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DEVELOPMENT OF AN ELECTRONIC MODULE BASED ON PBL-STEM IN A CONTEXTUAL ETHNOSCIENCE LEARNING "RED BRICK MAKING" TO IMPROVE STUDENTS' PROBLEM-SOLVING SKILLS

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Abstract

This research aims to: (1) produce an electronic science modules based on PBL-STEM in ethnoscience learning "red brick making" that are feasible to improve problem solving skills; (2) determine the practicality of electronic science modules based on PBL-STEM in ethnoscience learning "red brick making" " has been produced in improving problem solving skills; (3) determine the effectiveness of electronic science modules based on PBL-STEM in ethnoscience learning "red brick making" has been produced in improving problem solving skills. This research is development research by adapting Thiagarajan's 4-D model consisting of Define, Develop, Design, and Disseminate. This research involved 2 expert lecturers as validators, as well as 30 seventh-grade students of SMP N 3 Banguntapan as research subjects. The data analysis technique used qualitative and quantitative analysis. The effectiveness of LKPD through prerequisite test, paired sample t-test, and effect size test. The results showed that: (1) there has been produced electronic modules based on PBL-STEM on ethnoscience learning "red brick making" is very feasible to use in science learning; (2) electronic modules based on PBL-STEM on ethnoscience learning "red brick making" has been produced is very practical in improving students' problem solving skills (3) electronic modules based on PBL-STEM on ethnoscience learning "red brick making" has been produce is very effective in improving students' problem solving skills.

Keywords: Electronic Module, Ethnoscience, PBL, Problem-Solving Skills, STEM

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INTRODUCTION

The US-based Partnership for 21st Century Skills identified the skills needed in the 21st century as "The 4Cs": communication, collaboration, critical thinking, and creativity. These skills should be trained to learners in the context of core studies and 21st-century themes. Assessment and Teaching of 21st Century Skills (2018) categorizes 21st century skills into three skills namely: way of thinking, way of working, and skills for living in the world. Way of thinking includes creativity, innovation, critical thinking, problem-solving, and idea generation. Way of working improves communication, collaboration, and teamwork in the workplace. Skills for living in the world enhance a person's sense of self-worth as a citizen of a country, whether global or local, their ability to improve their lives and careers, and their sense of self-worth as a personal or social being. Furthermore, skills for living in the world are based on information literacy, advances in information technology, and new forms of communication, as well as the ability to learn and work through social media networks.

One of the components of way of thinking in 21st century skills is problem-solving. Problem-solving is a collaborative strategy that combines diverse cognitive styles to enable students to select and apply the most appropriate information when tackling complex tasks (Setiawan et al., 2020). Purwaningsih et al. (2020) showed that purpose-built teaching materials significantly improved students' problem-solving performance in physics, thereby strengthening their ability to analyze complex situations critically and generate innovative solutions, two indispensable competencies for the modern world. According to OECD (2020), problem-solving is one of the key future competencies, enabling learners to analyze problems, make informed decisions, and adapt to fast-changing technological and social contexts. Therefore, developing students' problem-solving skills is vital to prepare them as adaptive, competent individuals in the 21st century.

Although the 21st-century curriculum highlights problem-solving as a core "way of thinking," Indonesia's PISA 2022 results reveal a clear proficiency gap. Only about 34 % of Indonesian students reach Level 2 or above in science meaning they can correctly explain common scientific phenomena and, in simple cases, judge whether a conclusion is valid based on given data compared to an OECD average of 76% (OECD, 2023). Even more striking, virtually no Indonesian students attain the highest proficiency levels (Levels 5–6), whereas 7% of students across OECD countries do (OECD, 2023). This imbalance shows that most learners lack the deeper conceptual and analytical skills needed for tackling complex, real-world problems. Such findings underscore the urgent need for context-rich, hands-on learning tools like a PBL-STEM ethnoscience electronic module on red-brick making that guide students step by step through authentic problem-solving experiences.

In addition to PISA, the Trends in International Mathematics and Science Study (TIMSS) 2019 results also reveal learning gaps among Indonesian students. Indonesia scored 397 in science and 395 in mathematics, both below the international average of 500 (Mullis et al., 2020). Particularly, students showed weaknesses in applying science knowledge to problem-solving situations that require higher-order reasoning, further emphasizing the need for innovative teaching approaches that enhance students' analytical and critical skills.

The ability to reason and think critically, logically, and systematically that emphasizes collaborative learning and the application of scientific knowledge, creativity, and problem-solving can be formed through the implementation of STEM-based integrated education. According to Lestari, et al. (2017), STEM aims for students to find innovative solutions by being oriented towards real problem-solving activities. Research by Viana, et al. (2022) states that using a problem-based learning model or PBL learning model with a STEM approach is effective for teachers to use in learning activities because it is successful in improving students' problem-solving skills.

Nurhasnah et al. (2022) stated that ethnoscience-based STEM learning (STEM-Etno) can be an alternative for science teachers in teaching science concepts by connecting indigenous scientific knowledge with scientific science. Through ethnoscience-based STEM learning, students can develop an attitude of love for the culture and character of their nation. In addition, students can understand natural events around them and relate them to the knowledge they are learning.

Ethnoscience is knowledge possessed by an ethnic group or community obtained by following procedures that are part of the community's tradition and the truth can be tested empirically (Sudarmin, 2014). In science learning, ethnoscience can serve either as learning content or context. In this study, ethnoscience specifically the traditional practice of red-brick making is used as a learning context, not as the main science content. The local process of making bricks provides a real-life foundation for exploring concepts such as heat transfer and environmental impact in a culturally relevant way.One of the common ethnoscience or community habits is the making of red bricks. Red brick is certainly familiar to everyone, of course for students because the red brick making industry is easy to find. If adjusted to the learning outcomes of science subjects in the Merdeka Curriculum, the learning outcome of heat transfer material is that students are able to measure the amount of temperature caused by the given heat energy, as well as being able to distinguish heat insulators and conductors. Then, environmental pollution material is related to pollution material in the ecology chapter with the Learning Outcome (CP), namely students are able to design efforts to prevent and overcome pollution and climate change.

This STEM-based ethnoscience learning process integrates indigenous science knowledge with the use of technology for real problem-solving. Ethnoscience-STEM learning is implemented through silo, embedded, and integrated approaches by considering the limits in reconstructing science (Khoiri & Sunarno, 2018). STEM learning with an ethnoscience approach encourages students to use their STEM knowledge and skills to identify problems in the context of culture or local wisdom, and to find solutions. The holistic approach of STEM (Science, Technology, Engineering, and Mathematics) from four disciplines offers great potential for improving the quality of learning. STEM motivates students to become proficient in designing, developing, and utilizing technology and to apply it in an integrated way to solve problems (Kapila & Iskander, 2014). Thus, this ethnoscience STEM learning can be an implementation in overcoming educational problems regarding existing problem-solving skills.

STEM education is an interdisciplinary approach that integrates science, technology, engineering, and mathematics to solve real-world problems. Electronic module is not just an ordinary digital learning tool, but it is specially designed so that the students' learning process involves STEM-based problem-solving activities. In this way, the module helps develop important 21st-century skills such as critical thinking, creativity, and problem solving.

The materials and activities in the electronic module are arranged according to STEM principles, where students are encouraged to observe phenomena, analyze problems, design appropriate solutions, and apply science, technology, engineering, and mathematics concepts in an integrated manner during the learning process (Adhelacahya et al., 2023). A module is a type of instructional material that consists of a summary of content that is comprehensively and methodically designed to help learners perform learning and master the specified learning objectives. According to Husein (2010), electronic modules that use technology have the advantage of electronic module facilities such as images, audio, and video that can create a learning experience for students, increase student motivation, and improve student problem-solving skills.

In this study, we focus on the traditional practice of red brick making, a ubiquitous ethnoscience, as a context for exploring the concepts of heat transfer and environmental pollution aligned with national standards. By embedding these scientific principles in a familiar cultural activity, we aimed to bridge students' everyday experiences with formal scientific inquiry.

Some previous studies have developed learning materials using a combination of PBL and ethnoscience. For instance, Sudarmin et al. (2023) created an Ethno-STEM project-based learning design for a secondary metabolite chemistry course aimed at improving students' conservation and entrepreneurial character. However, these studies often focus on character development or specific chemistry content at the higher education level. Meanwhile few studies have developed interactive electronic modules that integrate PBL, STEM, and ethnoscience to target problem-solving skills among junior high school students. In particular, the use of local ethnoscience contexts such as red-brick making in PBL-STEM digital learning environments remains underexplored. This study seeks to fill that gap by designing, implementing, and evaluating a contextualized electronic module for middle school science.

Based on the problems described above, the researcher is interested in conducting development research of teaching materials in the form of Electronic Modules Based on PBL-STEM in Ethnoscience Learning "Making Red Brick" to Improve Students' Problem-Solving Skills. In detail, the purpose of this research is: (1) to produce an electronic science modules based on PBL-STEM in ethnoscience learning "red brick making" that are feasible to improve problem solving skills; (2) to determine the practicality of electronic science modules based on PBL-STEM in ethnoscience learning "red brick making" " has been produced in improving problem solving skills; (3) to determine the effectiveness of electronic science modules based on PBL-STEM in ethnoscience learning "red brick making" has been produced in improving problem solving skills

METHOD

Research Design

This research is a type of development research that follows the 4-D development model (Define, Design, Develop, Disseminate) from

Thiagarajan & Semmel (1974). In order to evaluate the effectiveness of the developed electronic module, this study also employed a quasi-experimental design, specifically a one-group pretest-posttest approach. In the 4-D model, the develop stage includes product validation and limited trials. To measure the impact of the product, this study incorporated an experimental evaluation. Therefore, the one-group pretest-posttest design was applied specifically during the testing phase to assess the effectiveness of the developed module in improving students' problem-solving skills. Figure 1 illustrates the research design (Kuntjojo, 2009: 46).

O1 Pretest	X	O2 Posttest

Figure 1. One group pretest-posttest

Research Objects

This development research was conducted at SMP Negeri 3 Banguntapan, the period of this research was from March to May 2023. The subjects of this study were 2 lecturers of material and media experts, science teachers and 30 students of class VII G.

Data Collection Techniques

The research instruments used include a science teacher interview sheet, an electronic module validation sheet, a student and science teacher response questionnaire on the electronic module, a learning implementation observation sheet, and pretest and posttest questions.

The electronic module's feasibility analysis involved calculating the average score, which was then converted into a four-scale qualitative value, as shown in Table 1.

Table 1. Conversion of actual score to scale four

Range	Category
$Mi+1.5Sdi<X \leq Mi+3Sdi$	Very feasible
$Mi<X \leq Mi+1.5Sdi$	Feasible
$Mi-1.5Sdi<X \leq Mi$	Less feasible
$Mi-3Sdi<X \leq Mi-1.5Sdi$	Not feasible

The practicality of the electronic module was evaluated by students and science teachers. The average score was calculated and then converted into a four-scale value, as shown in Table 2.

Table 2. Conversion of actual score to scale four

Range	Category
$Mi+1.5Sdi<X \leq Mi+3Sdi$	Very Practical
$Mi<X \leq Mi+1.5Sdi$	Practical
$Mi-1.5Sdi<X \leq Mi$	Less Practical
$Mi-3Sdi<X \leq Mi-1.5Sdi$	Not Practical

The electronic module's effectiveness is demonstrated by the improvement in the problem-solving skills of students, as measured by pretest and posttest scores. This improvement was analyzed using the prerequisite test, paired sample t-test, and effect size. The normality of the data was assessed using the Shapiro-Wilk test with the SPSS 25 application.

The effect size test in this study was used to determine the effect of using electronic science modules based on PBL-STEM on ethnoscience learning on students' problem-solving skills. The effect size in this study was calculated using the following d Cohen's formula.

$$ES = \frac{Me - Mc}{SD}$$

Figure 2. d Cohen's effect size formula

The effect size value can be seen based on the Cohen's Delta value, which is then converted to qualitative data in Table 3.

Table 3. Effect size category

Range	Category
$0 < d \leq 0.2$	Small effect
$0.2 < d \leq 0.5$	Medium effect
$0.5 < d \leq 0.8$	Large effect
$d > 0.8$	Very large effect

RESULTS AND DISCUSSION

The type of research used is research and development (R&D) using the 4-D model, which consists of four stages: define, design, develop, and disseminate.

The define phase aims to identify and determine the learning requirements, which include learning objectives and learning material constraints. The steps are front-end analysis, learner analysis, task analysis, concept analysis, and specification of learning objectives. The planning stage (design) aims to design the developed electronic module with steps including instrument preparation, media selection, format selection, and making initial designs. The development stage aims to produce revised electronic module products based on input from experts. This stage will be reviewed by the lectures who will revise and produce Draft II. After this, the electronic module was validated by expert lecturers on material and media aspects, which were then revised and produced draft III as a qualified electronic module and could be tested. The Disseminate stage aims to disseminate the limited use of electronic modules.

The validation stage aims to test the feasibility of the electronic science module from the material aspect and media aspect according to the validator teacher. The validation of the material feasibility is checked from three aspects, namely the suitability of the material, the language, and the presentation. The validation assessment results by Expert Lecturer I and Expert Lecturer II are presented in Table 4.

Table 4. Results of material feasibility assessment of electronic modules by expert lecturers

No	Aspects	Average	Max	Category
1	Appropriateness of material	18	20	Very Feasible
2	Language	10	12	Very Feasible
3	Presentation	11.5	12	Very Feasible
	All aspects	39.5	44	Very Feasible

Based on Table 4, the average score obtained from the assessment of the feasibility of the material in all aspects is 39.5 out of the total score of 44 with the category "very feasible", so it is feasible to use in the learning process. The expert lecturer's assessment of the feasibility of the material has several suggestions and comments, in general there are writing or language rules, inappropriate learning outcomes, learning objectives, incorrect question writing procedures and the material contained in the electronic module. This is the same as the characteristics of electronic modules according to Daryanto & Dwicahyono (2014), namely that the electronic module must fulfill the characteristics of self-instruction, which includes the clarity of objectives, material, questions, and language used. In addition, it must also fulfill the characters of self-contained, stand-alone, adaptive, and user-friendly. Kautsari et al., (2023) stated that a good module is a module whose material is presented as a whole, makes it easy for learners to understand it, allows learners to explore freely, presents varied questions, and is communicative.

The validation of media feasibility consists of three aspects, namely software aspects, learning design, and visual communication. The results of the validation assessment by expert lecturer I and expert lecturer II are shown in Table 5.

Table 5. Results of media feasibility assessment of electronic modules by expert lecturers

No	Aspects	Average	Max	Category
1	Software	14,5	15	Very Feasible
2	Learning design	7	8	Very Feasible
3	Attractiveness	11	12	Very Feasible
	All aspects	32,5	36	Very Feasible

Based on Table 5, the average score of media feasibility in all aspects is 32.5 out of a total score of 36 with the category "very feasible", so it is suitable for use in the learning process. The expert lecturer's assessment of the media feasibility aspect has several suggestions and comments, namely, adding images and videos, adding instrumental music, and adjusting the location of captions. This is in line with the statement of Rusman, et al. (2013), which is that the components of computer-based instructional materials include support for links that lead to information. It can be said that the presence of hyperlinks can support the complexity of the material presented in the electronic module teaching materials. This means that students can access additional information about the material through the Internet network or YouTube, which is already available, so that students' insights are also increased.

Data from students' responses to electronic modules are used to determine the practicality of the electronic modules developed. The students' response questionnaire consists of 4 aspects, namely content feasibility, language, graphics, and usability. The data obtained from the students' response questionnaire to the electronic module can be seen in Table 6.

Table 6. Results of students' response to electronic module

No	Aspects	Average	Max	Category
1	Content feasibility	26.3	32	Very Practical
2	Language	19.2	24	Practical
3	Graphics	19.7	24	Very Practical
4	Usability	32.2	40	Practical
	All aspects	97.7	120	Very Practical

Table 6 shows that all aspects of the student response questionnaire have an average of 97.7 out of a maximum score of 120, which means that the score of the student response questionnaire is categorized as "very practical", so the developed electronic module is very practical to use in science learning. Electronic modules are interactive with image, audio and video facilities and easy to use anywhere and anytime, so they can increase motivation and make it easier to understand and solve science problems. This is in line with the statement of Husein (2010) that electronic modules that use technology have the advantage of electronic module facilities such as images, audio, and video can create a learning experience for students, increase student motivation, and improve student problem-solving skills. The growth of technology can facilitate learning activities, especially the development of electronic module teaching materials that have the advantages of images, videos, and animations that can improve students' problem-solving skills. Asri & Dwiningsih (2022) also stated that in the module, the language must use communicative language, the use of correct vocabulary is also needed so that the material is easily understood by students.

Data on the results of the science teacher's response to the Electronic Module Based on PBL-STEM on Ethnoscience Learning of Red Brick Making aims to determine the practicality of the product in terms of material aspects, appearance and usage aspects, and usability aspects. Data on the results of science teacher responses to electronic modules can be seen in Table 7.

Table 7. Result of science teacher to electronic module

No	Aspects	Average	Max	Category
1	Material	16	16	Very Practical
2	Appearance and usage	24	24	Very Practical
3	Usability	20	20	Very Practical
	All aspects	60	60	Very Practical

Based on Table 7, it can be concluded that the average score of all aspects of the science teacher response questionnaire is 60 out of a maximum score of 60 with the category of "very practical", so it can be concluded that the electronic module is very practical to use in science learning. The inclusion of an electronic module that integrates ethnoscience and STEM requires students to apply the knowledge acquired in the module to real-world scenarios in their environment, thereby enhancing their problem-solving abilities. Research conducted by Kamila et al. (2024) showed that the development of ethnoscience-based integrated science e-modules with the theme of *terasi rebon* obtained a very high level of validity. The implementation of ethnoscience in e-modules allows students to understand concrete forms of local culture while constructing community knowledge into structured scientific knowledge. Lestari et al. (2017) have also affirmed that STEM-based learning activities can be utilized as teaching aids and have a positive impact on improving reasoning skills, conceptual understanding, critical thinking, creative thinking, data presentation, interpretation, and condensation. This ultimately leads to a better understanding of fundamental concepts.

The electronic module that was found valid was tested at SMP N 3 Banguntapan. The pre-test and post-test questions included four indicators of Polya's problem-solving method. These questions were empirically tested to identify the valid and invalid ones. The valid questions were then tested in class VII G at SMP N 3 Banguntapan. The test results were analyzed and showed an average pretest score of 62.05 and an average posttest score of 80.10. The results of the analysis of the pretest and posttest scores can be seen in Figure 3.

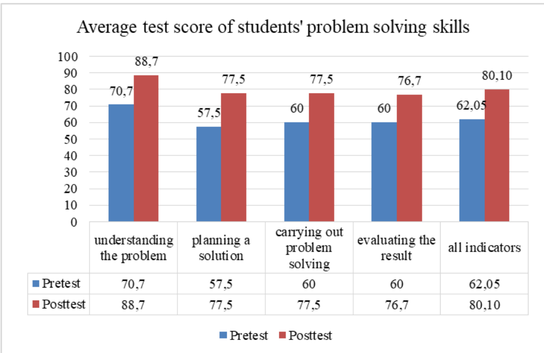

Figure 3. Average problem-solving skills test score

According to Figure 3, the average score of students in the posttest is higher than the average score in the pretest for each question indicator and overall. The pretest average for all problem-solving indicators is 62.05, whereas the posttest average for students' problem-solving skills is 80.10. This indicates that the use of electronic modules leads to a significant improvement in each aspect of students' problem-solving skills.

Based on the results of the paired sample t-test, the two-tailed significance value is 0.000

which is <0.05. This indicates that there is a significant difference between the pretest and posttest scores of problem-solving skills after using electronic science modules based on PBL-STEM in the ethnoscience learning "red brick making". Furthermore, the calculated t-value is 11.912 which is a positive number. This signifies that the posttest score is higher than the pretest score.

The results of the pretest and posttest of problem-solving skills were also analyzed using the effect size test which aims to determine the effect of using electronic modules. The recapitulation results of the effect size test on the pretest and posttest of each indicator of problem-solving skills can be seen in Figure 4.

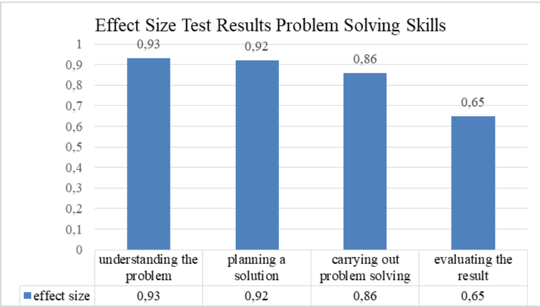

Figure 4. Effect size test results of problem-solving skill test

According to Figure 4, the indicator that has the highest effect size value for problem-solving skills is the ability to understand the problem. This indicator has a very large effect with a value of 0.93. This skill is the first step for students in working on problem-solving, so it only requires the ability to understand and identify problems based on existing information If students struggle with analyzing the problem, it will be difficult for them to solve it. Therefore, as stated by Gilad & Loeb (1983), understanding problems is the initial step for students to solve problems, and to do so, they must be able to understand the situation. Students must be able to understand problems using language that resembles problems in solving problems with Polya indicators.

The indicator with the lowest effect size value is the indicator of rechecking/evaluating, which has a value of 0.65 with a large effect category. This indicator requires the skill to critically check the correctness and effectiveness of the solution obtained from solution planning, in addition to the fact that students generally do not recheck the chosen answer because they are confident of their choice. This is in line with Nugraha & Luvy's (2018) statement that students were unable to provide evidence that the given solution is correct. In this indicator, students only work to solve the problem without convincing themselves of the correctness of the solution.

Overall, the results of the effect size test value of students' problem-solving skill amounted to 1.727 with a very large category, so that the use of Electronic Modules Based on PBL-STEM in Ethnoscience Learning "Red Brick Making" developed has a very large influence on improving students' problem-solving skill. According to Cohen (1998), if the effect size value is more than 0.8 ($d > 0.8$), it is considered to have a "very large" effect.

The relationship between the feasibility, practicality, and effectiveness of electronic modules is clear. Electronic modules categorized as very feasible and very practical tend to be more effective because they meet students' learning needs and are easy to use. Feasibility ensures the content on the e-module is valid in terms of material, appearance, and aligned with the material and learning objectives, while practicality ensures the content and design are attractive and accessible. Both support the improvement of problem-solving abilities because students are more actively involved and focused in the learning process. These qualities create a supportive environment that allows students to focus on knowledge application and problem solving, which is reflected in improved post-test scores and large effect sizes. This sequence of alignment between design, implementation and impact confirms the power of the module.

Based on the results of the study, it can be seen that the electronic science module based on PBL-STEM on ethnoscience learning "Red Brick Making" is effective in improving problem-solving skills. Electronic modules are designed to present STEM information and concepts interactively and engagingly. In the development of this module, the ethnoscience approach is utilized to establish a connection between STEM concepts and local culture, which helps learners see the relationship between STEM concepts and culture in the students' daily lives. This is in line with the research of Nurhasnah et al. (2022), ethnoscience-based STEM learning (STEM-Etno) can be an alternative for science teachers in teaching science concepts by connecting indigenous scientific knowledge with scientific science. Through ethnoscience-based STEM learning, students can develop an attitude of love for the culture and character of their nation. In addition, students can understand natural events around them and relate them to the knowledge they are learning.

STEM learning with an ethnoscience approach encourages students to use their STEM knowledge and skills to identify problems in the context of culture or local wisdom, and to find solutions. The holistic approach of STEM (Science, Technology, Engineering, and Mathematics) from four disciplines offers great potential for improving the quality of learning. STEM motivates students to become proficient in designing, developing, and utilizing technology and to apply it in an integrated way to solve problems (Kapila & Iskander, 2014).

STEM-PBL based electronic modules can improve problem-solving skills in ethnoscience by providing contextualized and interactive learning experiences, where students are invited to identify real problems related to local culture, design science and technology-based solutions, and collaborate in groups. This approach encourages students to actively apply scientific concepts through problem-based projects relevant to local wisdom, so that they are able to integrate cultural knowledge with critical and creative thinking processes. In addition, the use of interactive and digital-based e-modules makes it easier for students to learn independently and reflectively, strengthening the learning process that is oriented towards solving real problems in the context of ethnoscience.

Figure 5. Electronic module based on PBL-STEM in ethnoscience learning “red brick making”

CONCLUSIONS AND SUGGESTIONS

Conclusions

Based on the results of research and analysis, it can be concluded that: (1) there has been produced electronic modules based on PBL-STEM on ethnoscience learning “red brick making” is very feasible to use in science learning; (2) electronic modules based on PBL-STEM on ethnoscience learning “red brick making” has been produced is very practical in improving students’ problem solving skills (3) electronic modules based on PBL-STEM on ethnoscience learning “red brick making” has been produce is very effective in improving students’ problem solving skills.

Suggestions

Based on the final results and limitations of the study, the research, the suggestions that can be given are: 1) there is a need for maximum utilization of facilities and infrastructure, such as computer laboratories during learning; 2) before using the “PBL-STEM Based Science Electronic Module on Ethnoscience Learning “Red Brick Making”, it is required to give advanced direction to students in using the heyzine flipbook and live worksheet applications; 3) PBL-STEM-based science electronic modules on ethnoscience learning can be further developed on other science materials that are relevant to the local context of students.

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