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# Development of STEM Integrated Physics E-Modules to Improve 21st Century Skills of Students

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**Abstract:** In the current era of the industrial revolution 4.0, students are required to have 21st century skills. The 21st century skills in question are students mastering the 4C skills, that are Communication, Collaboration, Critical thinking and Creativity skills. These four skills must be possessed by students to face the world in the 21st century. One of the current learning approaches that strongly supports the achievement of 21st century skills is STEM-based learning (Science, Technology, Engineering, and Mathematics). In supporting the interdisciplinary success of STEM in physics learning, it is necessary to have effective teaching materials, one of which is a module that students can use independently. In this case, the product developed is an integrated STEM physics e-module to improve the 21st century skills of class XI high school students. The e-module was developed using Flip PDF Professional software with reference to the plomp model. This research is carried out until the development or prototype stage. The research results obtained are the development of STEM integrated physics e-modules to improve students' 21st century skills which have been developed to be valid and practical to use in learning.

**Keywords:** E-Module physics; Integrated STEM; 21st century skills of Students

## Introduction

In the era of the industrial revolution 4.0, human resources are required to have 21st century skills. The development of science and technology is so rapid today, so that there is no more space limit for us to communicate with each other. The development of science and technology has an impact on global challenges and competition faced by every country. In Indonesia, it is necessary to create quality human resources to be able to compete with the wider community. With this basis, improving 21st century skills are able to prepare human resources to be competent in the current era of globalization.

21st century skills are the answer to the challenges of the industrial revolution 4.0 in the field of education. The 21st century skill in question is that everyone masters the 4C skills. This is confirmed by the Partnership for 21st Century Skills (P21: 2011) in the Framework for 21st Century Learning identifying the 4C skills in question are Communication, Collaboration, Critical thinking and Creativity skills. These four skills must be possessed by everyone to face the world in the 21st century.

Critical thinking is a skill to perform various analysis, assessment, evaluation, reconstruction, decision making that leads to rational and logical action (King et al., 2010; Mahanal et al., 2019). Thinking about the subject, content, and problem is carried out through analysis, assessment, and reconstruction activities (Papp, 2014). Critical thinking indicators that can be used are: asking questions, looking for ways, answering questions and looking for reasons, looking for alternative solutions (Rahmawati 2014; Ennis 2011).

Creativity is a skill to find new things that have not existed before, are original, develop new solutions for each problem, and involve the ability to generate new, varied, and unique ideas (Leen, 2014). According to (Filsaime, 2008), creative thinking is a thinking process that has the characteristics of fluency, flexibility, originality and detailing or elaboration. The creativity indicator used consists of four indicators, namely: asking many questions, thinking of various ways,

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answering with many answers and providing various interpretations or reasons (Filsaimen, 2008).

Communication is a skill to express new thoughts, ideas, knowledge, or information, both in writing and orally (Greenstein, 2012). Indicators assessed on communication skills are in the form of conveying opinions and ideas appropriately (Husna, 2013), inferring information (Endang, 2006), using correct and effective sentences, and using appropriate punctuation marks (Amala, 2019).

Collaboration is the skill of working together effectively and showing respect for diverse team members, exercising fluency and willingness to make decisions needed to achieve common goals (Greenstein, 2012). Collaborating with others includes (1) being able to work effectively and respecting different team members, (2) demonstrating flexibility and a desire to be useful in making compromises to achieve common goals, and (3) taking responsibility in collaborative work and appreciate the contribution of each team member. (Redhana, 2019).

One of the current learning approaches that strongly supports the achievement of 21st century skills is STEM-based learning (Science, Technology, Engineering, and Mathematics) (Yusuf et al., 2018; Stohlmann et al., 2019). STEM consists of scientific aspects, namely the use of knowledge and science process skills to understand and manipulate natural phenomena (Hannover, 2011; Saputri et al., 2022). Technological aspects, namely using technology, namely knowing how new technology can be developed and technology can be used to facilitate human work. Technical aspects, namely operating, designing or assembling with reference to science and technology (Bligh, 2015). Mathematical aspects, namely to analyze, show evidence, solve problems, interpret solutions from data and calculation results.

To support STEM interdisciplinary success in physics learning, it is necessary to have effective teaching materials. Teaching materials are all forms of materials used to assist teachers in carrying out teaching and learning activities (Asrizal et al, 2018). Teaching materials that can support students in independent learning are modules (Depdiknas, 2008; Nurhasanah, 2020). In the module there is control over learning outcomes through the use of competency standards that must be achieved by students. That is, students become more responsible for all their actions. Therefore, this STEM-based physics module is very much needed in the learning process to see student success in terms of knowledge, skills and attitudes.

Based on research conducted by Kurniati (2021) stated that the use of e-modules can improve students' critical thinking skills and student motivation. Research conducted by Ulfa (2021) using STEM integrated physics module improves student learning outcomes in cognitive aspects. STEM-integrated e-modules provide significant results for students' critical thinking skills in science learning and STEM integration combines real concepts in learning so as to enable students to be able to compete in the new era (Shukri, 2020; Hasanudin et al., 2022). Based on previous researchers, it was concluded that the use of STEM integrated physics e-modules can improve student learning outcomes.

After conducting an initial study at SMAN 3 Padang and SMAN 9 Padang, it was found that the reality on the ground did not match the ideal conditions expected. Based on the results of interviews, it was found that in learning physics some teachers have not used teaching materials that are in accordance with the characteristics of students. During the COVID-19 pandemic, teachers used physics e-modules, e-modules were obtained from the internet, so e-modules did not match the characteristics of students. The results of teacher interviews stated that they had applied the 4C skills in learning physics, such as creative and critical skills. However, the learning resources used have not equipped students to improve students' 21st century skills in accordance with the demands of the curriculum.

Based on the analysis of the characteristics of students in schools, it was found that students' learning motivation was low, one of the reasons that supported the low learning motivation of students was seen from the acquisition of mid-semester exam scores of XI high school students with an average of 65.53. Furthermore, context analysis on STEM integration in textbooks used in learning. The results of the context analysis can be concluded that the application of the STEM concept in physics learning in several schools in the city of Padang is still limited.

Based on the facts presented, it is necessary to find a solution to solve this problem. One solution that can be done is to develop an integrated STEM electronic module to improve the 21st century skills of class XI high school students. This is supported by several advantages of the proposed solution. Electronic modules are one of the easiest learning resources to use because they can be studied anywhere and anytime, are more interesting, interactive, and the use of ICT in learning can improve student learning outcomes (Sudarsana et al., 2021; Benty, 2020). STEM-based learning requires students to have learning and innovation skills, which include critical thinking, creative, innovative, and able to communicate and collaborate.

The purpose of this study is to describe the results of the development stages of the STEM integrated physics e-module to improve students' 21st century skills in valid and practical criteria. Good results can provide a wealth of learning resources that are more innovative and creative. It is hoped that the products developed will be useful for further learning and research. Furthermore, this research is expected to be an alternative reference to improve the quality of learning in other fields of science.

## Method

This research is development research, that is development teaching materials in the form of STEM integrated physics e-modules to improve the 21st century skills of class XI high school students. E-Module was developed using Flip PDF Professional software with reference to the plomp model. According to Akker (2010), there are three stages in the research to develop the Plomp Model. First preliminary research, which is carried out to obtain information about problems in the field and to design products to be developed. Second, development or prototyping Phase a formative evaluation is carried out on the product being developed, formative evaluation activities are carried out through self-evaluation, expert review, one-to-one evaluation, small group and field tests. The flow of the formative evaluation can be seen in Figure 1. Third, Assessment Phase is carried out in the field test phase, aiming to determine the effectiveness of the physics e-module developed on the competence aspects of attitudes, knowledge aspects and skills aspects.

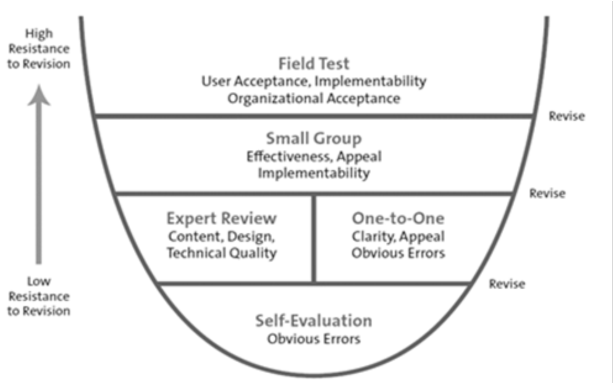


**Figure 1.** Formative Evaluation Flow (Tessmer, 1993)

This research was conducted at SMAN 9 Padang. The time of the study was carried out in the second semester of the 2021/2022 academic year. The subjects of this study were students of class XI MIPA 4 at SMAN 9 Padang. The purpose of this study is to describe the results of the development stages of the STEM integrated physics e-module to improve students' 21st century skills in valid and practical criteria.

The stages of research carried out include research preparation and research implementation. Research preparation in the preliminary research phase includes early observations of the learning process in schools, analysis of student characteristics and preparation of research instruments. The research was carried out by self-evaluation, expert review, one-to-one evaluation and came to the small group stage.

Data collection methods include targets, methods, instruments and research subjects. The first stage is the product validity test. The validity test of the developed product was carried out using an expert review sheet with 4 aspects, namely the feasibility of the substance of the material, the feasibility of visual communication, the feasibility of learning design, and the use of software. The analysis used to test the validity is as proposed by Aiken (Syaifuddin, 2014). The assessment is done by assigning a number between 1 (ie very unrepresentative or very irrelevant) to 4 (ie very representative or very relevant). The value of aiken v is obtained by using Equation 1.

$$V = \frac{\sum s}{[n(c-1)]} \quad (1)$$

Information:
- s = $r - l_o$
- $l_o$ = The lowest value of the validity assessment (lowest number = 1)
- c = The highest number of validity assessments (highest number = 4)
- r = Number given by validator

The results of Aiken's calculations range from 0 to 1 and the number 0.6 can be interpreted as having a fairly high coefficient. The value of V 0.6 and above is stated in the valid category (Syaifuddin, 2014).

The second stage of data collection was to ask 6 students for responses to the physics e-module through interviews and to ask the teachers and students of class XI MIPA 4 to respond to the physics e-module through a questionnaire. Data on student and teacher responses were obtained from practicality questionnaires. The percentage value is obtained by using Equation 2.

$$Responden\ score = \frac{total\ score\ obtained}{maximum\ score}\ x\ 100\% \quad (2)$$

The results of the calculation of the response score are divided into five criteria. The criteria for determining product practicality can be seen in Table 1.

**Table 1.** Category Practicality Product

| Interval | Category |
|---|---|
| 0 – 20 | Fail |
| 21 – 40 | Not enough |
| 41 – 60 | Enough |
| 61 – 80 | Well |
| 81 – 100 | Very well |

## Result and Discussion

In the Preliminary Research phase, activities are carried out to obtain information about problems in learning and determine the development needs to be carried out. This stage includes the results of student analysis using a student questionnaire sheet, the results of the analysis of learning problems using the teacher interview sheet instrument and the results of the analysis of learning activities using the context analysis sheet. Based on the results of the initial investigation, the product developed is the STEM integrated physics e-module to improve students' 21st century skills. The module developed refers to Prastowo (2011) consisting of: introduction, learning activities (title, material description, summary, worksheet and evaluation and closing.

In the Development or Prototyping Phase, a formative evaluation of the physics e-module is carried out. **First**, the self-evaluation was carried out by the researchers themselves, the results of the self-evaluation showed that there were still some spelling and punctuation errors, deficiencies in the product, there was no description of the images and videos in the e-module. The physics e-module was revised to fix errors found during self-evaluation. **Second**, the revised results are given to expert reviewers to be validated. The validity of the physics e-module was assessed by experts, namely three lecturers from Padang State University (UNP). The results of the validity of the STEM integrated physics e-module are seen in Table 2.

**Table 2.** The Validity of The STEM Integrated Physics E-Module

| Component | Aiken's Value | Criteria |
|---|---|---|
| Material Substance | 0.86 | Valid |
| Visual Communication | 0.82 | Valid |
| Learning Design | 0.88 | Valid |
| Software usage | 0.87 | Valid |
| Average | 0.86 | Valid |

Based on the data in Table 2 that the four aspects of validation on the value of Aiken's V> 0.6 in the valid criteria. From the four aspects of validity, the average value according to the validator is 0.86. It can be interpreted that the STEM integrated physics e-module to improve 21st century skills is in the valid category. The resulting e-module has met the feasibility aspects both in terms of content, learning design, visual display and the use of supporting software. These four components are the main components that must be considered in the development of ICT-based teaching materials (Kemendiknas, 2010). This means that the STEM integrated physics e-module can be used in the physics learning process.

The STEM integrated physics e-module is valid based on the aspect of material substance with an Aiken's V value of 0.86. Indicators of material substance include that the material in the physics e-module is correct according to scientific rules, the scope of the material presented is complete and raises new things and the material presented is easy to understand and uses standard language. Visual communication aspect with Aiken's V value of 0.82. Indicators of the visual communication aspect consist of navigation, letters, media, colors, images, animations and layouts in the STEM integrated physics e-module. This is similarly expressed by Hamdani (2011) which states that the use of consistent type and size of letters and the attractive design used will increase students' motivation and comfort in learning.

Aspects of learning design with Aiken's V value of 0.88. Indicators of the learning design aspect in the physics e-module include titles, core competencies and basic competencies, learning objectives, materials, worksheets, exercises and evaluations as well as references. Aspects of using software with Aiken's V value of 0.87. The indicators include the originality of the software used and feedback from the system to the user.

At the end of the instrument, the three experts were asked to provide a final recommendation of the product being assessed. The three experts stated that the STEM integrated physics e-module still needs to be improved and so that this media is feasible as the main teaching material, improvements must be made, especially completing the description of the material with phenomena or symptoms that are in the environment around students and increasing evaluation questions in the physics e-module. at the level of HOTS questions.

**Third**, One to One Evaluation was conducted on 3 students using an interview instrument. The STEM integrated physics e-module is given to high, medium, and low ability students. Students are asked to read the physics e-module without being taught by the teacher first. The researcher gave questions to students after reading the physics e-module which was provided in the form of easy concept maps, materials, 21st century skills, and activity sheets. Students think that the electronic module arouses curiosity and interest in mastering physics material. This is because the physics e-module can be used anywhere at any time, and is accompanied by an understanding of the material through videos, animations, and practical activities using phet simulation. The physics e-module is already graphically valid because its size is according to age and material. Slameto (2010) states that the accuracy of the teaching materials used in the learning process will facilitate the acceptance of the subject matter provided.

**Fourth**, Small Group Evaluation is carried out by practicing the valid e-physics module on students. Small Group Evaluation was conducted on students of class XI MIPA 4 who came from medium and low abilities and one physics teacher in class XI of SMAN 9 Padang. The material being tested is the material of sound and light waves. Test the practicality of the physics e-module from a small group using a student questionnaire. The practicality questionnaire includes several indicators, namely usable, easy to use, appealing and cost effective (Sugiyono, 2007). The results of the practicality of student and teacher responses can be seen in Table 3.

**Table 3.** The results of the practicality of student and teacher

| Indicator | Student Response | | Teacher response | |
|---|---|---|---|---|
| | Value | Category | Value | Category |
| Usable | 78.57 | Well | 85.00 | Very Well |
| Easy To Use | 75.69 | Well | 90.00 | Very Well |
| Appealing | 79.74 | Well | 90.00 | Very Well |
| Cost Effective | 81.94 | Very Well | 95.00 | Very Well |
| Average | 78.98 | Well | 90.00 | Very Well |

Based on Table 3 it can be seen that the level of practicality of the STEM integrated physics e-module is based on student responses with an average practicality value of 78.98. This can be indicated that the practicality of the STEM integrated physics e-module according to students in small groups in good criteria. Based on the teacher's response, the average practicality value was 90.00. It can be interpreted that the practicality of the STEM integrated physics e-module based on the teacher's response is very good.

Students in small groups still need a long time to understand the physics e-module. The e-module physics lesson has been revised and refined in its design so that students can study it in an optimal time. The highest score is in the statement of color composition in the physics e-module, which is interesting to read. The physics e-module is designed in color so that it is attractive to students and ultimately raises motivation in learning. Thus, a revision was made based on suggestions from teachers and students, so that it can be tested in large groups of STEM integrated physics e-module products that can improve students' 21st century skills. Ramli (2020) stated that the integration of STEM concepts in physics e-modules can improve learning and innovation skills, which include critical, creative, innovative thinking, as well as being able to communicate and collaborate.

## Conclusion

Based on the results of the development of the STEM integrated physics e-module to improve students' 21st century skills, in the first stage, self-evaluation resulted in the STEM integrated physics e-module to be tested for validity by experts. The second stage is an expert review, producing a valid STEM integrated physics e-module that has met the feasibility of the material substance, the feasibility of visual communication, the feasibility of learning design, and the use of software with an average value of 0.86. The next stage is a one-to-one and small group evaluation, from the responses of students and teachers stating that the physics e-module is useable, easy to use, appealing, and cost effective with an average value of 78.98 student responses in the good category and an average score. the average teacher response is 90.00 in the very good category. So, it can be concluded that the development of STEM integrated physics e-modules to improve the 21st century skills of students developed is valid and practical to use in learning.


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