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Stem Problem-Based Learning Module: A Solution to Overcome Elementary Students' Poor Problem-Solving Skills

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Abstract

Problem-solving skills are required to solve difficulties encountered in daily life. These skills are important but rarely mastered by fourth grade elementary school students. One explanation for this is that the learning tools have not been specifically designed to help pupils develop their problem-solving skills. The purpose of this research and development project was to generate a valid STEM-PBL module using the ADDIE procedure (analysis, design, development, implementation, and evaluation). The content validity was evaluated by a science learning expert, a learning technology expert, and a language expert. Construct validity was determined through an experimental study conducted with a group of students. The Likert scale was used to assess the product and the Content Validity Index (CVI) of the instrument was analyzed. The students' problem-solving skills were examined using a multiple choice test. The paired sample t-test was used to determine the differences in students' problem-solving skills following the module's implementation. The STEM-PBL module was successfully developed for fourth graders of elementary school. This module integrates the STEM's components as well as problem-based learning syntax. The module is arranged according to the characteristics of elementary school students, namely self-instruction, self-contained, stand alone, adaptive, and users friendly. The module was declared valid in terms of content by a science learning expert, a educational technology expert, and a linguist. The application of the module indicates differences in the research participants' pretest and post-test scores. The module includes practical tasks and problem-solving discussions that aid in the development of problem-solving skills.

Key words: STEM, Problem-based Learning, Science education, problem-solving skills.

Introduction

The advancement of science and technology in the twenty-first century has increased the standard for job requirements. To generate innovation in a variety of industries, superior and competitive human resources are required. Human resources are developed beginning in elementary school through a process of learning that connects theory to real-world challenges. Khalil & Osman (2017)Technology, Engineering, and Mathematics (STEM argue that in the 21st century, it is important to prepare students to stay relevant in life and work, which of course are very complex and competitive.

The 21st century problems are increasingly complex in many fields, one of which is the environment. Environmental problems occur globally, including extreme climate change (Cramer et al., 2018), pollution (Reddy et al., 2017), overpopulation, depletion of natural resources, waste disposal, biodiversity loss, deforestation, ocean acidification, depletion of the ozone layer, as well as limited energy sources (Singh & Singh, 2017). These issues demand the assistance of human resources with strong problem-solving skills.

Problem-solving skills are a process of using prior knowledge and generating new knowledge (Nadila, 2021). This ability is relevant to success in achieving solutions to various types of problems. Problem-solving skills must be cultivated at a young age, as they can help children develop cognitive abilities. Problem-solving teaches children how to identify and solve difficulties (Fessakis et al., 2013; Vuran et al., 2020). Problem-solving skills are critical for elementary school students, as they are trained to be problem solvers from an early age (Adel Al-khati, 2012; Yayuk et al., 2020; Mirici & Uzel, 2019). However, there are numerous lessons that have not explicitly emphasized real-world problem-solving (Dunlosky et al., 2013).

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Real-world problem-solving skills can be developed through learning that relates classroom theory to real-world phenomena. The classroom can employ a STEM approach with the primary objective of bridging the gap between school and the real world. STEM integration provides students with opportunity to develop and explore technology through meaningful learning processes in real-world contexts (Shahali et al., 2016). STEM is a multidisciplinary learning that integrates knowledge and skills in the fields of science, technology, engineering, and mathematics (Le et al., 2015; Retnowati et al., 2020; Tseng et al., 2011). STEM students are able to identify, apply and integrate concepts to understand complex problems and generate innovative solutions to solve these problems (Basham & Marino, 2013; Margot & Kettler, 2019).

The advantage of STEM learning is that it focuses on solutions by building prototypes that encourage students to think creatively and critically. This allows students to realize that there are many ways to find solutions, as they engage in brainstorming to identify problems and propose solutions (Siew, 2017). This process of finding solutions requires students to engage in critical thinking and problem-solving (Alfi et al., 2016). Prior to learning, students work in teams to solve problems that are not yet clear, then discuss them to define and contextualize the problems. Following that, each team plans and constructs the solutions (Cooper & Heaverlo, 2013). The process of discussion until finding a solution requires full involvement in every stage of learning.

Torlakson (2014) explains that STEM is an ideal match for problem-based learning because both are capable of connecting pupils to real-world challenges. Problem-based learning (PBL) is a method of planning learning in order to accomplish an instructional goal (Hung et al., 2008). PBL is a learning model that stimulates students through problem-posing and problem-solving. Students acquire knowledge and improve problem-solving skills during the problem-solving process (Hesse et al., 2015). Students are confronted with multidisciplinary problems in PBL, and the solution entails a number of courses (Dobson & Tomkinson, 2012). STEM and PBL are capable of establishing a cohesive learning system and promoting active learning. STEM-PBL learning is an excellent fit for integrated science education because it has been shown to improve learning outcomes, creative and critical thinking skills, problem-solving abilities, and other competencies.

The success of STEM implementation in the classroom can be determined by three criteria: student learning outcomes, school type, and method/procedure of implementation (Hudha et al., 2019; Saptarani et al., 2019). This approach will be more effective if it is accompanied by clear instructional materials and processes. The teaching materials are available in both printed and non-printed formats. Printed instructional resources include books, worksheets, modules, and handouts (Hamdani, 2011:175). The characteristics of the topic matter influence the development of instructional materials (Oktavia, 2019). A learning process is deemed to be successful if the teacher is able to make the learning content easily understandable to students and to pique their interest in learning. In contrast, instructors' constraints in generating instructional materials are a result of a lack of effective and relevant material sources with current information, as well as a lack of time to prepare for recent curriculum changes. Therefore, teacher professional competence is considered a key component in helping teachers innovate (Al Salami et al., 2017).

Farihah et al (2021) were successful in examining the potential for game-based STEM modules to motivate and engage pupils. Kasim et al (2018) also succeeded in establishing a constructivism-based PRO-STEM curriculum on biodiversity and ecosystems. This module's development is guided by a project-based learning methodology. Numerous studies have demonstrated that STEM modules outperform other modules in terms of conceptual knowledge, higher order thinking skills, and design project activities. The studies developed effective STEM modules to engage and motivate pupils, but the modules produced are neither futuristic or easily accessible. Handayani et al (2021)including in the field of education. A country must be able to compete globally from the aspects of modern science and technology, one of which is through education. Education requires learning materials as a reference in the 21st-century. The purpose of this study was to develop learning media in the form of electronic modules for students on critical-thinking skills. The method used was Research and Development (R&D developed an online STEM-integrated physics module that uses quizzes to help students improve their critical thinking skills, however the content has not been confirmed by experts. In fact, content validation is the most critical step before field testing a product. The STEM module developed by (Vossen et al., 2020) encourages different perspectives between students and teachers. (Vossen et al., 2020) proposes that teachers pay attention to differences in student preferences when implementing STEM modules. Different pupils appear to have varying approaches to problem-solving, and the STEM module's structure must reflect this. Based on the problem description, urgency, and preliminary study, this study aimed to develop a STEM-PBL module capable of overcoming the weaknesses of the existing STEM modules, enhancing students' problem-solving skills, and serving as a supplement to previously circulated teaching materials at school.

Research Objectives

1. What are the characteristics of the STEM-PBL module developed in this study?
2. What are the results of the STEM-PBL module content and construct validity tests?

3. What is the impact of STEM problem-based learning modules on students' problem-solving skills in elementary school?

Method

The Development Model

This research and development project followed the ADDIE procedure which entails the following stages: *analyze, design, develop, implement, dan evaluate* (Aldoobie, 2015; Branch, 2009; Welty, 2007). The ADDIE steps are described in detail in the following sections.

1. *Analyze*

The "Analyze" stage involved doing a needs analysis for the development of the STEM-PBL module, analyzing the curriculum/content, and analyzing the students. The needs analysis was conducted through interviews with ten elementary school instructors and twenty fourth grade elementary school pupils who were randomly selected to represent their respective groups in Yogyakarta City. Based on these interviews, it was established that fourth grade elementary school students nowadays require modules as instructional tools. Additionally, the curriculum analysis revealed that the theme that best suits the STEM-PBL characteristics is "Always Save Energy". This theme presents numerous contextual issues that students face on a daily basis but is difficult to explore in class because it requires fieldwork. After conducting a needs analysis on students' interest in instructional materials, the design of this STEM-PBL module was inspired.

2. *Design*

In this research, the "Design" stage refers to the process of developing a STEM-PBL module that is methodical in its construction and content. The STEM-PBL module must adhere to the features of a module, which include self-instruction, self-contained, stand alone, adaptive, user-friendly (Daryono & Rochmadi, 2020; Murdianto et al., 2021; Santoso & Albaniah, 2020; Yulando & Franklin Chi, 2019). At this stage, the STEM-PBL module's structure was being finalized. It included a cover page, an introduction, a table of contents, a learning outcome, features, a user guide, an introduction, material integrated with PBL syntax, a summary, a discussion, a formative exam, and a bibliography. The PBL syntax for learning activities is as follows: 1) problem orientation, 2) student organization, 3) investigation, 4) work prevention, and 5) analysis and reflection. Along with the STEM-PBL module, this stage resulted in the design of the research instruments, namely a module assessment sheet, an interview sheet, and an observation guide. This stage culminated in the creation of a STEM-PBL module draft and research instruments.

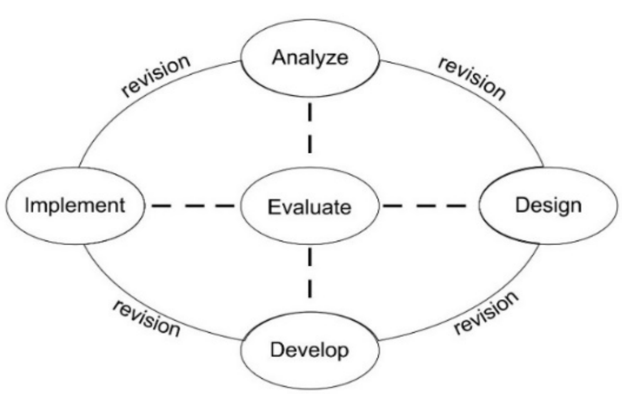

FIg. 1: ADDIE Development Model

3. *Develop*

At this stage, the content validity and construct validity of the STEM-PBL module draft was checked by a science learning expert, an educational technology expert, and a language expert. Expert validation includes quantitative assessment and input on the module's material, presentation, language, and pedagogical content. Then, the module was tried out in a classroom to examine its effect on students' problem-solving skills.

4. *Implement*

The implementation stage was carried out at the Muhammadiyah Bausasran 1 elementary school in Yogyakarta, Indonesia. Twenty eight fourth-grade students were involved in the study. The effectiveness of the module was measured based on the implementation of the lesson plan and students› learning outcomes.

5. *Evaluate*

The "Evaluate" stage was conducted at the end of the *analyze, design, develop*, and *implement stages*. The evaluation was performed on the STEM-PBL module development and on the students' learning outcomes.

Participants

the participants involved in this study were three experts, namely a science learning expert, an educational technology expert, and a linguist. In the limited test, it takes 8 4th graders for the readability test and one class to test the impact of the module.

Data Collecting and Instrument

Need assessment data in this study were collected through interviews, while the product was assessed using a Likert scale rubric with the following criteria: 5 (excellent), 4 (good), 3 (moderate), 2 (fair), and 1 (poor). The Likert scale was used to measure the Content Validity Index (CVI) because it is easier to quantify. The Content Validity Index (CVI) is one of the most suitable formulas to be used in testing the content validity of the STEM-PBL module because there was more than one expert involved in this validation, namely a science learning expert, an educational technology expert, and a linguist. Observations were made on the learning process with the STEM-PBL module to ensure that the module was running according to the lesson plan. The students' problem-solving skills were assessed using an essay question whose indicators refer to Crebert et al (2017).

Data Analysis

The qualitative data were analyzed using a descriptive qualitative analysis method. Content Validity Index (CVI) was used to examine the expert validation data by calculating the percentage of items considered relevant by each expert and determining the average percentage of the experts' scores. The result of the Content Validity Index (CVI) analysis was defined descriptively in the form of validity categorization/classification. The module's validity was decided based on the validity classification suggested by Guilford: $0.80 < rxy < 1.00$: very good, $0.60 < rxy < 0.80$: good; $0.40 < rxy < 0.60$: fair, $0.20 < rxy < 0.40$: poor, $0.00 < rxy < 0.20$: very poor; and $rxy < 0.00$: not valid (Guilford, 1956). The paired sample t-test was conducted to analyze the difference in students' problem-solving skills following the implementation of the STEM-PBL module.

Findings

The Characteristics of the STEM-PBL module

The STEM-PBL module is formatted in A4. The cover is printed on 230 grams of ivory paper, while the content pages are printed on 120 grams of art paper. Corel Draw X7 was used to build the module, which features Comic King, Arial, and Quicksand fonts. The STEM-PBL module focuses on the topic "Always Saves Energy," which is the second theme learned by the fourth-grade students at school. The STEM-PBL module incorporated the ideal components of an instructional module, namely: 1) The learning objectives, which are typically expressed as specific behaviors that can be measured; 2) Instructions for use, specifically instructions on how students learn; 3) Learning activities, which contain the material that students must study; 4) A summary of the material. 5) Assignments and exercises; 6) Bibliography; 7) Criteria for Module Success; and 8) Answer key. The module's science component is illustrated through the topic on alternate energy sources. The incorporation of educational videos linked to a QR code exemplifies technology. Engineering is exemplified by the activity of prototyping waterwheels and windmills utilizing readily available materials, while mathematics is represented in the module through measuring problem-solving tasks and statistical data.

PBL is integrated into the module through the problem-based learning activities, namely Orientation, Organization, Investigation, Development, Evaluation (Asyari et al., 2016; Du & Chaaban, 2020)

The STEM-PBL module includes a practicum in which students learn how to construct a simple alternative energy prototype using recycled materials. The module provides science courses aligned with the following Basic Competencies: 1) identifying various energy sources, changes in energy forms, and alternative energy sources (wind, water, solar, geothermal, organic fuels, and nuclear) in everyday life; 2) understanding various forms of energy sources and alternative energy (wind, water, solar, geothermal, organic fuels, and nuclear) in daily life.

The STEM-PBL module embodies the module's ideal features, namely (1) self-instruction; the module enables an individual to study freely and without relying on third parties; (2) stand alone; the module as a whole contains all necessary learning resources; (3) self-contained; the module is not dependent on or required to be utilized in conjunction with other educational resources; (4) adaptable, the compiled module is adaptable to the advancement of science and technology and is adaptable for application in hardware; and (5) user-friendly, the module must have instructions and information displays that are both informative and nice to the user, as well as conveniently available in the necessary locations. In this case, the STEM-PBL module utilizes straightforward language that is easy to comprehend and incorporates regularly used vocabulary (Yulando & Franklin Chi, 2019).

Validity of the STEM-PBL module

a. Content Validity

The module›s content validity was examined by three experts, namely a science education expert, a educational technology expert, and a language expert. Recommendations from experts for module improvement are explained as follows.

1. It is necessary to provide a full explanation of the content, improve the use of pictures to aid students' comprehension, and provide a summary of the material at the end of each chapter.
2. It is important to include a recap of the subject to assist students in comprehending the preceding chapter.
3. It is necessary to improve the module's grammar, which must include references to PUEBI and punctuation that is appropriate for the context of the sentence being used. Throughout the module, it is discovered that the usage of punctuation is excessive and does not correspond to the sentence's context.
4. Scenarios for learning utilizing the STEM-PBL module should be customized to students' developmental levels, learning styles, and pace of comprehension.
5. It is important to improve the QR barcode since some of the QR barcodes in the module are inaccessible; the source of all pictures must be specified; the font size must be consistent; and the use of punctuation marks must be double-checked.

After receiving feedback from these experts, the module was revised. The STEM module's assessment by a science expert on the aspects of Self-Instruction, Self-Contained, Stand-alone, Adaptive, and User-Friendly is adequate (mean score = 74, ideal percentage of 77.8%). Figure 2 illustrates the score for each aspect.

As illustrated in Figure 3, each aspect of the module is "very valid." In terms of language, the module was evaluated on eight criteria: sentence structure accuracy, sentence effectiveness, term standardization, communicativeness, use of dialogical and interactive language, compliance with Indonesian language rules, use of terms, symbols, and icons, and conformity to student needs (Purwono, 2008). The findings indicate that the STEM-PBL module is very feasible to implement, with an optimum implementation rate of 86%. Figure 4 illustrates the score of each component of language assessment.

The assessment of the module based on its consistency, format, organization, and attractiveness indicates an optimal proportion of 87.69%, belonging to the very feasible category. Figure 3 illustrates the score for each aspect.

The STEM-PBL module's practicality was determined by the lesson plan's implementation and the module's ease of use by the teacher and students. The examination of practicality yielded an optimum percentage of 85.71% in the extremely feasible category. The teacher's evaluation of the media's appearance and utility indicates an optimal rate of 92% (very feasible).

Construct Validity

The construct validity test was used to ascertain the differences in students' problem-solving skills prior to and after the module's implementation. The paired sample t-test results are presented in Table 1.

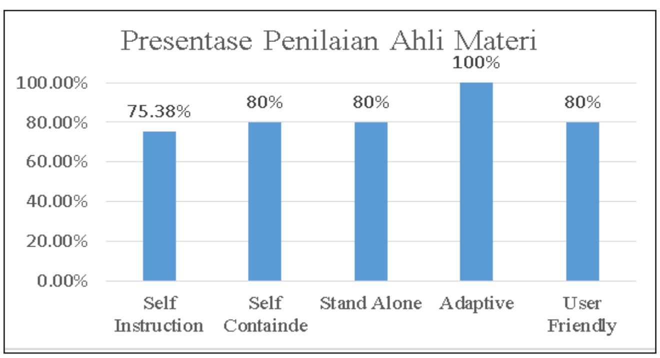

Fig. 2: Science Expert Validation Scores

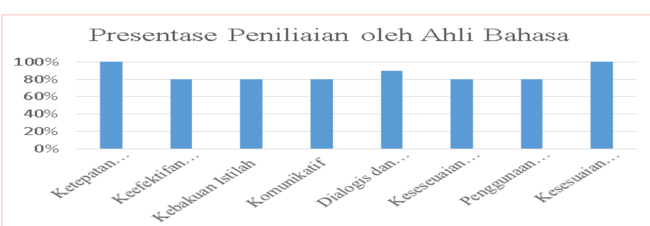

Fig. 3: Linguist Validation Scores

Fig. 4: Media Expert Validation Scores

Table 1: Paired sample t-test

		Paired Differences			
		95% Confidence Interval of the Difference			
		Upper	*t*	*df*	*Sig. (2-tailed)*
Pair 2	Pretest - Posttest	-2.034	-2.704	16	.016

As shown in Table 1, Ho (there is a significant difference between the pretest and posttest scores) is rejected with a significance value of 0.016 (< 00.05). According to this statement, the STEM-PBL module is appropriate for developing the fourth-grade students' problem-solving skills in elementary school.

Discussion

The ADDIE procedure was used to construct the STEM-PBL module, which resulted in a module that was suitable for use as a stand-alone learning resource. STEM content in this module also aids students in their learning process by allowing them to create prototypes of alternative energy source equipment using materials found in their environment. Additionally, this module features QR barcode technology that connects to a simulation video depicting the process of creating alternative energy in real life. These features are extremely beneficial for students in gaining critical information that aids in their comprehension of the content. Students who view simulation videos have a high level of engagement (Sauter et al., 2013). The preparation and production of videos need a significant amount of time and resources (Coyne et al., 2018)Data Sources: Systematic search of the following databases was conducted in consultation with a librarian using the following databases: SCOPUS, MEDLINE, COCHRANE, PsycINFO databases. Keywords and MeSH terms: clinical skills, nursing, health, student, blended learning, video, simulation and teaching. Review Methods: Data extracted from the studies included author, year, aims, design, sample, skill taught, outcome measures and findings. After screening the articles, extracting project data and completing summary tables, critical appraisal of the projects was completed using the Mixed Methods Appraisal Tool (MMAT. Therefore, for efficiency purpose, the module incorporates videos that are already available on the YouTube platform by adding copyright.

The STEM-PBL module contains instructional materials, competencies, assessments, and feedback that enable students to learn autonomously. The module's material is designed to meet the needs of students who choose to study independently (Abidin & Walida, 2019; Howard & Miskowski, 2005; Serevina & Sari, 2018)e.g. creative, active, systematic, and effective (CASE. The STEM-PBL module has also met the requirements of self-instruction, self-contained, stand alone, adaptive, and user-friendly (Daryono & Rochmadi, 2020; E. S. Handayani et al., 2021; Murdianto et al., 2021; Santoso & Albaniah, 2020) *namely, (1* proven by the expert validation results. The STEM-PBL module gives a context for learning. The PBL model imparts color to this module via the syntax provided in each activity (Hung et al., 2008).

The STEM-PBL module is able to stimulate students to find their own answers to the problems presented (Hairida, 2016; D. Handayani et al., 2021; Kurniawan & Syafriani, 2021). Additionally, the module teaches students how to solve problems using their own knowledge. In science education, the appropriate and effective strategy is one that takes into account the situation's suitability and students' learning needs (Maryani & Amalia, 2018). The STEM module is beneficial when combined with the PBL model since the STEM approach requires students to address problems involving multiple disciplines (Al Salami et al., 2017; Margot & Kettler, 2019). This is consistent with PBL's properties, one of which is a strong emphasis on interdisciplinary science (Asyari et al., 2016). Aspects of the STEM approach can help make learning more fun for pupils and train them to improve their problem-solving skills (Barak & Assal, 2016; Sarah Kartini et al., 2021).

Problem-based learning offers a number of advantages, including the following: 1) familiarizing students with problems (problem posing) and challenging them to solve problems that are not only relevant to classroom learning but also exist in everyday life (real world) (Lestari & Mertasari, 2019); 2) creating social solidarity, as students are accustomed to conversing with their peers (Hasanah et al., 2020); 3) bringing the teacher closer to and more familiar with the students; 4) acquainting pupils with the process of performing experiments (Jones, 2006).

Conclusion

This study was successful in generating the STEM-PBL module with the theme "Always Save Energy," which was required of fourth grade elementary school students. This module incorporates components from science, technology, engineering, and mathematics and employs a problem-based learning syntax in its learning scenarios. The module is organized according to the characteristics of primary school students and the qualities of a module, which include self-instruction, self-contained, stand alone, adaptive, dan user-friendly. The module's content was validated by professionals in science education, educational technology, and language. Through practical activities and problem-solving discussions, this module can help students improve their problem-solving skills. The STEM scenarios and discussion activities offered in this module may aid in the accomplishment of convergent problem-solving tasks.

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