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Development of STEM-Based Biology E-Module to Improve Student Learning Outcomes

Irdawati[1*], Moralita Chatri[1], Kurnia Wulansari[1], Abdul Razak[1], Suci Fajrina[1]

[1] Master of Biological Education, Padang State University, Padang, Indonesia.

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Corresponding Author:
Irdawati
irdawati.amor40@gmail.com

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Abstract: One of the factors for improving the quality of education in schools is teaching materials. Based on the results of observations at SMAN 1 Sitiung students have not used e-modules but use electronic teaching materials in the form of pdf files downloaded from the internet and only in the form of writing and a few pictures. Based on the questionnaire results, it is known that students have difficulty understanding the concept of the respiratory system material. This causes low student learning outcomes as evidenced by the daily test scores that are still below the minimum completeness criteria. So, it takes teaching materials that can help in visualizing the subject matter. This type of research is Plomp model development research which consists of three stages: the initial investigation stage, the development or prototyping stage, and the assessment stage. The research subjects were class XI students at SMAN 1 Sitiung for the 2022-2023 academic year. Validation results by the validator on e-module-based Science Technology Engineering and Mathematics (STEM) show an average grade 88.05% (very valid). Practical results by Biology teachers showed an average score of 87.50% (very practical) and 88.28% students (very practical). Effectiveness test data has effectiveness with very effective criteria in terms of cognitive competency assessment with an average of 83.59, affective with an average of 84.24, and psychomotor with an average of 81.08.

Keywords: E-module; Learning outcomes; Science Technology Engineering and Mathematics (STEM)

Introduction

One of the factors for improving the quality of education in schools is teaching materials. However, not all schools have teaching materials in the form of e-modules. E-module is a digital learning media arranged systematically so students can learn independently and solve existing problems.

E-modules has an important role in the learning process that can assist teachers in explaining subject matter. The advantage of e-module compared to other print media is that it is interactive, e-module can be accessed via mobile phones, laptops or computers. So that the e-module can be used as one of the best alternatives to increase the understanding of students, and can improve the learning outcomes of these students (Pramana, 2020).

If used, e-modules help students learn with the various items in the e-modules so that students can learn independently. When students are not at school they can still use digital e-modules and can measure students' understanding of the material they have studied (Keji Fan, 2022).

The software used in making the e-module is Adobe Flash Professional CS6. Adobe Flash Professional CS6 can create and process text and objects with three-dimensional effects (Simanullang & Manullang, 2022). With the help of this application, e-modules can be made more interesting and there are animations related to the material so that students can interact directly and help students better understand the material.

Based on the observation results that students have not used e-modules but use electronic teaching materials in the form of pdf files downloaded from the internet and only in the form of writing and a few pictures. The

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results of interviews with biology teachers in class XI MIPA at SMAN 1 Sitiung, found that teachers still apply conventional learning and the learning process is still teacher-centered using the lecture learning method. This results in a lack of student activity in the learning process, such as a lack of students asking questions, a lack of responsibility in doing assignments and exercises, and a lack of students in understanding concepts. So, it takes teaching materials that can help in visualizing the subject matter.

Based on the results of observations, it is known that students' learning outcomes are still low and not yet achieve the Minimum Completeness Criteria, namely 75. One of the factors that can support improving learning outcomes is the e-module. E-module is a teaching material packaged digitally. E-module can help teachers facilitate students in learning (Asrial, 2020). Diantari (2018) states that e-modules are digital learning media arranged systematically so students can learn independently and solve existing problems. It can be concluded that e-modules are digital teaching materials that are systematically arranged and presented in electronic form. E-module can increase students' interest and motivation in learning.

Sholeh, et al. (2023) state that interactive e-modules can encourage students to learn independently. Their use can be done anywhere and anytime by students. Interactive e-modules increase student learning motivation, increase student activity, and make learning more meaningful, and improve learning outcomes.

To overcome these problems, it is necessary to develop biology e-modules for class XI SMA with a STEM-based approach. STEM is an acronym for Science Technology Engineering Mathematics which means an integrated learning approach that connects real-world applications with classroom learning that covers four disciplines: natural sciences (science), technology, engineering results, and mathematics (Gustiani et al., 2017).

STEM learning is a collaboration of the four fields of knowledge that are compatible with problems that occur in the real world (Torlakson, 2014). In accordance with previous research conducted by (Suryani et al., 2020) said that STEM-based digital modules can attract student motivation and improve students' abilities to learn independently.

Based on the problems raised, research was conducted on the Development of Science Technology Engineering, and Mathematics (STEM)-Based Biology E-module to Improve Student Learning Outcomes.

Method

This type of research is development research called Research and Development (R&D). This study aims to determine the validity, practicality, and effectiveness of a biology e-module based on science technology engineering, and mathematics (STEM) to improve student learning outcomes at SMAN 1 Sitiung. This research began in the even semester of January-June at SMAN 1 Sitiung for the 2022/2023 academic year. The research was conducted at the Faculty of Mathematics and Natural Sciences (FMIPA) Padang State University (UNP) and SMAN 1 Sitiung. The subjects of this study were 33 class X students of SMAN 1 Sitiung, three lecturers from the Department of Biology FMIPA UNP and one Biology teacher at SMAN 1 Sitiung. The object of this research is a STEM-based biology E-module using the Plomp model (Plomp & Nieveen, 2013).

Data Collection Phase for Preliminary Research (Preliminary Research Phase)

Teacher interview guide sheet instrument; Student response questionnaire sheet used for problem analysis; Student questionnaire sheet used for needs analysis.

Data Collection Stage in the Development or Prototype Phase

Self-Evaluation Instrument (Self Evaluation): the self-evaluation sheet is used to check the initial design of the product that has been developed; E-module Validation Instrument by Experts: The STEM-based e-module validation instrument sheet is used to determine the validity of the developed STEM-based e-module. The questionnaire is a list of questions given to other people who are willing to respond according to user requests. This validity sheet is filled in by expert lecturers or experts. To determine the level of validity of STEM-based e-modules, it can be determined using the criteria from Riduwan (2010) as shown in Table 1.

Table 1. E-module Validity Criteria

Validity Value (%)	Category
0 – 20	Invalid
21–40	Invalid
41–60	Valid Enough
61–80	Valid
81–100	Very Valid

Data Collection for Assessment Phase Instruments (Assessment Phase)

Practical Instruments

The practicality instrument was carried out using a questionnaire to find out the responses of teachers and students regarding the practicality of the product being developed. This practicality sheet is a questionnaire filled out by teachers and students who have carried out learning using the e-module-based STEM.

To determine the practical value of STEM-based e-modules, it is determined using modified criteria from Riduwan (2010) which can be seen in Table 2.

Table 2. E-module Practicality Criteria

Practicality Value (%)	Category
0 – 20	Impractical
21–40	Less Practical
41–60	Pretty Practical
61–80	Practical
81–10	Very Practical

Effectiveness Instrument

This instrument is used to collect effectiveness data, namely affective domain observation sheets (attitudes), psychomotor observation sheets (skills) and test assessment sheets for cognitive domain learning outcomes (knowledge). Students' competence is used to determine the percentage of students' success after participating in learning using STEM-based e-modules.

Knowledge Competency Analysis

Student learning outcomes are calculated based on the average score of the learning outcomes test analyzed from the minimum completeness criteria.

Table 3. Cognitive Aspect Assessment Criteria

Quality Score	Quality Value	Category
81–100	A	Very good
66–80	B	Good
56–65	C	Enough
46 – 55	D	Not enough
≤ 45	E	Bad

Attitude Competency Analysis

Analysis of students' learning competence results in the domain of attitudes (affective) with the percentage of completeness of learning competency results.

Table 4. Attitude Aspect Assessment Criteria

Percentage Range (%)	Criteria	Effectiveness Category
1 – 20	Very Not Good	Very Ineffective
21–40	Not good	Ineffective
41–60	Currently	Effective enough
61–80	Good	Effective
81–100	Very good	Very effective

Skills Competency Analysis

The results of learning competence in the realm of skills (psychomotor) are seen from the results of the assessment of the learning process carried out by students.

Table 5. Skills Aspect Assessment Criteria

Percentage Range (%)	Criteria	Effectiveness Category
1 – 20	Very Not Good	Very Ineffective
21–40	Not good	Ineffective
41–60	Currently	Effective enough
61–80	Good	Effective
81–100	Very good	Very effective

Result and Discussion

Initial Investigation Stage

The initial investigation phase aims to analyze problems or analyze needs such as collecting and analyzing information, defining problems needed in project development(Arianatasari & Hakim, 2018). The researcher conducted an analysis using a questionnaire to conduct an initial investigation. The analyzes carried out were problem analysis, needs analysis, curriculum analysis, learning media analysis, concept analysis, and student analysis.

Based on the analysis of the e-module that has been developed, it provides convenience in terms of use. Good at presenting material using language that is easy to understand and clear font size. E-module is also supported with images, videos and colors. The displayed image can help students focus on learning material so that it affects the level of understanding and attractiveness of students to learning material. Learning devices are said to be easy to use if they are appropriate in using language with simple sentences, consistent and easily understood by students (Faisal, 2015). Learning media also has colors, pictures and icons that match the characteristics of students.

Some of the deficiencies that are known from the analysis of problems, needs, curriculum analysis, concept analysis, and student analysis carried out become a reference for researchers in developing teaching materials that suit the needs of students. It is hoped that the e-module can solve students' problems in the learning process, complement the lack of learning media available in schools, and empower students' cognitive, affective, psychomotor and creative thinking abilities.

According to Nurrita, (2018) media that is interesting to students can be become a stimulus for students in carrying out the learning process. Development of an interactive e-module based on a STEM approach, aims to overcome the problem that there is a lack of integration of material with the realities of life, as well as for arouse attention or focus on learning.

Prototyping Stage

The first stage in the development of prototype I carried out was the design of the e-module by making a storyboard as a guide for researchers in making e-modules that match the criteria of students, as well as paying attention to the feasibility components of the construct, content, language, graphics of the e-module. In making the e-module storyboard refers to the elements of e-module preparation. According to Fatikhah, Ismu, & Izzati (2015) to make a good e-module, what must be done is to identify the elements

of its preparation, which consist of objectives, instructions for use, competencies to be achieved and evaluation.

The second stage in the development of self-evaluation prototype II is self-assessment by checking yourself about the feasibility of the content, construct, language, and graphics of the e-module. Furthermore, the validity test was carried out with experts (expert review).

Validation

The formative evaluation used is in the form of an e-module validation sheet based STEM. The quality criterion to be obtained from this stage is the validity of the product that has been made. Experts validate the e-module based STEM namely by three lecturers as validators. Results of e-module validity based STEM can be seen in Table 6.

Table 6. E-module Validation Results Based STEM

Rated aspect	Validity Value (%)	Criteria
Construct Aspect	88.33	Very Valid
Content Aspect	88.89	Very Valid
Graphic Aspect	87.50	Very Valid
Language Aspect	87.50	Very Valid
Total	352.22	Very Valid
Average	88.05	

Data Table 6 shows that the requirements to meet e-module validity criteria based STEM has been fulfilled. This can be seen from the overall average value of e-module validity based STEM namely 88.05% with very valid criteria. Therefore, e-module based STEM on the respiratory system system material developed can be used for the next stage.

Small Group Practicality

After the improvement process from the expert validation stage and one-to-one evaluation, then the e-module based STEM, then a practicality test is carried out by a small group. At this stage, four students with different learning outcomes (high, medium and low) were evaluated. The practicality test by small group students aims to see the practicality of the e-module based STEM on the digestive and respiratory systems. The results of the small group practice can be seen in Table 7.

Table 7. Small Group Practicality Test Results

Assessment Aspects	Average (%)	Criteria
Ease of use	83.30	Very Practical
Efficiency of learning time	100.00	Very Practical
Benefit	91.67	Very Practical
Total	275	Very Practical
Average	91.67	

The data in Table 7 shows that the practicality test results in the small group are with an overall average of 91.67% with very practical criteria. This shows that the e-module based STEM developed can already be used and very practical to use during the learning process. So that it can proceed to the assessment phase by conducting large group trials (field tests).

Assessment Stage

Large Group Practicality

The average results of STEM-based e-module practicality by large group students (field tests) can be seen in Table 8.

Table 8. Results of the Large Group Practicality Test (Field Test)

Assessment Aspects	Average (%)	Criteria
Ease of use	88.75	Very Practical
Efficiency of learning time	87.50	Very Practical
Benefit	88.61	Very Practical
Total	264.86	Very Practical
Average	88.28	

The data in Table 8 shows that the results of the STEM-based e-module practicality test by students in large groups (field tests) are an overall average of 88.28% with very practical criteria. This shows that the practicality of STEM-based e-modules by students is very practical to use from the aspect of evaluating ease of use, efficiency of learning time, and benefits in learning activities.

The purpose of making a learning e-module is so that teachers and students: (a) can clarify and simplify the presentation of messages so that they are not too verbal; (b) to overcome the limitations of time, space, and senses; (c) appropriately and varied to increase motivation and enthusiasm for learning; (d) enable independent learning according to their abilities and interests; (e) can measure and evaluate the learning process and output themselves (Lumbantobing et al., 2019).

Effectiveness

Cognitive Competency Assessment

Cognitive competency assessment can be obtained through a final test in the form of multiple choice/objective questions given to students in the experimental class and control class. Work on the final test questions is carried out at the end of the learning meeting. This assessment is used to see the effectiveness of STEM-based e-modules. The results of the average value of cognitive competence are seen in Table 9.

Table 9. Average Cognitive Competency Results

Class	Min Value	Max Value	Amount	Average
Experiment	70	95	2675	83.59
Control	65	90	2380	79.33

Data Table 9. shows that the average value of cognitive competence in the experimental class is higher than the control class. The experimental class is a class that is given treatment in the form of using STEM-based e-modules, while the control class is a class without the use of STEM-based e-modules. The average value of the experimental class was 83.59 using STEM-based e-modules, while the average value of the control class was 79.33 not using STEM-based e-modules.

In STEM-based e-modules, practice questions or assignments must be done by students so that they can respond and know their level of mastery of the material being studied using the e-module. The questions and exercises contained in the e-module refer to competencies that must be mastered by students in studying the e-module. Students can evaluate their understanding of the material they are learning by working on the practice questions contained in the STEM-based e-module.

According to Hurrahma & Sylvia (2022); Qotimah & Mulyadi (2021) an increase in students' cognitive abilities occurs due to meaningful learning experiences, this occurs because students use STEM-based e-modules that contain learning material, besides that there are interactive features such as videos and questions, and e -Modules are developed based on STEM elements to provide meaningful new knowledge and experiences and cause learning outcomes to be obtained by students to increase.

The STEM approach is an approach in education where Science, Technology, Engineering, and Mathematics are integrated with the educational process focusing on solving problems in real everyday life and professional life (Davidi et al., 2021). The STEM approach shows students how concepts, principles, techniques, science, technology, engineering, and mathematics (STEM) are integrated to develop products, processes, and systems that benefit human life (Utami et al., 2017). Students must actively use technology products in learning with the STEM approach (Kaniawati et al., 2015). STEM learning connects material with life, involves students in practice, guides students in practice, utilizes technology, uses active student learning strategies, communicates actively with students, and gives group assignments. Integrating STEM learning with simple technology can help understand the material and improve thinking skills (Yusuf et al., 2019).

Affective Competency Assessment

The assessment of affective competence was carried out by observers by assessing and observing the activities of students both in the experimental class and in the control class during the learning process. During the learning process, the observer makes observations and fills in students' affective competency assessment questionnaire (attitude). The average results of the affective competency analysis of students during the learning process can be seen in Table 10.

Table 10. Average Affective Competency Results

Class	Amount	Average	Criteria
Experiment	2695.83	84.24	Very good
Control	2416.67	80.56	Good

Data Table 10. shows that the average value of the experimental and control classes' affective competence is different. It is known that the average value of the experimental class is 84.24, while the average value of the control class is 80.56. It can be concluded that the affective competence of students in the experimental class using STEM-based e-modules is better than the control class.

Psychomotor Competency Assessment

Psychomotor competency assessment was carried out by observers by filling out questionnaires observing the activities of students both in the experimental class and in the control class during the learning process. The average results of the psychomotor competency analysis of students during the learning process can be seen in Table 11.

Table 11. Average Psychomotor Competency Results

Class	Amount	Average	Criteria
Experiment	2594.44	81.08	Very good
Control	2322.22	77.41	Good

Table 11 shows that the average value of the psychomotor competence of students in the experimental and control classes is different. The result of the average value of the experimental class was 81.08 while the average value of the control class was 77.41. It can be concluded that the psychomotor competence of students in the experimental class who used STEM based e-modules was better than the control class who did not use STEM-based e-modules.

In Parwati, Suryawan, and Apsari., (2018) there are two sources of factors that influence learning outcomes, namely internal factors and external factors, internal factors include physiological factors, and psychological factors include basic intelligence, motivation, interests, attitudes, talents, self-confidence and fatigue factor. Meanwhile, external factors include the way parents educate, relations between family members, home

atmosphere, family economic situation, parental understanding, cultural background, school factors, namely teaching methods, curriculum, teacher-student relationships, student-student relationships, school discipline, learning tools, school time, student standards, building conditions, learning methods, homework and community factors, namely student activities in society, mass media, social friends, forms of community life.

According to Tribelas & Almunawaroh (2021) e-modules are one solution for studying at home, firstly providing digital teaching and learning materials prepared with interactive videos, audio, images and animations to develop students' interest, secondly they can be used online or offline and thirdly assist students and teachers with teaching and learning experiences. Using e-modules, which combine technological advances with learning, students gain new experiences and build student knowledge (Jaenudin & Murwaningsih, 2017).

Conclusion

Based on the research results, the following conclusions are obtained. E-module-based Science Technology Engineering and Mathematics (STEM) has effective criteria for cognitive competence assessment of students with an average of 83.59. E-module-based Science Technology Engineering and Mathematics (STEM) has effectiveness with very effective criteria in terms of the affective competency assessment of students with an average of 84.24. E-module-based Science Technology Engineering and Mathematics (STEM) has effective criteria for the psychomotor competency assessment of students with an average of 81.08.

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Author Contributions
I conducted a literature review and provided advice in compiling articles. MC, conducting literature reviews, validators and providing advice in compiling articles. KW conceptualized research ideas, designed methodologies, conducted research, analyzed data, responsible for management and coordination. AR and SF provided suggestions in compiling articles.

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The authors declare no conflict of interest. The funders had no role in the study's design; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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