

Development of Physics E-Module Integrated with STEM Approach to Promote Students' Critical and Creative Thinking Skills

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Abstract: Twenty first century learning requires students to have critical thinking skills, creative thinking, communication, and collaboration. The learning outcomes show that students' independence is very lacking and students' critical and creative thinking skills are low. This development aims to produce a product in the form of an e-module physics class XI senior high school integrated with the STEM approach with critical and creative thinking skills as a solution to this problem. The purpose of this study was to determine the initial studies, the validity, and practicality of using STEM-integrated e-modules. The development model used is the ADDIE development model. The data analysis technique used is descriptive statistics. Based on the data that has been analyzed there are three research results. First, at the analysis stage, an analysis of learning activities is carried out, student needs analysis, and educator interviews. Second, the validation result is 0.82 with a valid category. Third, the result of practicality by students is 79.5 and the result of practicality by educators is 87.5 with practical and very practical categories. The results of this study imply that students become more active and creative because of STEM activities. The results of the study concluded that the STEM approach integrated physics e-module is valid and practical for use in learning.

Keywords: ADDIE model; Creative thinking; Critical thinking; E-module; STEM approach

Introduction

Advances in information technology allow a variety of information to flow quickly (Affandy et al., 2019). Bukhari et al. (2019) stated that the role of digital technology is also needed in facing 21st-century education as it is today. The 21st-century learning implies that a teacher must use digital technology, communication facilities, and/or appropriate networks to access, manage, integrate, evaluate, and create information to function in a lesson (Solihudin, 2018). 21st-century learning provides opportunities for students to develop their skills in mastering technology

and information. Thus, students can develop their knowledge and skills through the application of technology and information in learning.

Important 21st-century skills are given to students in learning and should be included in the curriculum (Sibille et al., 2010; Greenstein, 2012; Griffin et al., 2017). 21st-century skills are needed by students for the process of solving problems, communicating, collaborating with others in obtaining new information, and adapting quickly to new environments (Ahmed & Taha, 2021; Adhelacahya et al., 2023). Creative thinking skills need to be improved so students can provide some ideas for solving a problem (Armandita et al.,

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2018). Critical thinking skills need to be improved because they are very important to support the success of student understanding (Pamungkas et al., 2019). Critical thinking skills is a very important aspect to provide students with (Sugiarti & Dwikoranto, 2021).

Implementation of learning should be able to develop students' 21st-century skills. The 21st century does not only rely on knowledge but skills also play a role in 21st century learning. Skills are an important component needed in various fields in life (Wijaya et al., 2016). The 21st-century learning paradigm aims to form human resources with the ability to think critically, creatively, collaboratively, and communicatively (Asrizal et al., 2019). 21st-century learning can also hone and develop students' skills in achieving learning goals (Asrizal et al., 2020). The 21st-century learning paradigm emphasizes the ability of students to find out from various sources, formulate problems, think analytically, and collaborate and collaborate in solving problems (Research and Development Ministry of Education and Culture, 2013).

ICT is needed to support 21st-century learning. ICT plays an important role in learning so a learning process is formed that makes students more active by encouraging interaction between learning components so that students are more enthusiastic about learning (Saxena, 2017; Das, 2019; Zafar, 2019). ICT-based teaching materials are teaching materials that are designed and arranged using ICT tools to make it easier for students to learn. ICT-based teaching materials have advantages, namely: providing convenience in learning, encouraging interest and activeness in the process of discussing learning materials, facilitating assessment of learning progress, and making it easier to discuss and interact using internet facilities (Nnaekwe & Ugwu, 2019; Usman & Asrizal, 2020). ICT teaching materials need to be used in physics learning to create active learning, interactive, and meaningful. Therefore, the use of ICT in learning can make it easy for students to develop their thinking skills (Asrizal et al., 2022).

Problems that occur in the field show that students critical thinking skills and creative thinking skills are still not by the expected conditions. This is based on the results of an initial study conducted at SMAN 1 Sungaipuh by using an instrument to give tests on creative thinking skills and critical thinking skills as well as interviews with teachers. In addition, the attitude of independence and interest in student learning is still low. Implementation of education still using the lecture method, so that the teacher explains the material as a whole first and then directs students to work on the questions in the book Students tend to be passive, and the role of students in learning activities is relatively low, so the learning process is still

teacher-centered causing low thinking and creative skills students (Adhelacahya et al., 2023; Marta & Ramli, 2020). Based on the analysis that has been done then one effort that can be done is to develop teaching materials in the form of modules that suit the needs of students. Improving student learning independence, developed by technology and information.

E-Modules are learning media that provide systematic learning so that students can learn independently to achieve certain learning goals, which are presented in electronic form containing interactive animation, video, and audio (Sari et al., 2021; Sofyan et al., 2019). E-modules consist of various series of learning activities in achieving a learning goal. E-Modules must be arranged systematically which means that the modules have conformity with predetermined learning objectives, needs, and characteristics so that they can train students' independence (Asrizal et al., 2022; Festiyed et al., 2020). The developed e-module integrates STEM into learning. STEM is very important because it provides training for students to be able to integrate all aspects at once including science, technology, engineering, and mathematics. UNESCO revealed that the integration of Science, Technology, Engineering, and Mathematics is an aspect that grows in both developed and developing countries (El-Deghaidy & Mansour, 2015).

The integration of these STEM aspects can support the improvement of student learning outcomes (Pangesti et al., 2017). The STEM learning approach can trigger the formation of student interest in learning and perceptions of professions related to STEM (Sulaeman et al., 2020). The application of STEM in learning activities with critical and creative thinking skills, so that students can find innovative solutions to real problems and can convey them well (Beers, 2011). Learning using STEM can help students solve problems and draw conclusions from previous learning by applying it through science, technology, engineering, and mathematics (Robert & Cantu, 2012; Lou et al., 2017).

The use of STEM-integrated e-modules will improve students' creative and critical thinking skills due to implementing real-world problems into students' lives. This research is needed to develop interesting and interactive teaching materials in the learning process. The interactive process is very necessary because it can clarify the material being taught through an attractive video display. The purpose of this study was to determine the results of the initial study research, determine the results of the validity test, and determine the results of the practicality test of using STEM-integrated e-modules.

Method

The type of research that will be carried out is research and development (Research and Development) because in this research learning tools will be developed. Sugiyono (2010) and Azwar (2015) suggests that the Research and Development (R&D) method is a research method used to develop or validate products used in education and learning. Meanwhile, development research according to Sukmadinata (2009), namely the process or steps to develop a new product or perfect an existing product, which can be accounted for.

Model ADDIE is a development step consisting of Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was developed to design learning systems (Mulyaningsih, 2012). The first phase of the research is needs analysis. Activities that have been carried out in this phase include: analyzing the analysis of learning activities, analysis of graduate competency standards, and analysis of student characteristics. Analysis of student characteristics regarding interest in learning, learning attitudes, learning motivation, and student learning styles.

The second phase of research is the design of the STEM-integrated e-module. Activities that have been carried out include the design of e-modules. The e-module uses a professional 3d page flip application in its manufacture. The designed e-module includes a learning approach, namely the STEM learning approach. The structure of the e-module is cover, preface, table of contents, introduction, main section, and closing. This e-module design, it will be made interactive such as providing illustrations, video, and audio.

The third phase of research is Development. This activity is carried out after the e-module has been designed. At the development stage, the validity test was carried out. The product validation test aims to determine whether the product developed has been declared valid by experts so that it is suitable for use by students in learning. Data collection was made in the form of validation questionnaire sheets. Data analysis techniques in this study used descriptive statistics to analyze the validity of the statistical analysis displayed in tabular form. The validation questionnaire was validated by expert validators who were FMIPA UNP lecturers consisting of content feasibility, construction feasibility, language feasibility, and graphic feasibility.

The fourth phase is implementation. The next step is to test the practicality of the product. The product practicality test aims to find out that the product is practically used in learning. Data collection was made in the form of practicality questionnaire sheets. Data

analysis techniques in this study used descriptive statistics in analyzing practicality. According to Riduwan (2009) validation analysis and practicality can be obtained by dividing the score obtained by the maximum score and then multiplying by one hundred percent. In addition, the validity and practicality value categories range from 0 to 20 which are not good, 21 to 40 are not good, 41 to 60 are quite good, 61 to 80 are good, 80 to 100 are very good.

Result and Discussion

Needs Analysis

The first needs analysis is an analysis of learning activities. Learning activities consist of several indicators (Rahmi & Nurcahaya, 2020), namely: Preliminary activities; The core activities consisting of applying the learning approach and using learning resources; and Closing activities. The results of preliminary indicator research can be seen in the graph below.

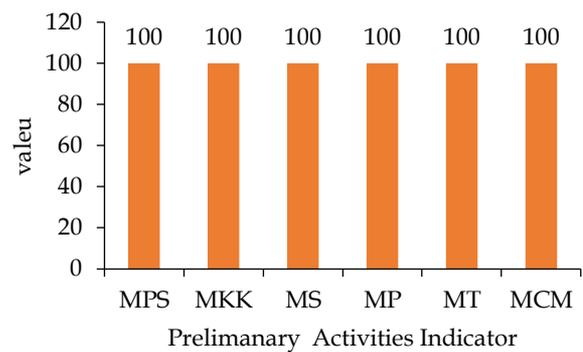


Figure 1. Results of preliminary activity indicator analysis

The introductory part of the learning activities consists of several indicators, namely: educators start learning by focusing students' attention (MPS); educators start learning by creating conducive conditions (MKK); educators motivate students to be actively involved in learning activities (MS); educators ask questions that relate previous knowledge to the material to be studied (MP); educators explain learning objectives (MT); educators convey the scope of material and explanations of activity descriptions according to the syllabus (MCM). The results of the preliminary indicator research have a perfect percentage. This concludes that learning is by the standard process demands contained in Permendikbud No. 22 (2016). The results of the core section analysis can be seen in Figure 2.

Learning activities in the core part consist of the first three parts, the use of models and methods (PMDM) which has three indicators: educators use

models in learning physics; educators use learning methods that vary at each meeting; and educators carry out the learning process according to the learning method or model in the lesson plans. Second, learning media (MP) has four indicators: the media used is relevant to the learning objectives; the media used can help present real objects in learning activities; learning media can increase student learning motivation; and the learning media used is technology-based. The third is learning resources (SB) consisting of several indicators: students use modules as learning resources.

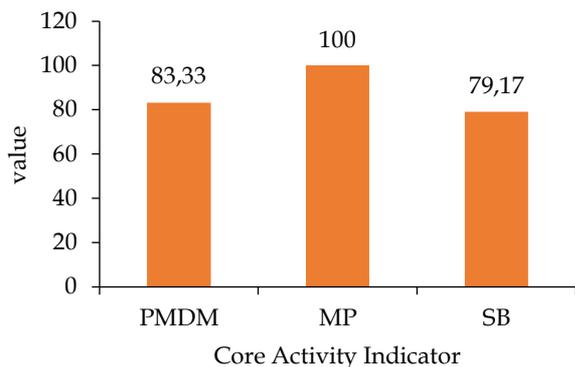


Figure 2. Results of core activity indicators

Results analysis that has been done, some problems need attention, such as the learning resources used. The results of the analysis of the learning approach and the use of learning resources get a low score. This shows that the teacher does not apply the learning approach and maximizes the use of learning resources to direct student activities (Yulkifli et al., 2022). Activity analysis This shows that teaching materials are needed that can help students in solving problems. The results of the closing section analysis can be seen in the image below.

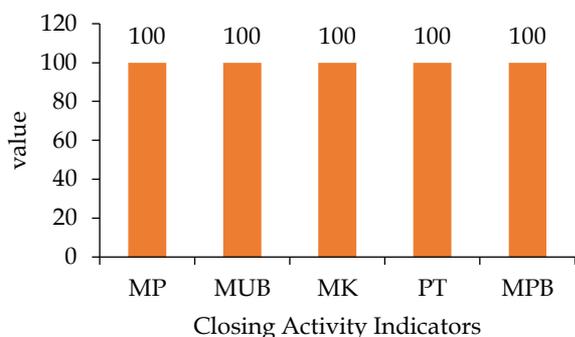


Figure 3. Results of closing activity indicators

The learning activities in the closing section have five indicators: educators involve students in concluding learning (MP); educators provide feedback

on learning processes and outcomes (MUB); educators give quizzes (MK); educators follow up in the form of giving assignments (PT); and educators deliver the subject of the next material. The results of the preliminary indicator research have a perfect percentage. This concludes that learning is by the standard process demands contained in Permendikbud No. 22 (2016).

The second analysis of needs is an analysis of student characteristics related to creative thinking skills, students' critical thinking skills, and student knowledge. The value of critical and creative thinking is obtained from the initial test while the value of student knowledge comes from student learning outcomes in the form of tests. This analysis aims to determine the value of students' creative thinking skills, critical skills, and knowledge. Analysis of creative thinking skills (KBKF) and critical thinking skills (KBAS) as well as student knowledge can be seen in the following Table 1.

Table 1. Statistical parameter value of KBK data, KPS, and student knowledge

Statistical Parameters	KBKS	KBKF	Knowledge
Average	63.44	74.38	56.17
Mode	53.33	75	65
Median	66.67	75	57.5
The highest score	83.33	81.25	75
Lowest Value	40.00	56.25	35
Reach	43.33	25	40

Based on Table 1 it can be explained that the lowest value of the assessment skills, creative thinking, critical skills, and student knowledge separately respectively 56.25, 40.00, and 35. While the highest values respectively are 81.25, 83.33, and 75. The average of student's creative thinking skills is 74.38, students' critical thinking skills are 64.44 and student knowledge is 56.17. This shows that the average value of skills in creative thinking is in the medium category. students' critical thinking skills and knowledge are in a low category. Reach the value of the results of the assessment of students' creative thinking skills, critical thinking skills, and knowledge respectively are 25, 43.33, and 40. Values that often appear in skills assessment creative thinking, critical thinking skills, and students' knowledge respectively are 75, 53.33, and 65. Creative thinking skills are in the moderate category. critical thinking skills and knowledge are in a low category. The midpoint of the thinking skills research creative, critical thinking skills and student knowledge are 75, 66.67, and 57.5. critical thinking skills are in the moderate category. Critical thinking

skills and knowledge at low value. Based on these three assessments, it can be seen that students' critical thinking skills and knowledge have not achieved the desired results expected this requires an internal renewal of learning to get more optimal results and in line with expectations.

The third needs analysis is student analysis. Analysis was carried out to determine the character of students. Some of the indicators analyzed are attitude indicators (S), knowledge indicators, interest indicators (MT), motivation indicators (MV), learning style indicators (GB), and learning independence (KB). The research results can be seen in the graph below.

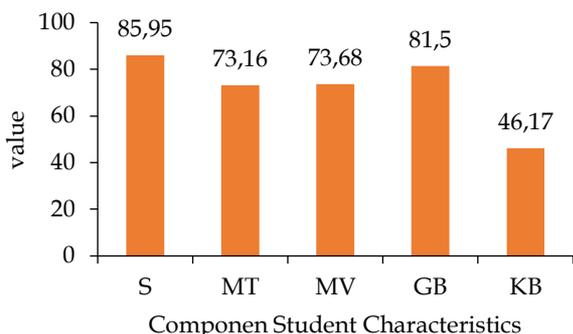


Figure 4. Analysis of student characteristics

Analysis of student characteristics has an average of 72.1. The attitude indicator has an average of 85.95 in the good category. Interest and motivation indicators respectively have an average of 73.16% and 73.68 sufficient categories. Learning styles have an average of 81.50 good categories. Learning independence has the lowest average, namely 57.78, which is in the very poor category. The attitude indicator has shown good results, this means that students have behaved according to religious teachings and applied good social attitudes in their environment.

Analysis of students' interest and learning motivation towards learning Physics, in general, is still in the sufficient category. Things that need to be improved are the students' interest in learning Physics. Analysis of student learning independence towards learning Physics, in general, is still in the very lacking category. The obstacles faced by students are that they are still not independent in doing assignments and are lacking in finding other reference sources in learning. One way to overcome this is to use learning resources in the form of e-modules. where the module is a systematic teaching material that is the goals to be achieved by the characteristics and needs of students so that students can learn independently or without guidance from the teacher (Sholeha et al., 2019).

STEM Integrated E-Module Description

The results of the next study are product descriptions. The product developed is an integrated STEM e-module to encourage students' critical thinking skills and creative thinking skills. The e-module is designed based on the e-module writing structure. The following is the result of the e-module cover which can be seen in Figure 5.

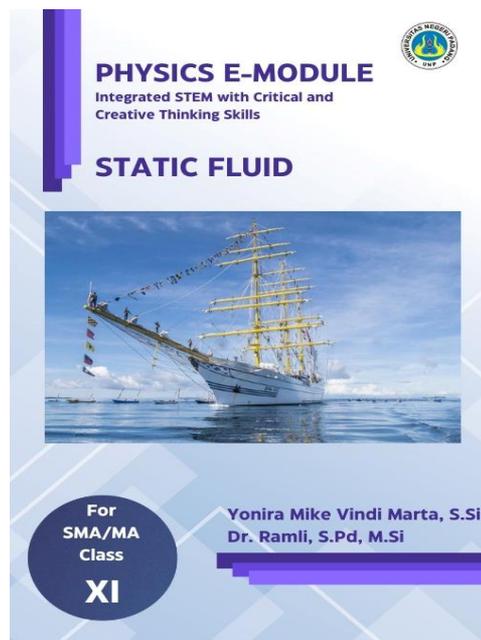


Figure 5. Covers

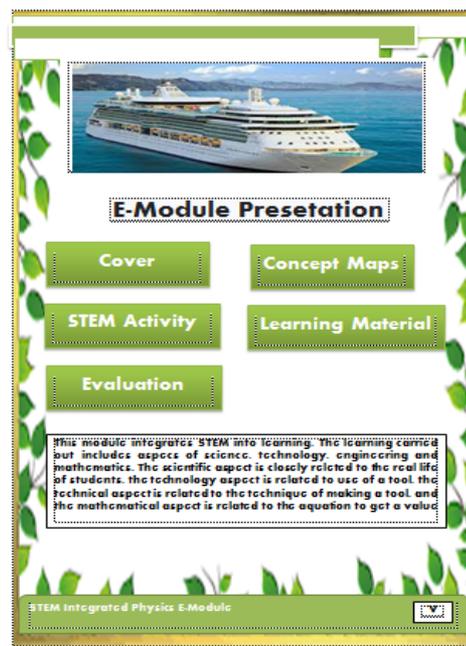


Figure 6. E-Module presentation

At the beginning of this e-module, there is a cover and an engineering section on STEM activities. The e-module cover display contains the title, author, semester, and class. This teaching material is provided for class XI high school students in semester 1. The cover display is made as attractive as possible by balancing the colors and providing animations that depict the contents of the e-module. On the cover of the e-module, there is an image of hydraulic jacks, sinking objects, and mosquitoes that stick to the surface of the water. These images represent the static fluid material to be studied. The e-module contains learning objectives, material descriptions containing STEM material and activities, summaries, exercises, and evaluations. STEM integration in e-modules can be seen in STEM activities in teaching materials. Seeing the application of material to technology, experiencing direct experience making technological engineering through the engineering section and completing tests of critical thinking skills and creative thinking as well as looking for answers in the mathematics section according to the technology discussed.

Validity of STEM Integrated E-Module

The validation results of the STEM integrated physics e-module to encourage students' critical and creative thinking skills were carried out by 3 lecturers with valid criteria. The aspects that are assessed in the validation are content feasibility, construction, language, and graphics. Content eligibility is a test of the validity of content or material, covering the suitability of KD, conformity with the needs of teaching materials, and the correctness of the substance of learning materials. The validity of this language indicator assesses whether the information in teaching materials reaches students as users of teaching materials. Construction validity assesses the various components of the intervention that are related to one another. The validity of the graphical indicator assesses how the appearance, type, and size of the text used, layout, and illustrations or pictures related to the material so that readers can understand and understand the material in the e-module properly. Validation results can be seen in the following Table 2.

Table 2. E-module validation results

Rated aspect	Expert Validator	
	Aiken's V score	Criteria
Fill	0.82	Valid
Construction	0.88	Valid
Language	0.87	Valid
Graphic	0.90	Valid
Average	0.86	Valid

Based on the analysis of the data in the figure it can be explained that the value of each component varies with the lowest value 0.82 and the highest value 0.90. The value of the validation test results according to experts on the e-module can be determined by finding the average value of all assessment components. The results showed that STEM-integrated electronic teaching materials were declared valid. The average value of the STEM integrated e-module validation results according to experts is 0.86 which is in the very good category. This is by Syahiddah et al. (2021) and Kiswanda et al. (2022) that the development of the STEM approach e-module is in the valid category. Previously the e-module had been revised according to suggestions from the validator.

Practicality of STEM Integrated E-Module

The results of the research after the product has been validated are then carried out by practicality tests by students and educators to find out the practicality of the products that have been developed. The practicality instrument used has an assessment component that includes ease of use, time efficiency, and benefits. Practical results can be seen in the following Table 3.

Table 3. Practicality by students

Indicator	Mark (%)	Category
Ease of use	77.5	Practical
Time efficient	80	Practical
Benefit	81	Very Practical
Average	79.5	Practical

Based on the data analysis of the practicality component of students, values were in the range of 77.5 to 81. The average value of the practicality component was 79.5, which was in the good category. The value given by the students on the practicality test sheet instrument states that the STEM-integrated static fluid e-module is practically used in physics learning. Ease of use indicators consist of Ease to use; easy to deliver material; Ease of finding concepts; the ease of controlling learning activities. Time efficiency indicators consist of timeliness of study; can learn at their own pace; and can be used to train independence. The benefit indicator consists of several e-module uses that have been created for specific student use.

Practicality is also carried out by educators. The practicality instrument used has an assessment component that includes ease of use, time efficiency, and benefits. Practical results can be seen in the following Table 4.

Table 4. Practicality by educators

Indicator	Mark (%)	Category
Ease of use	87.5	Very Practical
Time efficient	87	Very Practical
Benefit	88	Very Practical
Average	87.5	Very Practical

The practicality instrument by educators consists of three indicators, namely ease of use, time efficiency and benefits. The easy-to-use indicators consist of several sub-indicators, namely: easy to use in the learning process; the steps in the e-module make it easier to translate learning material; make the learning process clearer; make it easier to find physics principles and concepts; makes it easier to guide students; can increase the productivity of learning activities; can be used as a learning resource. Time efficiency indicators consist of using time e-modules more efficiently; with e-modules students can study according to their own pace; e-modules can be used as additional teaching materials; can be used to train independence. The Technology component in the E-Module can increase students' knowledge and insights regarding the material; The Engineering component in the E-Module can guide students to do simple projects related to the material; The Mathematics component in the E-Module can guide students to solve problems mathematically by appropriate; E-Module helps students in independent learning; and E-Module can improve students' critical thinking skills; and E-Modules can improve students' creative thinking skills.

The results of the practicality of the integrated e-module STEM approach and the ability to think critically and creatively educators are in the very practical category. The highest percentage, namely benefits of 88, then followed by indicators of ease of use and time efficiency, namely 87.5 and 87. The results of the study show that STEM-integrated electronic teaching materials are declared valid and practical in improving students' skills. By the results of previous research by Nazifah & Asrizal (2022) the development of STEM-integrated physics e-modules to improve students' critical and creative thinking skills that have been developed is valid and practical for use in learning. The application of the STEM approach in learning can also improve student learning outcomes. These results are consistent with previous research that the STEM approach affects student learning outcomes (Nasution et al., 2022). Ramli et al. (2020) states that the integration of STEM concepts in physics e-modules can improve learning and innovation skills, which include critical and creative thinking.

Conclusion

Based on the research that has been done, it can be concluded that the development of STEM-integrated physics e-modules to encourage critical and creative thinking skills is feasible to use. Judging from the results of product validation with a valid category. The practical results of students are in the practical category, which means that the e-module is easy to use, has an efficient and useful time, and improves students' critical and creative thinking skills. The conclusion of this research is the development of STEM-integrated physics e-modules to encourage students' critical and creative thinking skills which are developed valid and practical for use in learning.

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Author Contributions

Collecting data, analyzing data, writing original drafts, Y.M.V.M.; methodology, data curation, A.; review writing, visualization, R.

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Conflicts of Interest

The authors declare no conflict of interest.

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