ISSN 2987-4270
PLE
Physics Learning and Education
Vol. 1 No. 2 (2023), page 62-70

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

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ABSTRACT

The era of industrial revolution 4.0 aims to develop human resources who can discuss creatively and think critically. Teachers can take advantage of technological developments by designing e-modules that integrate with STEM approaches that improve students' critical and creative thinking skills. The purpose of this study was to determine the results of validation of integrated e-modules the STEM approach. This research belongs to the research and development that designs up to the demonstration test stage using a four-dimensional development model. The data collection tool used validation sheets. The data collection tool used validation sheets. The result obtained from the mean V is 0.68, which is within the valid category. Based on the results of the study, it was concluded that an integrated work and energy materials e-module using a STEM approach would be suitable for use in a Grade X physics class. The e-modules integrated with STEM approach will be further developed and used as standalone learning materials to overcome the challenges of Industrial Revolution 4.0. This enhances student ability to think critically and creatively, leading to meaningful learning.

Keywords: E-module; STEM approach; critical thinking; creative thinking; work and energy.

I. INTRODUCTION

Industrial Revolution 4.0 is a digital revolution where cyber and automation technologies work together. Industrial Revolution 4.0 is expected to create human resources (HR) who can debate and think critically, logically and systematically to face global challenges and improve national economies. Facing the industrial revolution 4.0 requires efforts, good strategies from various groups, both from regulators (government), academics and practitioners. In a study the involvement of academics is needed to realize Industry 4.0. The involvement of academics in this context is an attempt to reform the direction and goals of education [1]. The direction and purpose of education is currently known as 21st century education, where 21st century education not only emphasizes learning materials, but also emphasizes four criteria known as 4C skills (Critical thinking, Creative thinking, Collaboration and Communication). The educational goals in 21st century learning that must be achieved by students are broad knowledge insights, able to think critically and creatively think, can work together with teams, communicate well, create and can influence a work [2]. Learning activities in the 21st century are student-centered and require students to be active. The context used in learning is related to technologies currently under development [3].

The goals of 21st century education can be achieved by changing the national curriculum to the 2013 curriculum, which prioritizes 21st century skills-based learning [4]. The 21st century skills prepares students to face digital challenges head-on. The educational curriculum identifies five competencies that students need to possess when entering the industrial revolution 4.0 era: 1) critical thinking skills, 2) creativity and innovation skills, and 3) good communication skills, 4) collaborative and collaborative, and 5) self-confidence. In addition, the 2013 curriculum is designed to encourage students to observe, ask a lot of questions (critical), debate a lot (creative), and communicate what they have learned and understood [5].

Indonesian education units conduct face-to-face learning directly to observe students' 21st century skills. When an emergency occurs (Covid-19 pandemic) requires students to learn independently by utilizing teaching materials such as e-modules. E-modules are very important in the learning process. This is because e-modules make it easier for students to study independently and help students understand the learning material [6].

However, it was found that the conditions occurring did not correspond to the expected ideal conditions. First, from the results of observations on the use of e-modules in schools, were still in the less category, namely 51.79. Second, the analysis of documents on the integration of STEM approaches into textbooks satisfies 57.32 within the category. Third, the results of the literature review show that the work and energy material is very difficult for students to understand. Fourth, the performance evaluation results indicate that critical thinking skills are still lacking, that is 54.71, and creative thinking skills for students in this category are average 54.5.

Starting from the ideal situation and the reality on the field, there are gaps. The gap can be seen that the modules used in schools have not been integrated with the STEM approach. This gap is a problem in this study. To solve these problems, the solution is to develop of work and energy e-module integrated STEM approaches to improve students' critical and creative thinking. E-modules are digital or non-printed course materials systematically assembled for use with independent learning purposes that may require critical and creative thinking from students. E-modules are modules in digital form, consisting of text, images, videos, or a combination of both, containing materials with simulations suitable for learning [7]. The learning process with e-modules makes it easy for students to access anytime, and anywhere.

Using e-modules in learning activities can improve students' skills for the 21st century. One of these is the design of integrated STEM (Science, Technology, Engineering and Mathematics) e-modules, allowing students to gain a holistic understanding of the connections between the natural sciences through 21st century learning experience [8]. STEM-based learning can train students to use technology to solve environmental problems [9]. STEM is a change in education today, is considered very appropriate to be applied so that students have a logical, systematic, critical and creative mindset [10]. In addition, the e-module is equipped with a virtual labs. Virtual laboratory is a practicum carried out by students without using a real laboratory that allows students to connect theoretical aspects with practical aspects. Virtual laboratories will create student-centered learning, improve students' critical and creative thinking skills [11].

Critical thinking is thinking reflectively or reasoning that emphasizes making decisions about what to believe, and what actions to take [12]. One way to improve critical thinking skills is through student-centered learning such as. The use of e-modules in learning activities [13]. During the learning process critical thinking can be trained by conditioning students to find problems and find the right solution to these problems [14]. According to Fernando, critical thinking skills are skills that can find ideas, analyze these ideas in detail so that they can produce a good and appropriate conclusion [15]. So, critical thinking skills are skills possessed in detail, knowing the root of the problem, analyzing the problem, finding the right solution, and evaluating the solution to the problem it self.

Creative thinking skills are the ability to collaborate on new ideas found using existing ideas [16]. A person is said to have creative thinking ability if he or she can tap into their own potential by generating new or unique creativity [17]. Creative thinking, therefore, is the ability to create new things out of one's own possibilities.

Many similar studies have been carried out, but they are not integrated with the STEM approach. The emergence of interest in conducting this research is because the research was carried out by integrating STEM in electronically packaged using Flip PDF Corporate Edition Software. Therefore. this research was conducted with the aim of knowing the results of the integrated e-module validation of the STEM approach.

II. METHOD

This studies technique belongs to the sort of studies and improvement/R&D). Research and development is a studies technique used to develop a selected product, and check the effectiveness of the product [18]. In education, development studies is a studies version used to broaden or validate merchandise utilized in training and learning [19].

The development model used in this research is the 4-D model (four D models). The 4-D development model has four main stages that must be carried out. The first stage is the defining stage,the second is the design stage,the third is the development stage,and the fourth is the dissemination stage [20]. The four main stages of the 4-D development model consist of several steps that need to be carried out. The definition stage, namely the stage of determining and defining learning needs using an integrated e-module with the STEM approach. The steps taken at this stage are front-end analysis (identification of basic problems), student analysis, task analysis, and concept analysis. Design phase, this phase is carried out with the purpose of designing the product. The steps taken are formulating learning activities, selecting and determining the e-module format. The development stage, namely the stage of conducting validity tests, revising products, and testing students. The last stage of deployment is to disseminate the product that has been designed. Based on the four stages of development, this research is limited to the development stage, that is validation testing.

This survey tool uses a validation test sheet. To find out the results of product validity, the validation test sheet consists of five feasibility indicators. The indicators consist of aspects of material content, visual communication presentation, learning design, software use, and STEM assessment. Verification sheets are filled out by three experts.

Results of the data analysis of the validity test results of the e-module integrated STEM approach, were analyzed using the Aiken's V [21]. Validation Aiken's V, the e-module is interpreted as very valid if the value of V>0.8, the e-module is interpreted as valid if the value is 0.4<V 0.8, and the e-module is interpreted as less valid if the value of V 0.4 [22]. Validated data were analyzed using descriptive statistics. Descriptive statistics are statistics used for data collection and data presentation, so that useful and easy-to-understand information is obtained [23]. The data collection used in this study is described in tabular and graphical form. Tables and graphics make data recording clearer and provide clear and accurate information.

III. RESULTS AND DISCUSSION

Results

The results of this study are the validity of the integrated e-module STEM approach. Validation results are used to determine the feasibility of the developed modulus and as a guide for revision of the generated modulus. The young's modulus verification test device integrated into the STEM approach is based on five feasibility factors: material content feasibility, visual communication presentation feasibility, learning design feasibility, and software usage feasibility. Evaluated based on likelihood. and the feasibility of STEM evaluation.

a. Validation Test Results for The Material Substance Feasibility Indicators

The validity test was carried out on the feasibility of the e-module material substance integrated with the STEM approach. The feasibility of the content of the material consists of four indicators: veracity (MS1), completeness of the material (MS2), timeliness (MS3), and readability (MS4). Results of the test plot for the feasibility validity of the substance of the e-module material with the STEM approach are described in Figure 1.

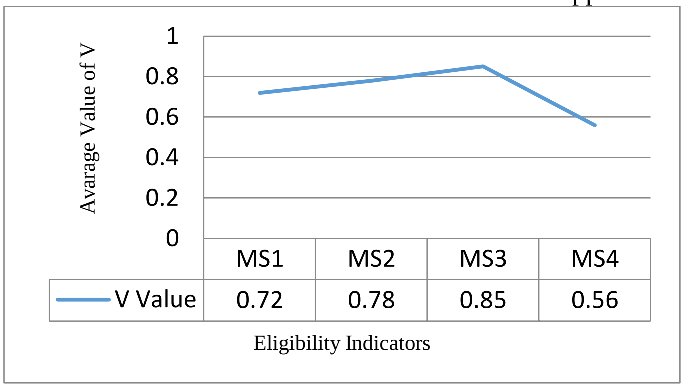

Figure. 1. Indicators Feasibility Validation Test Results for The Substance of The Material

Based on Figure 1, it can be analyzed that the validation test data for each indicator of material feasibility are very valid and in the valid category. The feasibility of the material work and energy is 0.73 which is included in the valid category. The test result data shows that the current indicator has the highest average value of V. This is because the material presented in the e-module meets the requirements of the latest curriculum (Curriculum 2013). Additionally, the e-module is integrated with the STEM approach, a technology developed using modern applications and adapted to current real-world conditions. The STEM approach integrated e-module has the lowest V because there are still incorrect index writing rules, so the legibility validation value is lower compared to other indicators. Based on the suggestions and input of the validator, revisions were made to the product being developed.

b. Validation Test Results for The Visual Communication Display Feasibility Indicators

A second evaluation was conducted on the feasibility of e-modules for visual communication displays using the integrated STEM approach. The feasibility of displaying visual communication consists of several assessment indicators, including: navigation indicators (VCD1), letters (VCD2), media (VCD3), colors (VCD4), animations (VCD5), and layout (VCD6). The results of the test plot for the validity of the visual communication display on the e-module integrated STEM approach as described in Figure 2.

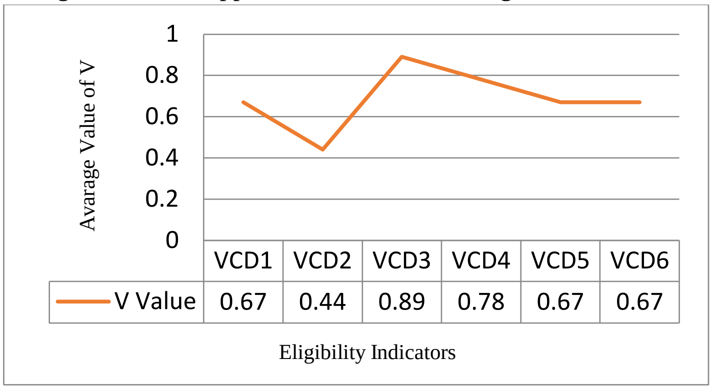

Figure 2. Indicators Feasibility Validation Test Results for The Visual Communication Display

In Figure 2, it can be revealed that each indicator of the feasibility of the e-module visual communication display is in the very valid and valid category. The indicator that has the V is the media indicator, while the V is the letter indicator. The high value of media indicator validation is because in the e-module integrated of the STEM approach there are images and their sources, animations, PheT simulation, interactive evaluation buttons, and videos and their supporting sources. In addition to this, the e-module also contains more than one learning media. The letter indicator received a lower score than other indicators, due to the use of an inaccurate writing size. Data analysis results for the feasibility component of the visual communication display showed a mean V of 0.69 that was within the valid categories.

c. Validation Test Results for The Learning Design Feasibility Indicators

Validation tests on the feasibility of an e-module learning design integrated for the STEM concept have been performed. The feasibility of the learning design is measured by 9 indicators including title (LD1), core and basic competencies (LD2), learning objectives (LD3), materials (LD4), sample questions (LD5), exercises (LD6), and tasks. consists of Instructions (LD7), Compiler (LD8), Reference (LD9). The plot results for each feasibility indicator of the learning design are shown in Figure 3.

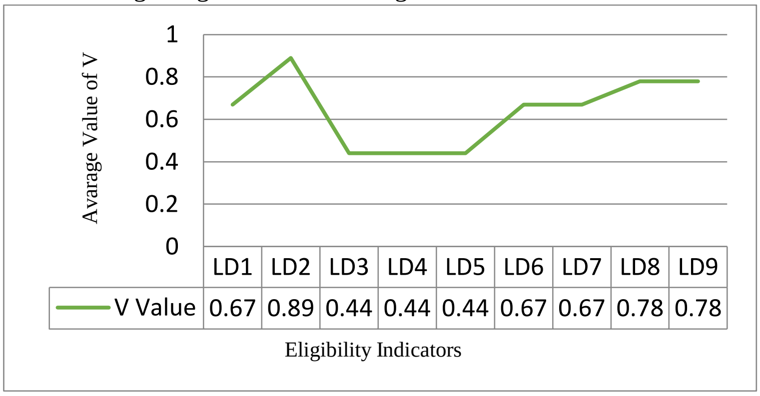

Figure 3. Indicators Feasibility Validation Test Results for The Learning Design

In Figure 3, we can see that the validation tests for each indicator of the feasibility in aspect of the learning design are in the highly valid and effective category. The evaluation results for each index result in a V of 0.64 for valid category validation interpretations. As a result of data analysis, core competence and basic competence indicators showed significantly higher validation values than other indicators. This is because the e-module integrated with STEM approach has core competencies and base competencies corresponding to the 2013 curriculum. The compiler and reference indicators have the same validation value, because the cover e-module contains the identity of the author (name and institution). The e module was designed with reference to at least 5 references.

d. Validation Test Results for The Usage Software Feasibility Indicators

The validity test of the e-module integrated STEM approach was carried out on the feasibility of using the software. The indicators assessed for this feasibility are interactivity (feedback from system to user) (PLP1), software (PLP2), and originality (PLP3). Based on data analysis, the results of test plots regarding the feasibility of using the software are shown in Figure 4.

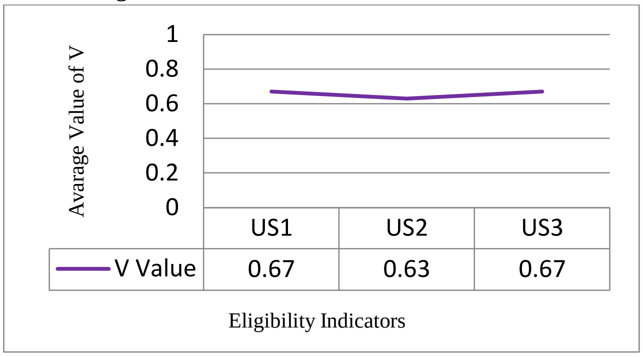

Figure 4. Indicators Feasibility Validation Test Results for The Usage Software

From Figure 4, it can be analyzed that all indicators of the feasibility of using the software for elastic modulus are in valid categories. Judging from the feasibility index of software use, the integrated e-module STEM approach is a two-way system-to-student approach in the learning process, as the e-module uses the software, PheT Media Virtual Lab, and Microsoft Office Word software generated orientation. Next, the e-modules contain images, videos, and animations that you create yourself and are supported by sources as original material. Based on the validation test results, the feasibility of using the integrated module mint approach is in the valid category with an average V of 0.65.

e. Validation Test Results for The STEM Assessment Feasibility Indicators

A fifth validation test was conducted on the feasibility of integrated STEM e-module evaluation of the STEM approach. The indicators assessed on the feasibility of this STEM assessment include science (PS1), technology (PS2), engineering (PS4), and mathematics (PS4). The results of the validation test plots for these four indicators are shown in Figure 5.

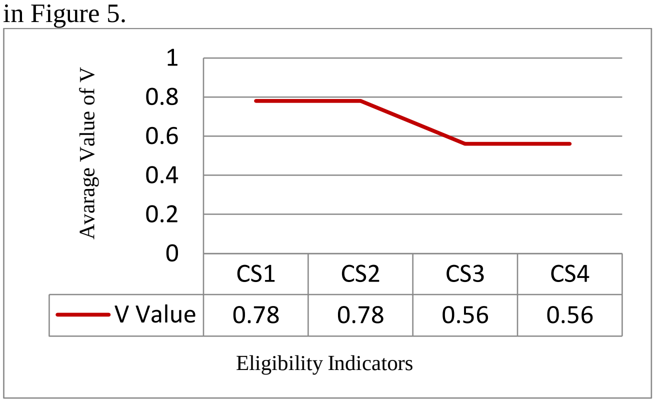

Figure 5. Indicators Feasibility Validation Test Results for The STEM Asessment

Using Fig. 5, it can be explained that the results of validation tests on the feasibility of integrated E-modulus mint evaluation of the STEM approach show a V of 0.69, which is in the valid category. From the evaluation of each index to the feasibility of the STEM evaluation and the modulus of elasticity, it falls into a reasonable category. The relevance of the STEM assessment is reasonable as the material presented corresponds to the current real situation.In addition, in the e-module there are examples of technology related to science, there is knowledge of design and working principles of technology, and contains the mathematical basis that underlies the design of technology. Each indicator of STEM assessment feasibility triggers the emergence of critical and creative thinking skills in students.

A plausibility check for each component of the integrated elastic modulus feasibility of the mint approach resulted in V mean values ranging from 0.64 to 0.73, which were classified as plausible. The data analysis that has been described can be recapitulated into tabular form. The recapitulation of the average value of the STEM integrated e-module validity test can be described in Table 2.

Tabel 2. Recapitulation Aiken's V of The Integrated STEM E-module Validation Test

Aspect	Average V Value
Material substance	0,73
Visual communication display	0,69
Learning design	0,64
Usage software	0,65
STEM assessment	0,67

Based on Table 2 outlining Aiken's V validation tests for the work and energy e-module integrated STEM approaches, the average V value for validation interpretation of 0.68 is in the valid category. This indicates that the developed e-module is suitable for use in physics learning process. The highest V-value is in the material feasibility of matter and the lowest is the feasibility of learning the design in the e-module.This difference in value occurs because there are different strengths and weaknesses in each component of the feasibility assessment.

Discussion

The results of this study are to see the results of the validity test of the integrated e-module with the STEM approach. Based on the results of the data analysis that has been carried out, the average V value of the e-module is integrated with the STEM approach declared valid of the five feasibility components assessed. Integrated e-module feasibility components the STEM approach consists of: the feasibility of material substance, the feasibility of visual communication display, feasibility learning design, feasibility of using software, and feasibility of STEM assessment.

The physical material presented in the e-module corresponds to everyday conditions, so the feasibility of the integrated e-module physical material using the mint approach is in a valid category. We can understand matter by building a material relationship with real-world situations [24]. In addition, e-modules are being developed according to the student's needs and his 2013 curriculum. According to the Ministry of National Education, the materials developed should correspond to the applicable curriculum [25]. Judging from the readability, the developed e-modules correspond to proper and correct Indonesian language rules and are easy to understand. The modules used for study are in line with Plastovo's opinion that they should be simple, clear and effective so that the material can be easily understood by students [26].

The use of attractive color combinations is implemented in e-modules, so the feasibility of visual communication representation of e-modules is interpreted as valid. The use of attractive colors should increase students' interest in learning with the developed e-module [27]. In addition, e-modules are equipped with audio which can create a more pleasant learning atmosphere [28]. The e-module with the integrated STEM approach is designed with a proportional layout or layout. According to Rustan, an e-module needs to be developed by paying attention to the layout, because it will have a strong effect on the readers [29]. For this reason, the unity of the elements in the e-module must be related to each other and arranged appropriately.

The feasibility validity of the learning design is supported by the core competencies, basic competencies, indicators and learning objectives of the e-module according to the presented material. According to Nasution, the benefits of learning that are clearly presented will create more focused learning [30]. The design of an e-module with a integrated STEM approach has referred to various relevant references. So that e-modules are not considered plagiarism of other people's work, it is necessary to include reference sources when taking pictures, videos and others [31]. A development research, validation test of learning design feasibility is very important to do, because it affects students' reading interest [32]. The feasibility component of the software using e-modules with the integrated STEM approach is categorized as valid, because e-modules generate interactions in the learning process. The STEM approach integrated e-module has several supporting applications. The combination of several supporting applications in the e-module is even more interesting, because it is equipped with text, video, images and animation. This supporting application will increase student enthusiasm in learning [33].

The feasibility of the e-module STEM assessment is declared valid, because it includes every assessment indicator. Metrics cover STEM components such as science, technology, engineering, and mathematics. Each component of STEM is a catalyst for developing students' critical and creative thinking skills. An advantage of the integrated Young's modulus STEM approach is that materials focus on everyday life problems and provide solutions to these problems [34]. According to Abdurrahman, her STEM approach integrated into young's modules is effective in improving the creativity and critical thinking skills of her students [35].

The five components of the feasibility of the e-modulus integrated with the mint approach have different validation values. This difference in value occurs because there are advantages and disadvantages to each component of the feasibility assessment. defects in the developed product are corrected according to the verifier's suggestions and inputs. Product revisions have been made to make the developed e-module better and more suitable for use in high school class X physics learning process.

A limitation of this study is that the research phase extends only to the testing phase of product validation. This valid product can be used as an idea for further research. Further research that can be done is to conduct product trials in several classes. Then it can be developed again at the stage of mass deployment in a wider scope.

The second limitation is that this research only develops an integrated e-module with a STEM approach on work and energy materials. This limitation occurs due to the limited time of the researcher. The solution to overcome this obstacle, other researchers are expected to be able to develop an integrated e-module with the STEM approach in each class X high school physics material. That way students can use an e-module of integrated STEM concepts in every material in the learning process.

A third limitation is that the e-modules developed are limited to the Flip PDF Corporate Edition software. The solution is that other researchers are expected to develop an e-module with a integrated STEM approach using other applications. Applications that can be used such as Adobe Captivate, Sigil, and other similar applications. In addition, other researchers are expected to add software that can automatically recap student scores when doing exercises and sample questions. The use of the right application on the e-module will result in an increasingly high-quality e-module.

IV. CONCLUSION

The results of this study were conducted to test the effectiveness of the five components of the feasibility of young's modules integrated using the mint approach. The feasibility component consists of material content feasibility, visual communication representation feasibility, learning design feasibility, software use feasibility, and STEM assessment feasibility. Based on the data analysis results, the mean V-value for the integrated young's modulus mint approach is 0.68, and the validation interpretation falls within the valid category. From the results of the study, it can be concluded that the energy and working matter e-module using the mint integrated approach is suitable for use in class X SMA physics lessons. Therefore, it is expected that this study will be further developed to confirm the practicality and effectiveness of the e-modules integrated STEM approach on students' critical and creative thinking abilities.[35]

ACKNOWLEDGMENT

We thank the Padang State University for providing the opportunity for researchers to conduct their research and the FMIPA UNP of the Department of Physics as the forum for publishing this article. Similarly the Physics Department lecturer as a validator who has taken the time and thought and provided suggestions and input in the process of development of work and energy e-module integrated STEM approaches to improve students' critical and creative thinking for class X high school students.

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