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Development of Electronic Modules Based on STEM to Train Students' Creativity: Validity and Practicality Analysis

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Abstract

The STEM-based electronic module is a systematic presentation of learning materials to support students' independence with an approach in four fields of knowledge: science, technology, engineering, and mathematics. This study aims to describe the feasibility of this STEM-based electronic module to train students' creativity. The specific objectives of this study are to describe: (1) The validity of the STEM-based electronic physics module; and (2) The practicality of the STEM-based physics electronic module. The type of research was ADDIE, with the subject of the trial of 27 students at class X Science-1 in a public high school in Banjarmasin City, South Kalimantan, Indonesia. Data collection was obtained from observations, interviews, questionnaires, and tests. This research was analyzed qualitatively and quantitatively. The research results showed that: (1) the validity of the STEM-based electronic physics module was in a "very good" category, and (2) The practicality based on the implementation of the Lesson plan was categorized as "moderately practical". The existing STEM-based electronic physics modules (Science, Technology, Engineering, and Mathematics) to train students' creativity are still not suitable for learning. So, it can be concluded that the STEM-based physics electronic module is feasible to train students' creativity, and the direct result of this research was that educators could evaluate methods and media that support online learning more effectively for each meeting, and the results of this study can be used as input for teachers and teacher candidates. The next step of this research is to apply methods, learning models that support STEM and sufficient time to train students' creativity which is expected to be applied to face-to-face learning.

Keywords: Creativity; Electronic Module; STEM

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INTRODUCTION

Schools function as centres of culture and realize a national education system that educates the nation's life and promotes national culture. The provisions of the MPR RI (Court Representative of the Republic of Indonesia) in 1999 and Law No. 20 of 2003 have not made

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schools according to their functions. The government's efforts to make it happen have also become the fundamental basis for preparing the Ministry of Education and Culture's strategies in education. One of them is applying the STEM (Science, Technology, Engineering, and Mathematics) approach and 21st-century skills training (Handayani et al., 2021a).

STEM is a relevant approach to the nature of the world where the problems faced must be tied to Science, Technology, Engineering, and Mathematics, not only one of them (Zizka et al., 2021). Meanwhile, 21st-century skills are 4C skills which consist of Critical Thinking and Problem Solving, Creativity and Innovation, Communication, and Collaboration (Nurhaifa et al., 2020). Creativity is one of the essential 21st-century skills that must be trained from an early age, including when learning (Herak & Lamanepa, 2019), mastery of 21st-century skills is also a challenge for the younger generation to participate in the world of work in the future. Creativity is an individual mental process that gives birth to practical new ideas, methods, imagination, aesthetics, flexibility, integration, succession, discontinuity, and differentiation that are efficient in various fields for solving a problem (Dewantara, 2015).

Some research results can prove that STEM learning can have a positive influence on the knowledge and skills of 21st-century school-age children, some of which are research on STEM-based electronic modules, which are also seen as affecting the skills to be trained or improved (Cahyani et al., 2020; Herak & Lamanepa, 2019; Pertiwi et al., 2017; Wulansari & Madlazim, 2019; Yulianti et al., 2020). The 21st-century skills that STEM learning can develop are problem-solving, critical thinking, creative thinking, and collaboration (Waluyo & Wahyuni, 2021). However, at the beginning of 2020, which is precisely the beginning of March 2020, Indonesia was faced with a Coronavirus Disease outbreak which became the basis for the implementation of online learning, which became a new challenge for educators and students to be able to carry out effective learning. One of the efforts of educators to adapt to these online learning conditions is to create supporting media or teaching materials (Sari, 2020). Educators can create learning media that can support conditions and practical and effective media such as electronic modules that support students to learn independently with complete and adequate sources of knowledge (Handayani et al., 2021b).

Based on the results of observations and surveys of 34 students in general at High school Negeri 7 Banjarmasin, it was found that there were still many students who were not helped by textbooks and had little knowledge about STEM. It was strengthened by interviews with physics teachers in classes X and XI at high school, which also stated that many students still had difficulty understanding physics learning material. It is evidenced by the initial test, which resulted in 27 students of X Science-1 with an average score of 2,74 and 25 students of X Science-5 with an average score of 4,91.

Based on the conditions in the education sector in Indonesia in 2020, to improve the quality of education even during the COVID-19 pandemic, 21st-century skills must still be trained with the help of media that support online learning. Learning that trains 21st-century skills such as creativity can be combined with a STEM (Science, Technology, Engineering, and Mathematics) approach that presents relevant problems in

everyday life presented through media in the form of electronic module applications that are easily accessible anywhere and anytime. An electronic module is a form of presenting self-study materials that are systematically arranged into specific learning units, which are presented in an electronic format, where each lesson in it is connected by a link as navigation that makes students more interactive with the program, equipped with a presentation of video tutorials, animations and audio to enrich the learning experience.

The purpose of this research is to describe the feasibility of an electronic physics module based on STEM (Science, Technology, Engineering, and Mathematics) developed to train students' creativity. The purpose of this research is also spelt out specifically by the existence of a particular objective. The specific purpose of this research is to describe the validity and practicality of the developed electronic module.

METHOD

This research was a research and development (R&D) study. While the model used was the ADDIE development model (Analyze, Design, Development, Implementation, and Evaluation). The ADDIE model provides many opportunities for researchers to evaluate development activities at each stage to positively impact the quality of development products, such as minimizing the error rate or product shortages at the final stage of this model (Tegeh et al., 2014).

The subjects in this study were 33 students in class X Science-1. They were new students for the 2020/2021 academic year at High school Negeri 7 Banjarmasin. The feasibility of the electronic module based on STEM (Science, Technology, Engineering, and Mathematics) to train students' creativity was the object of this research.

The instruments used in this study were the developed e-module validation sheet, the cognitive and creativity test validation sheet, and student questionnaires. As for the creativity assessment's indicators used were fluency, flexibility, originality, and elaboration with the dimensions of creativity in the form of a person, press, process, and product.

The number obtained from the three validators was 369, and the assessment results were "average". Then, the validation results of each device were obtained, namely the electronic module, learning outcomes tests, and creativity tests which were adjusted to the categories in Table 1.

Table 1 Criteria for The Validation Aspects

Average Score	Category
$\bar{x} > 4{,}2$	Very good
$3{,}4 < \bar{x} \leq 4{,}2$	Good
$2{,}6 < \bar{x} \leq 3{,}4$	Good enough
$1{,}8 < \bar{x} \leq 2{,}6$	Not good
$\bar{x} \leq 1{,}8$	Not very good

(Widoyoko, 2016)

Meanwhile, to measure the validation results accuracy of the electronic module, the cognitive and creativity test and creativity were calculated using the Cronbach Alpha equation concerning categories according to Table 2 (Arikunto, 2013).

Table 2 Criteria for Aspects Of Reliability Assessment

Reliability coefficient	Reliability criteria
$0{,}800 < r \leq 1{,}00$	Very high
$0{,}600 < r \leq 0{,}800$	High
$0{,}400 < r \leq 0{,}600$	Fairly high
$0{,}200 < r \leq 0{,}400$	Low
$0{,}00 < r \leq 0{,}200$	Very low

Table 3 Criteria for The Implementation of The Lesson Plan

Average Score	Category
$3{,}2 < X$	Very practical
$2{,}4 < X \leq 3{,}2$	Practical
$1{,}6 < X \leq 2{,}4$	Pretty practical
$0{,}8 < X \leq 1{,}6$	Less practical
$X \leq 0{,}8$	Very impractical

Table 4 Criteria for Response Questionnaire Results

Average Score	Category
$\bar{x} > 4{,}2$	Very good
$3{,}4 < \bar{x} \leq 4{,}2$	Good
$2{,}6 < \bar{x} \leq 3{,}4$	Good enough
$1{,}8 < \bar{x} \leq 2{,}6$	Not good
$\bar{x} \leq 1{,}8$	Not very good

(Widoyoko, 2016)

While the electronic module practicality test was measured from the assessment results from three observers on the implementation of the lesson plan, the results of the average assessment were adjusted to the criteria in Table 3 and Table 4.

After all the data was obtained, it would be concluded whether the results were appropriate or not for this study. In addition, we could also find the weaknesses that must be overcome for further research.

RESULTS AND DISCUSSION

The results of this research were in the form of an electronic physics module based on STEM (Science, Technology, Engineering, and Mathematics) to train students' creativity on the topic of vectors. This module was developed through the professional Flip PDF software, which was set up to be easily accessed via a computer or smartphone. The assessment of the electronic module components based on STEM (Science, Technology, Engineering, and Mathematics) was in the "very good" category. It was shown from the validation results of the developed electronic module, categorized as very good with a very high degree of reliability.

Table 5 Validation Test Results for STEM-Based Electronic Physics Modules

No	Indicators	Component Rating	Average	Category
1	Contents	Software engineering Organization Language Evaluation	3,71	Very good
2	Display	Visual communication Format Attractiveness Font size and shape Language	3,69	Very good
3	STEM	STEM	3,60	Very good
Validity			3,69	Very good
Reliability			0,95	Very high

The validation of the STEM-based physics electronic module can be seen in Table 5.

The practicality of the developed electronic module was assessed based on

the implementation of the lesson plan used during learning which can be seen in Table 6.

Table 6 The practicality of STEM-based Physics Electronic Modules

Activity	Aspect	Average
Introduction	Delivering objectives and preparing students	2,57
Core	Demonstrating knowledge and skills	3,19
Activities	Guiding training	1,71
	Check students' understanding and provide feedback	1,26
	Provide advanced training and implementation	2,72
Closing		2,37
Average		2,29
Category		Pretty practical
Reliability		0,82
Degree of reliability		Very high

This module was prepared with the completeness of science, technology info, technology development (engineering), and the equations used. Science consists of the science of nature and its contents; science or knowledge is obtained through scientific processes such as observing, predicting, conducting experiments and making conclusions (Inayah et al., 2020; Ramayanti et al., 2017). The following is a picture of the electronic module (Figure 1). The image can be enlarged for clarity.

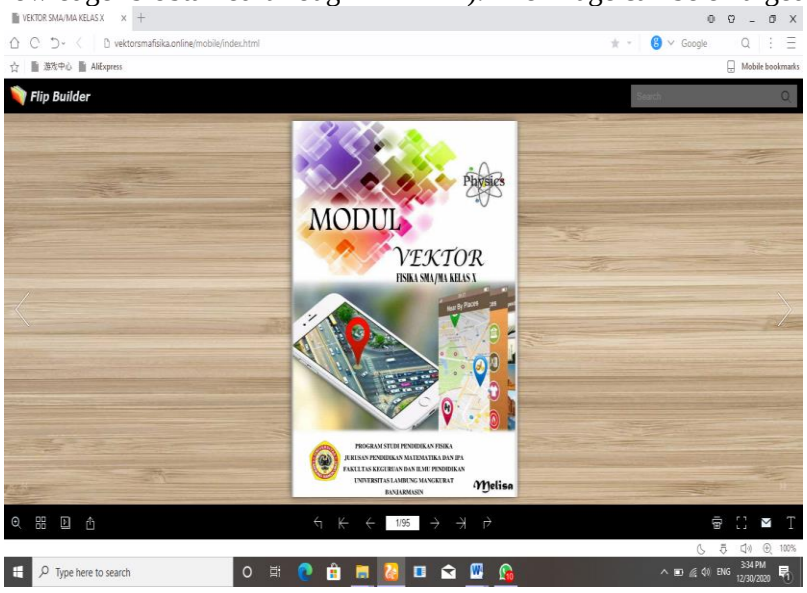

Figure 1 The developed electronic module

This electronic module also provides preliminary knowledge about STEM. It was intended to increase understanding and motivation for students before learning. The following Figure 2 is the STEM image on the electronic module, which can be enlarged to make it more clearly seen.

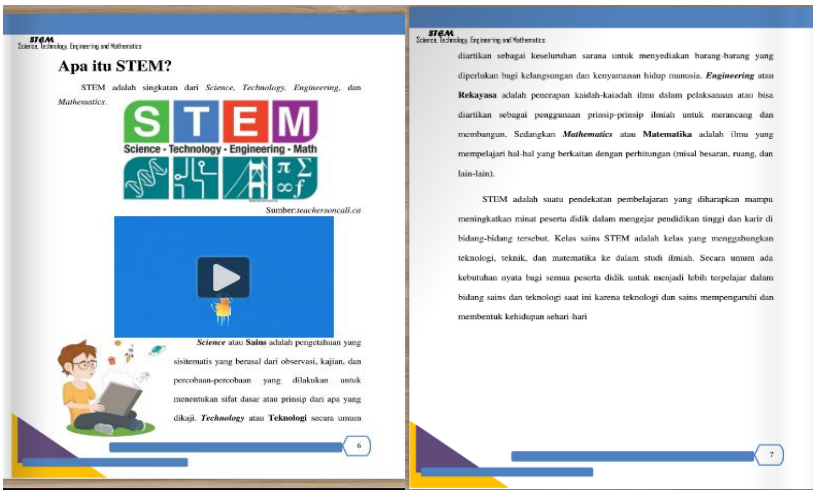

Figure 2 STEM

This "Technology Info" aims to add insight and provide an example of applying the material learned in everyday life. In addition, it aims to foster the curiosity of students. The following is an overview of "Technology Info" on the electronic module. The image (Figure 3) can be enlarged to make it more clearly seen.

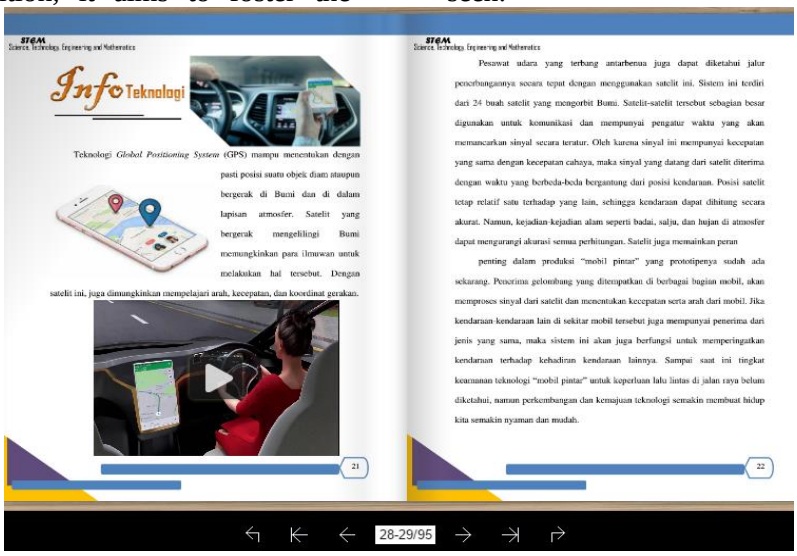

Figure 3 Technology Info

In addition, this electronic module aims to provide students with an understanding of the four fields of knowledge in STEM, the relationship between fields, how they are related, and adjustments to something trending in society. It also aims to stimulate themindset of students to innovate, be creative, and think about solutions to problems they face in everyday life that they may often encounter. Like the following Figure 4, the image can be enlarged for clarity.

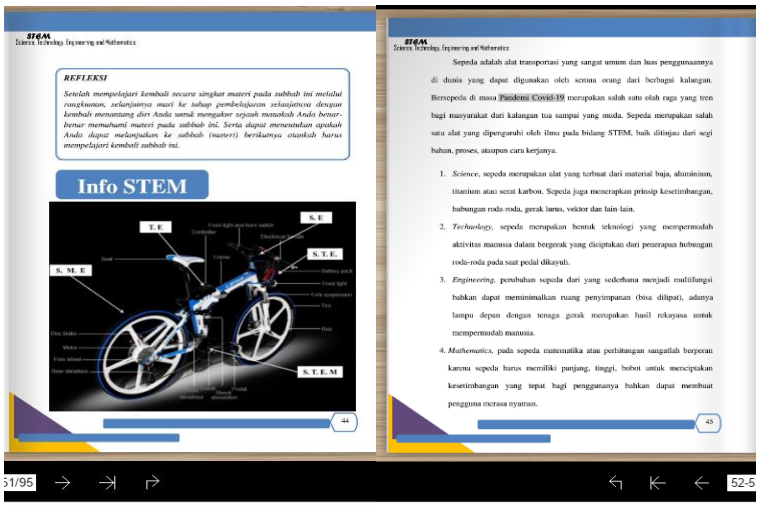

Figure 4 STEM Info

The assessment of the electronic module components based on STEM (Science, Technology, Engineering, and Mathematics) was categorized as "very good". It is shown in Table 5, the validation results of the developed electronic module were categorized as very good with a very high degree of reliability. The validated module assessment indicators were content, display, and STEM.

The content components are in the form of software engineering, organization, language, and evaluation. The amount of cellular data required to access this electronic module every time is approximately 12 MB (megabytes). It includes video playback, animation, and evaluation. However, this access does not require a large storage capacity, so it does not hamper device performance. Furthermore, this electronic module uses communicative language, is not monotonous and rigid to bring out the relevance of students to reading and studying the electronic module developed according to the indicators set by the Ministry of National Education (2017). The evaluation of this electronic module acts as a training session rather than a teacher assessment session. The results of the evaluation score will help analyze the weaknesses of students when doing an independent study using the electronic module. As the existence of the electronic module makes the learning process more centred on student activity (Student-centred) than the teachers' (Teacher-centered), this electronic module must also assist teachers in guiding students and increasing their treasury of learning resources (Susanti et al., 2020).

In terms of appearance, such as visual communication, format, attractiveness, shape and size of letters, and language, visual communication is also vital. The giving of color to the layout is related to the cognition and behavior of students. The colors in this electronic module are predominantly white and blue. The primary color that is widely used is white because this color can make writing visible. Besides that, the cover (front cover), pictures, animation of the electronic module also play an essential role in increasing attractiveness. The shape and size of the letters were used to make reading more accessible and provide variety to add interest. This electronic module uses five types of fonts with sizes 14 and 36, equipped with attractive

colours. In addition, the title of the material that stands out and the image on the front cover, accessing references in the form of articles or videos for students' curiosity, make this electronic module more interesting.

Meanwhile, STEM contains four complementary fields of knowledge: Science, Technology, Engineering, and Mathematics. These four areas of knowledge aim to motivate and further enrich information for students. Science consists of the science of nature and everything in it. Knowledge is obtained through scientific processes such as observing, predicting, conducting experiments and making conclusions (Inayah et al., 2020). The science in this module is presented by describing learning materials and additional information on science in life. Technology is a tool, machine and various things created to make human life more manageable with quality (Nuraeni, 2020). The technology in this module is presented in information about technological developments in line with the material being studied. Engineering is the knowledge and skills to apply science and mathematics concepts to produce technology to solve a problem (Awad & Barak, 2018; Barak, 2013). In this module, engineering is described with STEM information about engineering or technological developments and in learning activities in the form of practicum with making and testing. Meanwhile, the mathematics in this module is presented on the equations in determining the resultant vector using the component vector method or the cosine method.

During the validity test of the STEM-based physics electronic module (Science, Technology, Engineering, and Mathematics), the three validators suggested an explanation of the technical instructions for the features and navigation of the electronic module as well as the history of the application sources used to develop this electronic module. Therefore, the researchers explained the features and navigation of the electronic module that could be used when using this electronic module in the module user manual section. The researchers added a link to the source website page application used in the module user manual for historical sources of the application. This link also clarified the description of the features used by researchers who wanted to develop products using this application in full.

In Table 6, it can be seen that the aspects of guiding training and checking students' understanding and providing feedback received very low ratings. The first factor happens because of the lack of response or student activity when the supervisor starts. Second, the time allocation is not following the design of the electronic module, which is only two hours of lessons per meeting (2 x 45 minutes), so that learning materials must be compressed and many learning steps are not applied.

The initial design of this electronic module was with a time allocation of four hundred and five minutes (3 meetings with 135 minutes per meeting each week). However, due to the pandemic and learning through the online system, the learning time allocation was shortened to two hundred and seventy minutes (3 meetings). The time allocation was still a gross calculation because the learning time was less than 90 minutes per meeting. After all, students needed more time to process attendance and join online classes.

The researchers also evaluated each meeting based on the suggestions and

comments of 3 observers and the researchers' observations during the learning process. From the first meeting to the third meeting, the observers' suggestions and comments were to pay attention to the sequence of the learning process steps and their improvements to be carried out under the allocation of learning time. Therefore, in the guidance step, researchers or educators carried out discussions outside of class hours on class group forums or private chat forums when students were confused about doing guided exercises or material that has been delivered during learning through Google meet.

While researchers or educators evaluated the results of their observations at the 1st meeting, the distribution of attendance links was spread at 6 am, and the Google Meet link was shared at the start of the lesson at 8 am. The sharing of the Google Meet link caused the time for learning material to decrease by about 30 minutes because the joining process of all students took much time. It was also due to the teacher's mistake in creating a learning space on Google Meet, which was carried out by the researchers with educator account so that when explaining and sharing the participant material, the students who joined at that time were not approved, causing them missed the explanation of the material. Therefore, at the second meeting, the researchers shared the Google meet link at 7.45 in the morning (15 minutes before starting the lesson) and created a learning space on Google meet with the non-educators account so that the researcher could approve the students to join even when explaining and sharing the screen material. However, at this meeting, the material being taught contained a lot of arithmetic processes and equations which caused educators to be too fast in explaining the material presented, and another obstacle was the large number of students who did not provide supporting writing tools such as rulers and protractors so that they were constrained in describing vector. Moreover, at the 3rd meeting, before starting learning, the researcher ensured that students had a ruler and protractor through the presence attachment, namely a self-portrait by holding the writing instrument, and the educator also reflected on the material taught in the previous meeting in more extended time than the reflection of the material at the previous meeting.

Table 7 Results of the Student Response Questionnaire

No	Indicator	Average	Category
1	Benefit aspect	2,33	Good enough
2	Efficiency aspect	2,47	Good
3	Aspects of convenience	2,57	Good
Average		2,46	Good

33 students filled the student response questionnaire with the final results seen in Table 7. There were 45% of students who felt helped with a pleasant and not boring learning atmosphere. The low percentage of students' assistance to the developed electronic module indicates that there are still many shortcomings in terms of attractiveness and presentation of more information. However, this is also influenced by the characteristics of the students, in which only a few of them accessed the electronic module personally during learning or outside learning hours. It was proven by the researcher during a question and answer session about the contents of the developed electronic module. The learning atmosphere itself seemed more passive even in the question and answer session. Therefore, this

electronic module also has a low percentage in other aspects; 49% of students claimed to obtain new knowledge and information. It impacted 64% of students' interest in working in fields related to science and technology. Therefore, students who are enthusiastic about learning can increase motivation to pursue a career in the STEM field (Arís & Orcos, 2019).

The support of students for STEM-based electronic physics modules (Science, Technology, Engineering and Mathematics) is also supported by another factor, namely efficiency. 48% of students admitted that physics learning was completed on time using this electronic module. This low-efficiency percentage occurred because this electronic module was designed for 3 hours of lessons at each meeting (135 minutes), but the rules applied in High school Negeri 7 Banjarmasin during the pandemic stipulated only 2 hours of lessons per meeting (90 minutes). The steps in learning itself were not carried out perfectly. It was also due to online learning wherein there is a lack of two-way communication between students and educators during the learning process due to inadequate online media for this.

The last aspect that supports student assistance to the STEM-based electronic physics module (Science, Technology, Engineering and Mathematics) is the convenience aspect. These aspects include language, font size, and accessibility. 80% of students stated that the sentences or languages in the module made it easier to understand learning material. 38% of students also stated that the font size in this electronic module was not difficult in the learning process. The use of fonts for the electronic module itself has been adjusted to the comfort and readability level for those who learn it.

At the time of access, 86% of students stated that the electronic module access was quite fast. This electronic module was loaded in approximately eight seconds through the 4G data network (Fourth-Generation Technology). Loading on each module page was about one second. Meanwhile, the learning video can be played in less than two seconds. 77% of students stated that this electronic module could be accessed easily on various networks (wifi, 3G, or 4G). Smartphone battery power when using electronic modules was quite economical. 54% of students stated that the battery power remained stable and did not significantly decrease when accessing and using this electronic module.

The electronic physics module presented the application of the material in everyday life, even what students usually experience. Thus, students can present work in the form of a simple toy that applies vector concepts. The process of forming this creative ability must, of course, be encouraged by meaningful learning, where learning can strengthen students' abilities in a basic understanding of physics concepts and the ability to think, including analyzing, evaluating and ultimately being able to bring out the creativity of students (Cahyani et al., 2020). Physics is one of the sciences that can be oriented to various aspects of life. Physics is the study of events that exist in everyday life, which can be interpreted using the language of mathematics (Maisaroh et al., 2020). In addition, STEM learning can explore the creativity and innovation of students in solving problems in real life (Miriam et al., 2020). It shows that by referring to STEM, learning can train creativity and increase these students' creativity, but this must be supported by active learning in thinking and activities because ideas and activities

will continue to flow throughout the lives of creative people (Dewantara et al., 2021).

Let us look at the results of the creativity of students per indicator. It can be explained that the first aspect of creativity, which is the reference for assessment, namely fluency thinking skills (fluency), is the ability to generate lots of ideas and ideas, suggest many ways to do various things and look for many possible alternative answers and problem solving (Greenstein, 2012). This aspect is seen in terms of the process, for the experimental class has increased. In the second aspect, namely original thinking skills (originality), which is the ability to generate ideas or ideas and make new and unique combinations, use unusual ways of expressing oneself and being able to look for various possible solutions to problems through ways that others may not have thought of (Dewantara et al., 2021; Susilowati & Dewantara, 2021). This aspect is seen in terms of products and processes, in terms of experimental class products also experiencing an increase. The third aspect is elaboration, which is the ability to enrich or develop an idea, idea or product and the ability to detail objects, ideas and situations so that they are not only better but more interesting (Bayyinah et al., 2014). This aspect can be seen in terms of the process, which has increased in the experimental class.

Moreover, the fourth aspect, namely flexible thinking skills (flexibility), is using various approaches to overcome problems (Mentari et al., 2016). This aspect is seen in terms of Press, Person, Process, and Product. In terms of Press, Person, Process, and Product, the experimental class also experienced an increase.

The four aspects of creativity are closely related to the personalities described above. In contrast, these personalities cannot be intertwined or developed using learning that only communicates through screens. These personalities must be trained directly with active activities and good two-way communication, so students feel a sense of trust and care for educators to make learning more meaningful.

Based on the research and development that has been carried out, the researchers realize that there are weaknesses in this research and development, including learning time that did not correspond to the time allocation for the design of the electronic module, learning time was cut due to the process of students attending and joining the learning class, several students who were hampered when accessing to enter the learning class during online learning, the effectiveness of STEM-based electronic modules was low when referring to learning outcomes tests and creativity tests, formative evaluations on this electronic module also did not allow teachers to recap the scores from the work results of students. Therefore, teachers barely know the weaknesses or difficulties that students still face. The lack of activeness of students during training guidance, checking students' understanding and providing feedback made students less understood the material. In this study, creativity skills were too little trained during learning, and only one student completed the minimum completeness criteria in the Learning Outcome Test assessment from class X Science-1.

CONCLUSION

Based on the development and trial results, it is concluded that the electronic physics module based on STEM (Science, Technology, Engineering, and Mathematics) to increase students'

creativity was feasible for use in the learning process to increase students' creativity. It is supported by the validity of the STEM-based electronic physics module (Science, Technology, Engineering, and Mathematics) seen from the validity sheet included in the "very good" category; and the practicality seen from the observation of the lesson plan implementation was moderately practical. This media can support more effective online learning for each meeting, and the results of this study can be used as input for teachers and teacher candidates. Next, a recommendation is needed for future research on making this module more leverage in improving student learning outcomes.

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