.** Processing fruit and vegetable peel waste: a) Fermentation concept b) Enzymatic activities through fermentation c) Bacterial and organisms that can carry out fermentation
Technology	▪ **Product 1**. Processing diaper waste into flower pots Mixing technique for diaper waste with cement, glue, pots and plastic ▪ **Product 2.** Processing fruit and vegetable peel waste: The correct and effective fermentation technique
Engineering	▪ **Product 1**. Processing diaper waste into flower pots: a) Attractive flower pot design b) Functional pot design ▪ **Product 2.** Processing fruit and vegetable peel waste: a) Engineering the content of eco-enzymes as organic fertilizer b) Attractive product design
Mathematics	▪ **Product 1**. Processing diaper waste into flower pots Calculate the amount of cement, water, number of diapers used, time needed for the drying process ▪ **Product 2.** Processing fruit and vegetable peel waste: Measurement of the amount of vegetable and fruit peel used is measured using a scale, the amount of water used, the amount of molasses used

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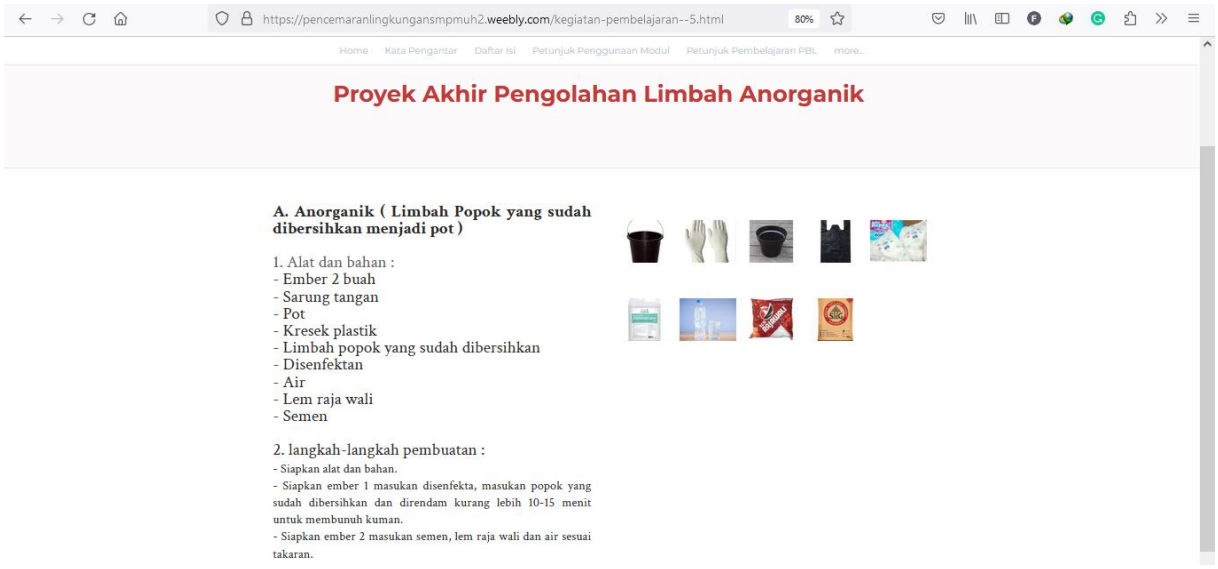

Figure 3. Student investigation activities in order to strengthen concepts

The practicality of learning media is carried out by looking at the results of response questionnaires by students and teachers which were filled out during the initial trial. The assessment of the science teacher's response obtained a percentage of 97% in the very practical category and the students' response to find out the practicality of learning media after being calculated received a percentage of 79% which was included in the practical category. The feasibility of learning media by media experts and material experts obtained results including; The overall media expert assessment of both aspects received a score of 58, a total percentage of feasibility, namely 77.5%, and the results of the material expert assessment received a score of 61 with a percentage of 98% calculated according to the formula. From this assessment, it can be concluded that according to Rahmat et al., (2021) at an achievement level of 70%-100% the electronic module learning media with the PBL-based STEM approach developed is categorized as very suitable for use with revisions. There are four aspects assessed in small-scale trials on students, namely; the interest aspect in learning media with a percentage of 86%, the material mastery aspect with a percentage of 74.5%, the appearance aspect with a percentage of 84%, and the implementation aspect with a percentage of 80%. The average feasibility test results from four aspects, namely 81%, are included in the very feasible category, with no need for revision (Dewi et al., 2018; Rahmat et al., 2021).

The t-test analysis shows that there is a significant difference between the pretest and post-test or it could be said that environmental pollution learning media uses electronic modules with a PBL-based STEM approach which can be accessed via smartphone, which has the potential to improve students' critical thinking skills. The results of the t-test showed that there was a significant difference in critical thinking skills between before ($M = 56.16$, $SD = 10.50$) and after ($M = 86.40$, $SD = 7.25$) on the use of learning media, $t(24) = 18.971$, $p < 0.001$. Following research conducted by Rasyid and Arif (2019) there is a difference in increasing critical thinking skills and positive responses to Android media (A. Ngurahrai et al., 2019). Mobile learning-based learning media has an effect on critical thinking skills so that it can be used as an alternative media for learning, and as experienced by (Winata et al., 2019) the application of Android media has a significant influence on students' critical thinking abilities.

The assessment results show that the electronic module learning media is feasible and needs revision at the beginning of the assessment, the media will be revised again based on suggestions and recommendations from media experts, material experts, and student responses in initial field trials. Suggestions & recommendations from media experts regarding the rare aspects of PBL learning can be added to make it clearer when used, essay questions or other things so that they can achieve indicators, adjust the writing for foreign languages, Ariel fonts for electronic modules, suitability of colors can be seen in the theory book colors, edu games can be adjusted to suit learning needs. Suggestions & recommendations from material experts, especially the STEM approach, are expected to use the project-based model because it will further strengthen the application of the STEM approach when learning takes place and if using PBL, it must be followed with practicum so that the STEM elements can be

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seen. Meanwhile, in the initial field trials on EDU games, they were given 2 opportunities/lives to play so that children did not answer carelessly.

CONCLUSION

Electronic modules with a STEM approach based on the PBL model as a science learning medium for environmental pollution material are in the very feasible category. Trials and gradual revisions were carried out to obtain results presenting all aspects of feasibility so that they were met. The results of practicality by science teachers and students of SMP Muhammadiyah 2 Batu are as follows: The results of calculating the percentage of practicality which includes three aspects are 97% and is included in the very practical category, while the calculation of the percentage of practicality of students which includes four aspects is 79% and is included in the category practical. Implementation is carried out after the learning media has been developed with initial field trials and validation with media and material experts. Implementation was carried out in class VII with 25 students of Muhammadiyah 2 Batu Middle School which was carried out offline and in a limited manner. The result is that students are very enthusiastic about participating in learning activities using e-modules, this can be seen from the percentage of interest aspects in media which reaches 86%. Testing the effectiveness of e-module learning media on environmental pollution material has the potential to improve student's critical thinking skills, this was obtained from the results of the pretest and posttest which showed significant differences.

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