23 (2), 2022, 754-765

Jurnal Pendidikan MIPA

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Design and Validation of STEM Integrated e-Modules on Environmental Pollution to Improve Problem-Solving Skills

Dina Else Fernandu[1], Abdurrahman[2], Dewi Lengkana[2]

[1]Graduate School of Science Education, Universitas Lampung, Indonesia.

[2]Department of Science Education, Universitas Lampung, Indonesia

Abstract: Scientific literacy about awareness and problem-solving skills related to environmental issues is one of the competencies that must be instilled in students in science learning in the future. However, teaching materials that have the potential to instill these competencies have not been easily accessed by students. The purpose of this study was to design and validate an integrated electronic module with a STEM approach on environmental pollution materials to improve problem-solving skills. This research uses Research and Development (R&D) method with ADDIE (Analysis, Design, Development, Implementation, Evaluation). The E-Module is designed for Project-Based learning (PJBL-STEM) with steps of Reflection, Research, Discovery, Application and Communication. The results of construct validation obtained a percentage of 89.4%, content validation yielded a percentage of 95% and language validation 91.7% with all very valid criteria. Based on the pre-test and post-test trials of the use of e-modules carried out on students, it was found that the N-gain was 0.40 with problem-solving criteria moderate for students. Overall, the research show that the developed e-module is validated with a very valid category and can improve students problem-solving skills.

Keywords: e-module, STEM, PjBL, problem-solving skills.

Abstrak: *Literasi sains tentang kesadaran and keterampilan menyelesaikan masalah terkait isu lingkungan merupakan salah satu kompetensi yang harus ditanamkan kepada siswa dalam pembelajaran sains di masa depan. Namun, bahan ajar yang berpotensi untuk menanamkan kompetensi tersebut belum dapat diakes oleh siswa dengan mudah. Tujuan penelitian ini untuk mendesain and memvalidasi module elektronik terintegrasi pendekatan STEM pada materi pencemaran lingkungan untuk meningkatkan kemampuan pemecahan masalah. Penelitian ini menggunakan metode Research and Development dengan desain ADDIE (Analisis, Disain, Pengembangan, Implementasi, Evaluasi). E-Module dirancang untuk pembelajaran berbasis Projek (PJBL-STEM) dengan Langkah-langkah Refleksi, Melakukan penyelidikan, Menemukan informasi, Menerapkan, Mengkomunikasikan. Hasil validasi konstruk diperoleh persentase 89.4%, validasi isi menghasilkan persentase 95% and validasi bahasa 91.7% dengan kriteria seluruhnya sangat valid. Berdasarkan pre-test and post-test uji coba penggunaan e-module yang dilakukan pada siswa, didapatkan N-gain 0,40 dengan kriteria pemecahan masalah pada siswa yaitu seandg. Secara keseluruhan, temuan penelitian menunjukkan bahwa e-module yang dikembangkan tervalidasi dengan kategori sangat valid and dapat meningkatkan kemampuan pemecahan masalah pada siswa.*

Kata kunci: *modul elektronik, STEM, PjBL, kemampuan pemecahan masalah.*

▪ INTRODUCTION

Problem-solving skils is an ability that must be possessed by students to find answers to a problem through a process that involves searching and managing information (Fitriyah, et al., 2018; Susiana, et al., 2018). Based on the results of research conducted by Rahayu (2021), students have problem-solving skills with low

Dina Else Fernandu
*Email: Dinaelsefernandu@gmail.com

DOI: http://dx.doi.org/10.23960/jpmipa/v23i2.pp754-765
Received: 17 April 2022
Accepted: 22 June 2022
Published: 11 July 2022

categories on environmental pollution material. The low problem-solving skills also appears in cases of environmental pollution in Indonesia. This is supported by national data published by the Ministry of Environment and Forestry (2020) regarding the 2019 Environmental Quality Index, Indonesia has an index value of 66.55 which is categorized as quite good. Ministry of Environment and Forestry in 2019 in Andianti, et al. (2020) recorded that from 98 rivers in Indonesia 54 rivers were lightly polluted, 6 rivers were lightly polluted-moderately polluted, and 38 rivers were lightly polluted-severely polluted. This situation is worse than the previous year in 2018, from 97 rivers in Indonesia, 67 rivers are lightly polluted, 5 rivers are lightly polluted and 25 rivers are lightly polluted and heavily polluted.

Environmental pollution itself is included in a complex problem and various disciplines are involved, it can also be called an ill structured problem. Problems that are not well structured are one of the types of problems that are often encountered in everyday life and are not limited by the domain of content learned in class (Jonassen, 2011). Unstructured problems represent complex challenges, the relevant causes of which are often unclear. Examples of such problems are sustainability issues such as climate change, environmental degradation or resource scarcity (Mitchell & Walinga, 2017). Groups in the problem solution process can play a crucial role. diversity plays an important role in the solution of ill-structured problems (Laureiro & Brusoni, 2018) Based on the results of research conducted by Supeno, et al. (2020) shows that the results of the ability of students to recognize problems, plan strategies, and apply strategies to ill structured problems are still largely unsatisfactory.

We need a learning model that is in accorandce with the needs of achieving problem-solving skills integrated with the STEM approach. According to Thovawira, F. A., Safitri, I., Supartik, et al. (2020), Project-based learning on environmental pollution material shows significant improvements in students' abilities, learning motivation, and student learning outcomes. In addition, the STEM-PjBL learning model has a significant effect on increasing students' abilities (Sukmawijaya, et al. (2019). Boss and Kraus (2007), define a project-based learning model as a learning model that emphasizes the activities of students in solving various open-ended problems and applying their knowledge in working on a project to produce a certain authentic product.

Integrated learning with the STEM approach is carried out to support the implementation of the use of E-modules and project-based learning models in environmental pollution materials. Implementing an integrated STEM approach in an educational system that has a very established segregated and discipline-based structure requires profound restructuring of the curriculum and lessons (Nadelson & Seifert, 2017). To apply an integrated STEM approach in learning, teachers must have knowledge of the content of science, engineering technology, and mathematics that they will apply (Eckman et al., 2016). The fact of the findings of El-Deghaidy & Mansour (2015), Teachers do not have sufficient understanding of T (technology) in STEM and they may not have an adequate understanding of the nature of science and technology, the interaction between the two disciplines. In addition to the challenge of finding inadequate resources and teacher knowledge, another major challenge for implementing an integrated STEM approach in learning is the lack of adequate information on how integrated STEM teaching and learning should be carried out (Thibaut, L., 2018).

Teaching materials are also important component in the application of learning in the classroom. The selection of teaching materials has more impact on student learning than the effectiveness of teachers (Chingos, 2012). One of the learning media used in learning is a module. Turel & Sanal (2018), states that electronic learning materials developed by integrating various text formats that can be alternative teaching materials with different functions so that they can be called electronic smart books. Based on research conducted by Almuharomah, et al. (2019); Zulaiha and Kusuma (2020), the module which is prepared as an integrated STEM learning material is able to improve 21st century skills and motivate students. According to Marpaung (2020), the use of modules in the learning process is effective for improving student learning outcomes. The use of modules supports student learning in the classroom, besides the modules chosen must also be in accorandce with the needs of technological advances in the era of the industrial revolution 4.0.

Technological progress cannot be separated in learning carried out in the 4.0 revolution era. Using electronic-based teaching materials is an option that can be applied in learning. According to Shoimin (2014) in the application of learning innovation and creation, it is necessary to master the material that is managed and displayed professionally. Another study conducted by Gayratovich, E, N., & Yuldashevna, T. O. (2020), using electronic media in the learning process also contributes to increasing the effectiveness of mastery of subjects for all fields of education, as well as increasing the quality and efficiency of growing learning. The use of electronic learning media is an option for the distance learning period as implemented during the covid-19 pandemic. Based on the findings of Almazova, N., et al. (2020), it takes a computer literacy level, electronic environment and support, academic staff readiness and students' readiness for online learning to prepare for electronic media-based learning. One of the applications is by using an electronic-based module. E-Modules are learning materials that have been systematically designed based on a certain curriculum and designed in the form of a certain time unit that can be displayed using electronic devices (Priatna, et al. 2017). Puspitasari, et al. (2019), states that the use of electronic modules is also effectively implemented in student learning. The use of E-Modules in learning as a renewable innovation effort for educators to improve students' thinking skills according to the demands of the 21st century (Pujiati, et al. 2019).

▪ METHOD

This study uses a research and development design (R&D) with the ADDIE development model (Analyze, Design, Development, Implementation, Evaluation). This research was conducted in November 2021 at SMP Global Maandi, Bandar Lampung for seventh grade students with the subject of development research, namely E-Modules. The research was conducted to produce a product, namely teaching materials in the form of an integrated E-Module with a STEM approach on environmental pollution materials. This research consists of five stages, needs analysis, instrument design, instrument development, implementation, and evaluation. The stages are as follows.

First, stage of analysis, at the analysis stage, the researcher analyzes the teacher's needs for teaching materials in the form of an integrated e-module with a STEM

approach that can improve problem-solving abilities. In addition, a literature study was also carried out by reviewing literature and research results relevant to development research, namely literature studies on E-Modules, STEM (Science, Technology, Engineering and Mathematics), students' problem-solving abilities, and Project Based Learning models. Second, design phase, the design phase carried out by the researcher includes, compiling the structural framework of the E-Module teaching materials, determining the systematic presentation of the material, illustrations, visualizations, writing a draft of the STEM integrated E-Module product, and making story boards. At this stage, the researcher also made the validity of the E-Module instrument and pretest-posttest questions. Third, development phase, the phase preparation of teaching materials, product development, in the form of E-Modules is carried out according to the designs that have been prepared. The e-module developed at this stage is a product that can already be implemented. Fourth, implementation phase, application of science learning by using an electronic module that was developed taking into account the stages of STEM-integrated project-based learning. Fifth, evaluation phase, the evaluation stage is carried out during the analysis, design, development and implementation phase. Evaluation is done to determine the quality of the product and the results are used as feedback to improve the product. Evaluation is also carried out to determine the level of problem-solving skills.

E-module integrated STEM environmental pollution material to improve problem-solving skills.

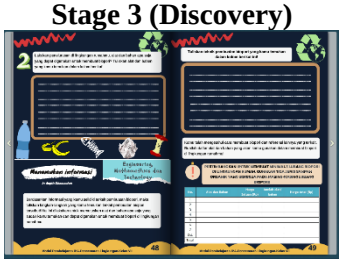
The e-module integrated with the STEM approach to environmental pollution material to improve problem-solving skills is an electronic learning medium that is compiled based on the systematics of module with STEM-Project-based learning stages (PJBL-STEM). The stages of integrated project-based learning using the STEM approach are listed in the following table.

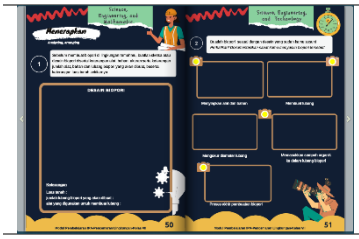
Table 1. Stages of integrated project-based learning using the STEM approach

Stages of Learning	Learning Activities
Stage 1 Reflection	At this stage, it is expected to be able to bring students into the context of the problem and inspire students to conduct investigations
Stage 2 Research	The stages carried out, so that students can search for information while still being guided by the teacher
Stage 3 Discovery	At this stage, there are collaboration between students in finding information and link it to findings of the information obtained
Stage 4 Application	This stage is carried out to conduct trials of the product or solution submitted to solve the problem
Stage 5 Communication	Delivery of products or solutions designed to communication, collaboration skills and receive and apply constructive feedback

Design the e-module display using a graphic design application, namely Canva application, then to make an electronic module using the Kvisoft FlipBook Maker application. The following is a display of an integrated e-module with a STEM approach with Project-based Learning stages on environmental pollution material to improve problem-solving abilities.

Table 2. E-module display

E-Module Display	Description
Cover and Mind Map 	E-Module identity in the form of cover, author's name, class, subject and subject matter Mind map for environmental pollution learning materials
Stage 1 (Reflection) 	***Science* (S)** - Starting with phenomena related to environmental pollution due to waste - Accompanied by questions related to the phenomenon of pollution due to waste - Using concepts to explain the phenomenon of the impact of pollution due to waste - Build motivation and interest in the phenomenon of pollution due to waste ***Technology* (T)** - Conducting investigations using gadget media (watching videos) as an application of the use of technology
Stage 2 (Research) 	***Science* (S)** - Investigating the solution to pollution caused by plastic waste by making biopori using single-use plastic bottles - Understand the scientific steps taken to investigate the solution ***Technology* (T)** - Conducting investigations using gadget media as the application of technology use
Stage 3 (Discovery) 	***Science* (S)** - Analyze the need for product creation from the selected idea solution ***Mathematics* (M)** - Calculation of the costs required to produce the product ***Technology* (T)** - Conducting investigations using gadget media as the application of technology use ***Engineering* (E)** - List the needs related to the technical implementation of the implementation of the solution - Designing the biopore design that will be made
Stage 4 (Application)	***Science* (S)** - Deciding on the preparation of products with details of relevant requirements ***Engineering* (E)** - Develop products based on the designed design

	*Mathematics (M)* - Mathematical calculation formulas applied to product design
Stage 5 (Communication) 	***Science, Technology, Engineering, Mathematics* (STEM)** - Communicate ideas and design decisions with scientific explanations

Data Analysis and Techniques

Product validation data is known by using a validation sheet instrument. Validation data consists of material content validation data containing the feasibility of environmental pollution material, media construct validation data and language validation data used in e-modules. On the validation sheet using an assessment with Guttman Scale. Answers are made with the highest score of 1 (one) for yes answers and the lowest 0 (zero) for no answers (Sugiyono, 2013). The results obtained are calculated as a percentage by dividing the score obtained by the maximum score, and multiplied by 100%. Then, the results obtained are interpreted, 81-100% very valid, 61-80% valid, 41-60% quite valid, 21-40% less valid, and 0-20% invalid (Riduwan, 2010).

Furthermore, the test data of students' problem-solving skills were taken at the implementation stage of the small group trial of the STEM integrated E-Module product being developed. The data was obtained from the pretest-posttest question instrument which was given during implementation to students.

Each student gets a score for the correct answer. Furthermore, the N-Gain calculation is also carried out to see the amount of students' abilities. Calculation on the value of NGain by dividing the results of reducing the posttest and pretest scores by the results of reducing the maximum score with the pretest score. The criteria for interpreting the NGain score, score >70 high, 0,30-0,70 medium, and ≤ 0,30 low (Lestari, E. Karunia, 2017).

▪ RESULT AND DISSCUSSION

The module has the characteristics of Self Instruction (can be used for independent study), Self-contained (learning materials are prepared thoroughly), Stand Alone (not dependent on teaching materials or other media), Adaptive (adjusting the development of science and technology), and User Friendly (easy to use) (Daryanto, 2013). The learning modules developed are designed in electronic form (E-Modules) to make it easier for students to access them, especially when distance learning is being implemented during the COVID-19 pandemic (Nurmayanti, 2021). In the e-module there are audio, audio-visual, and multimedia as learning media that can be accessed using a personal computer or laptop by students. Text, photos, graphic arts, sound,

animation, and video that are integrated into multimedia are elements that can be used in electronic learning media (Laksana, D., N., L., et al. 2019).

The module developed in this research is used to improve the problem-solving skills of students. E-module used to improve problem-solving skills gets an n-gain value of 0.5 with a medium category. The problem-solving dimensions used were adapted from research conducted by Cheng, et al. (2018), consists of five dimensions, including identifying known conceptions that might help solve the problem, providing possible explanations for the problem, providing two possibilities provide two possible solutions to solve the problem, evaluate their solutions and decide which one is the most applicable solution and interpret the data and results. In addition, the developed e-module is also adapted to the stages of the project-based learning model. According to Laboy & Rush (2010), there are five stages carried out by students, including Reflection, Conducting Investigation (Research), Finding information (Discovery), Application, Communication.

The e-module was developed in accorandce with core competencies, basic competencies, objectives, instructions for use, material descriptions consisting of 3 sub-chapters, namely the process of environmental pollution, impacts and efforts to overcome environmental pollution, and solutions to environmental pollution. In addition, each sub-chapter is equipped with a summary, practice questions and discussion assignments. In the sub-chapter on solutions to environmental pollution, it is also accompanied by instructions for implementing projects that can be carried out by students in their learning.

In the development of e-module products, validation data from experts is needed to assess the feasibility of e-modules to be used in learning in a wide scope and test questions used to measure problem-solving skills. This e-module was validated by constructors, materials and language experts. In the construct validation sheet used there are 18 indicators, with 27 statement items used, including the Conformity of Handout Construction Developed with Ideal E-Module Format, E-Module Display, Conformity of E-Module Construction Developed with STEM Integrated PPA Syntax, Construction Conformity E-Module with STEM (Science, Technology, Engineering and Mathematical) approach, Suitability of E-Module Construction Developed with Problem-solving Ability. The data obtained are as follows:

Table 3. Construct validity test results by experts

No.	Aspects measured	Interpretation	Percentage
1.	Compatibility of Handout Construction Developed with Ideal E-Module Format	67%	Valid
2.	E-Module Display	100%	Very Valid
3.	Compatibility of E-Module Construction Developed with STEM Integrated PPA Syntax	80%	Valid
4.	Compatibility of E-Module Construction with STEM (Science, Technology, Engineering and Mathematical) approach	100%	Very Valid
5.	Compatibility of Developed E-Module Construction with Problem-Solving skills	100%	Very Valid

Average	89,4%	Very Valid

Based on the histogram of the construct validation results obtained by the experts, the average percentage obtained is 87%, interpreted according to the interpretation table, the result is that the e-module developed is very valid, can be used in broad learning. Furthermore, on the material validation sheet there are 10 indicators consisting of 20 statement items. The following is a table of material validation test results:

Table 4. Material validation test results by experts

No.	Statement	Percentage	Interpretation
1.	Conformity of the contents of the E-Module with KI, KD and Indicators	100%	Very Valid
2.	The suitability of the concepts and definitions presented in	100%	Very Valid
3.	Accurate E-Module	100%	Very Valid
4.	Facts and data suitability, case examples presented in the E-Module are in accorandce with real life	100%	Very Valid
5.	The suitability of the images and tables presented in the E-Module is in accorandce with the description of the material and daily life.	100%	Very Valid
6.	The suitability of the video presented in the E-Module is in accorandce with the description of the material	100%	Very Valid
7.	Suitability The language used in the E-Module is communicative and easy to understand.	50%	Quite Valid
8.	Suitability of practice questions with indicators	100%	Very Valid
9.	Suitability of material description	100%	Very Valid
10.	Conformity of the summary and competency test with the material	100%	Very Valid
	Average	95%	Sangat Valid

Based on the histogram of the material validation results obtained by experts, the average percentage obtained is 95%, interpreted according to the interpretation table, the result is that the e-module developed is very valid, can be used in broad learning.

On the Language Validation sheet there are 6 indicators consisting of 7 statement items. Based on this, the results obtained from the validation of linguists are as follows:

Table 5. Language validity test results by experts

No.	Statement	Percentage	Interpretation
1.	The language used is communicative, does not cause double meaning, according to students' thinking	100%	Very Valid
2.	The sentences used can be understood by students	100%	Very Valid
3.	Appropriate text size used	100%	Very Valid
4.	The standard word used is correct	100%	Very Valid

5.	The grammar and punctuation used are correct	50%	Quite Valid
6.	The sentence used is effective	100%	Very Valid
	Average	91,7%	Very Valid

Based on the histogram of the construct validation results obtained by the experts, the average percentage obtained is 91.7%, interpreted according to the interpretation table, the result is that the e-module developed is very valid, can be used in broad learning. Overall, the validation tests obtained are as follows:

Table 6. The average results of the validity test

No.	Type of Validation	Percentage	Interpretation
1.	Construct	89,4%	Very Valid
2.	Content	95%	Very Valid
3.	Language	91,7%	Very Valid
	Average	91,9%	Very Valid

Based on the overall data related to the validation carried out by experts, it was obtained an average of 91.9% with a very valid interpretation. Thus, the STEM integrated e-module on environmental pollution material to improve problem-solving skills developed is very valid for use in learning.

In addition to validity, data on the effectiveness of using modules to measure students' problem-solving skills were also obtained after learning using the developed e-module. Problem-solving skills was measured using pretest and posttest questions consisting of 10 essay questions that were adjusted to problem-solving indicators. Pretest questions are given before learning begins, then posttest questions are given when learning has been carried out using the e-module that has been developed.

The results of the test items used in the pretest and posttest were calculated to determine the validity and reliability of the problem-solving skills test questions. The highest score in the pretest was 73, while the lowest score was 45, with an average score of 59. In the posttest the highest score was 86 and the lowest score was 70, with an average score of 75. In general, there was an increase in the value of the pretest and posttest obtained. Furthermore, from the results obtained, calculations are carried out to get the N-gain value. N-Gain calculation results from the pretest posttest problem-solving skills of 0.40 with a moderate interpretation.

▪ CONCLUSION

The research was conducted to determine the validity and effectiveness of the use of e-modules that are integrated with the STEM approach on environmental pollution materials to improve problem solving abilities. The research was conducted on seventh grade students of SMP Global Madani, Bandar Lampung, Lampung in 2021. The integrated module of the STEM approach on environmental pollution material developed has very valid criteria with moderate effectiveness to improve students' problem-solving skills. Thus, it shows that students' problem-solving skills can be improved by using E-modules as learning media, especially on environmental pollution material, by integrating the STEM approach using a project-based learning model.

Based on the research that has been done, by adapting the learning carried out, namely distance learning and requiring students to study independently, it was found that there was an ease in the implementation of learning by using e-modules as learning media. However, it is also necessary to pay attention to the availability of devices to access electronic modules and access to electricity and internet networks when they want to implement learning using the developed STEM integrated electronic module because its use requires electronic devices and internet network facilities.

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