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PRACTICALITY OF STEM INTEGRATED ELECTRONIC PHYSICS TEACHING MATERIALS ON ELASTICITY MATERIALS TO IMPROVE 21st CENTURY SKILLS OF STUDENTS

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ABSTRACT

The breakneck internet access speed evidences the progress of society in the 21st century. Internet access speed is a form of community progress 5.0 in obtaining quality information. 21st-century skills have been born along with the development of information and communication technology (ICT). The rapid growth of ICT raises concerns about the human workforce that can be replaced by robots. The first actual condition is that 21st-century skills such as problem-solving, creative thinking, collaboration, and communication, are still low. The second exact condition is that the teaching materials used have not been integrated with STEM, with a value of 48%. The purpose of this study was to determine the practicality of developing STEM integrated electronics physics teaching materials to improve students' 21st-century skills. This study uses the type of research R&D (Research & Development). While the model used is the Plomp model. Based on the research results that have been done, it can be concluded that the results of the practicality of teaching materials in the one-to-one, small group, and field test trials are 80, 84, and 83, respectively. This can be interpreted that the electronic teaching materials developed are practical and can be used when learning physics.

Keywords : *Electronic Teaching Material; 21century skills; STEM-Integrated*

I. INTRODUCTION

The breakneck internet access speed has proved the progress of society in the 21st century. Internet access speed is a form of community progress 5.0 in obtaining quality information. One way that can be done to get quality information is to combine the internet with real-life [1]. This shows that there are new challenges for the government to improve quality education. Quality education can be seen from the quality of human resources produced by a country. Education is considered successful if the teacher transfers all knowledge, skills, and attitudes to students. The skills that students need today are 21st-century skills.

The 21st-century skills have been born along with the development of information and communication technology. The rapid growth of information and communication technology raises concerns about the human workforce that robots can replace [2]. To prevent these worries, students need to master 21st-century skills, such as communicating, collaborating, creative and critical thinking [3]. Skills in the 21st century are divided into four categories: the way of working, which includes communication and collaboration skills in groups [4]. Therefore, the skills required in the 4.0 industrial revolution era emphasize students' skills in processing information critically, creatively and then working with groups and communicating both orally and in writing.

The first skill that must be mastered by students is critical thinking skills. Critical thinking skills are skills that the younger generation must master in the face of increasingly tough global competition with the development of science and technology. Critical thinking is the ability to analyze an idea based on logical reasoning to consider using specific measures or standards. Critical thinking skills are trained by providing opportunities to comment, criticize, expand and enrich explanations. Researchers use several characteristics of critical thinking skills in

cognitive knowledge, namely interpretation, analysis, evaluation, inferring, and explaining [5]. So, these indicators can be used to measure the extent of student mastery of learning materials.

The second skill that is no less important is the skill of creative thinking. Creative thinking is a skill in finding new things that have not existed before, which is original, developing various solutions to problems, and involving ideas to create new, varied and unique items [6-7]. Creative thinking is also interpreted as a thinking activity so that creativity appears in students or thinking to produce new things for themselves. Creative thinking skills in students can be measured by paying attention to the characteristics they have. The features of students who have creative thinking skills can be seen from the following descriptions, 1) fluency, 2) flexible thinking, 3) original, 4) elaboration, 5) assessing [8]. Therefore, these indicators will make it easier for teachers to determine the extent of student mastery of the learning material.

The learning process cannot be separated from students' skills in collaborating in groups. Collaborative skills are an attempt to demonstrate an ability to work effectively and respectfully with diverse teams to achieve common goals with shared responsibilities [9]. The importance of collaboration is trained from an early age to accept differences by respecting each other and prioritizing common interests. The purpose of collaborating is to prepare the ability to work effectively, flexibly, and be responsible for group work to achieve common goals [10]. Thus, collaboration skills require students' cooperation and a sense of responsibility in completing group projects.

Communication skills are needed in the continuity of learning and the world of work. Communication skills are skills in expressing ideas, knowledge, or information obtained logically [11]. Communication skills transfer information or messages to others for mutual understanding [12]. Indicators of communication skills that can be measured are: (1) seeking information; (2) listening and observing; (3) scientific writing; (4) representing information; and (5) presenting knowledge [13]. Therefore, communication skills can help students in conveying an idea or opinion in learning.

The 21st century skills of students are still low. The student's initial skills test was conducted in one of the senior high schools in Padang. The test is given in the form of essay questions that have been researched by previous researchers. The trial aims to measure students' initial skills, namely critical and creative thinking skills and communication skills through writing. The critical and creative thinking skills test consists of 4 essay questions, 52% of students answered incorrectly while 48% answered the original. While on communication skills in writing, tables of experimental results and pictures of observations of objects are presented, as many as 50% of students make only up to the stage of discussing the contents of tables and figures. While 14% of students make original answers, such as providing definitions of terms that are not related to the contents of tables and figures, and 36% of students did not answer. Thus, students' 21st-century skills can be improved by developing learning tools such as teaching materials.

The development of teaching materials is one of the alternative strategies to improve the quality of learning in schools [14]. In comparison, the teaching materials themselves are teaching materials that are systematically arranged that are used by teachers and students during learning both at school and home [15]. The effectiveness of teaching materials can be determined by considering the criteria for preparing suitable teaching materials. The requirements for good teaching materials include: (1) increasing student interest in learning, (2) made for students, (3) describing instructional objectives, (4) designed based on a flexible learning system, (5) the composition of teaching materials takes into account the competencies and needs of students, (6) provide opportunities for students to practice, (7) reduce students' obstacles in learning, (8) use a semi-formal writing style, (9) there is an evaluation test, (10) the coherence of the material is based on student needs. This shows that the development of teaching materials is left to the teacher by taking into account the applicable rules. Teaching materials can also be developed in electronic form or called electronic teaching materials.

Electronic teaching materials are learning materials that are arranged systematically by applying current technology. Agree with Asrizal (2021) that electronic teaching materials are learning materials presented electronically by following technological developments [16]. Electronic teaching materials are materials whose content is in electronic form, whether in audio, audio-visual, or interactive media [17]. The preparation of ICT-based teaching materials needs to pay attention to the established criteria, including the planning stage, preparation

stage, preparation stage, assessment stage, and delivery stage [18]. Teaching materials will make it easier for students to master the material, complete assignments, and learn independently.

Teaching materials will be even more interesting if integrated with STEM (Sciences, Technology, Engineering, and Mathematics). STEM is a learning process that combines four disciplines: science, technology, engineering, and mathematics [19]. Interestingly, the STEM approach can predict learning for the future or career. Student competencies have been formed at the elementary and secondary school levels because they have been equipped with skills and mathematics [20]. Some of the STEM goals that must be known are that students have 21st-century skills such as critical thinking, finding solutions to problems, being innovative, collaborating and communicating, and mastering good adaptability, leadership, socio-cultural skills [21]. Thus, teaching materials that contain STEM can add students' knowledge and skills in other fields of science.

The STEM approach can be developed if it is associated with phenomena in the natural environment so that learning is realized that presents actual facts experienced by students. The steps for implementing STEM the four aspects in it have characteristics as, (1) the scientific aspect, namely the scientific discipline that discusses the laws, principles, concepts of nature, (2) the technology aspect: technology is not a scientific discipline, but the technology is a tool that can help humans, (3) engineering aspects: knowledge in designing tools using the concepts of science, mathematics and technology, (4) mathematical aspects: knowledge related to patterns, numbers, and equations to interpret solutions based on mathematical calculations [22].

Several previous studies are relevant to this research. The first research conducted by Lestari with the results of developing LKS (Student Worksheets) with a STEM approach can improve students' critical thinking skills. Followed by study conducted by Mu'minah and Aripin (2019) with the results of ICT-assisted STEM-based science learning that can improve students' 21st-century skills [23]. Then research conducted by Rasmi (2020) with learning outcomes using STEM-assisted slingshot toy projects is better than ordinary learning on elasticity material and more creative student learning process [24]. So it can be concluded that the development of STEM integrated teaching materials can accelerate students' skills.

The research conducted is different from previous research. Previous researchers examined the implementation of STEM-based worksheets and the effect of STEM. Previous research only looked at the impact of using learning with a STEM approach. The research was conducted to develop STEM integrated physics teaching materials on elasticity materials to improve students' 21st-century skills. This research was conducted based on initial observations; the 21st century skills of students such as solving problems, creative thinking, collaboration, and communication are still low. One of the causes of the standard abilities of these students is the unavailability of electronic teaching materials that contain STEM indicators to support students' 21st-century skills. The purpose of this research is to determine the level of effectiveness of using STEM integrated physics electronic teaching materials to improve students' 21st-century skills. The results of this study revealed that students showed positive responses to the developed electronic teaching materials. They can access the links to teaching materials easily through their mobile phones and enjoy the interactive games presented in the lesson.

II. METHOD

This study uses the type of research R&D (Research & Development). Meanwhile, the model used is the Plomp model. Development research aims to solve a problem by designing and developing a product [25]. The development of the Plomp Model is divided into three stages, namely: (1) preliminary research, (2) development or prototyping phase, and (3) assessment phase. Preliminary research is conducted by analyzing needs and reviewing previous research. The development or prototyping phase is done by designing products based on preliminary research. The last stage of the Plomp model is to conduct trials and evaluate the product.

Products in the form of STEM integrated electronic teaching materials have a good appearance. Only a few product displays can be displayed in this paper. The cover (Figure 1) of the teaching material already describes the contents of the teaching material. On the cover there is a title, author's name, and a picture of the shock absorber as one of the spring applications on the vehicle. Display content is very interesting (Figure 2). The elasticity material is equipped with a clear picture. In addition, the material is equipped with questions to train students' creative thinking skills. STEM is integrated into student worksheets (Figure 3). Students are introduced to the

definition of STEM first. Furthermore, the application of elasticity in everyday life is explained, one of which is conveyors. Each STEM component is separated in order to make it easier for students to understand the conveyor.

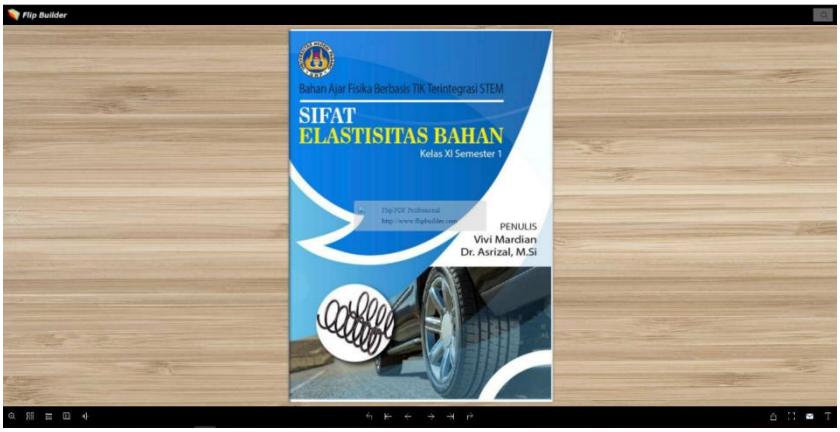

Fig 1. Cover

Fig 2. Content Display

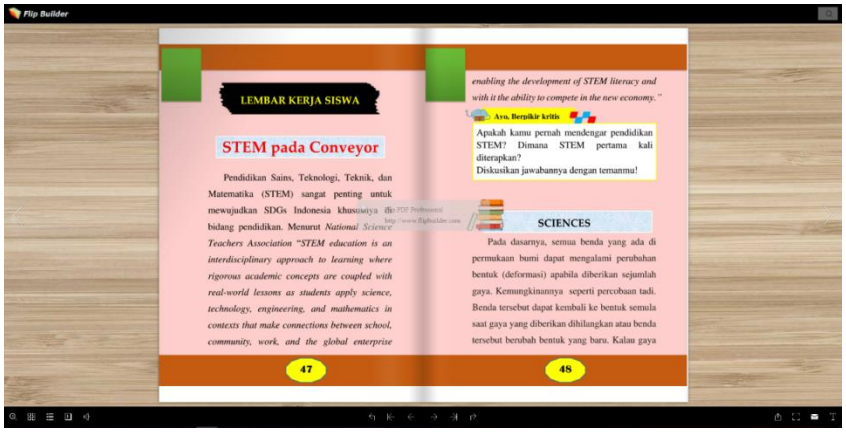

Fig 3. Integrated STEM

A practicality test is carried out after the product is declared valid by experts. The practicality test is divided into three stages: one-to-one, small group, and field. One to one practicality test was given to 3 students. The selection is based on one student who has high, medium, and low scores. The next practicality test, namely the small group test, was given to 9 students. The selection is based on students who have high, medium, and low scores respectively. The field test practicality test was given to the experimental class only which consisted of 27 students (8 male students and 18 female students). The data collection instrument used was the STEM-integrated electronic teaching material practical instrument sheet. The researcher acts as a teacher during the practicality test of the validated teaching materials. The steps taken in the practicality test are introducing STEM integrated

electronic teaching materials to elasticity materials to improve students' 21st-century skills. Then after being tested, students fill out the practical instrument of STEM integrated electronic teaching materials.

The next stage is practical data analysis. The score given to each indicator shows the level of condition of the indicator. Scores are provided on a scale of 1-4. The practical results are calculated by dividing the score obtained by the maximum score and then multiplying the ideal score, such as 100. The interpretation of the results of data analysis is described based on the Likert scale. Practical criteria can be seen in table 1.

Table1. Practicality Test Interpretation Criteria

Interval	Category
80-100	Very Good
66-79	Good
56-65	Medium
40-55	Less
30-39	Fail

(Sourse: [26])

III. RESULTS AND DISCUSSION

The results of the practicality test were obtained from the analysis of the practicality test sheet according to the students. The practicality test instrument filled out by students was a questionnaire on the use of STEM integrated electronic teaching materials. The product practicality assessment grid was developed based on the guide for developing teaching materials by plomp 2013. The practicality questionnaire has six components, namely: Usable (US), Easy to use (EU), Appealing (AP), Clarity (CL), STEM Integration (SI), and Superiority (SP). The product practicality test was carried out at the one-to-one, small group, and field test stages.

No	Assessment criteria
A	**Usable**
1	The learning process carried out helps me achieve my learning goals
2	I can learn better with STEM integrated electronic teaching materials
3	STEM integrated electronic teaching materials can help me accelerate mastery of physics material
4	The learning process using STEM integrated electronic teaching materials can improve my learning activities
5	STEM integrated electronic teaching materials are useful for me in mastering physics thoroughly
6	I can control the way I learn in the learning process that is applied by the teacher
B	**Easy to Use**
1	STEM integrated electronic teaching materials that are applied by the teacher make it easier for me to learn physics
2	I can easily control my learning activities in STEM integrated electronic teaching materials that are applied by the teacher
3	STEM integrated electronic teaching materials make it easy to remember physics processes and materials
4	The application of STEM integrated electronic teaching materials makes the learning process and material easier
5	Application of STEM integrated electronic teaching materials, physics processes and materials are easier to master
6	The application of STEM integrated electronic teaching materials is easier to improve students' ICT skills
7	Real world situations and scientific activities make it easier for me to master physics
C	**Appealing**
1	Learning by linking physics learning materials with real-world life is interesting
2	Learning by giving real life examples is interesting
3	Interesting activities to explore physical situations in everyday life
4	Application of STEM integrated electronic teaching materials with interesting real-world situations
5	Physics investigation activities that have been carried out in interesting learning
6	Physics practice activities related to real-world situations are interesting
7	Activities to communicate the results of interesting physics investigations
D	**Clarity**
1	The purpose of learning physics is clear in the teaching materials

2	Physical phenomena in the real world in STEM integrated teaching materials are clearer
3	Physics learning material is clear in teaching materials
4	The steps of physics investigation work in STEM integrated teaching materials are clearer
5	The instructions given in the physics exercise in the teaching materials are clear
E	**Integrated STEM**
1	There is supporting information in the form of applications of elasticity properties in the form of science, technology, engineering, and mathematics in teaching materials
2	STEM knowledge in materials can increase understanding of the material's elasticity properties
3	STEM indicators in teaching materials are well detailed so that they are easy to understand
4	Examples of STEM presented in teaching materials are quite diverse
5	The application of STEM described in teaching materials is a contemporary technology
F	**Advantages of E-Leaching Materials**
1	Accessible with laptops and smartphones
2	Accessible without additional apps
3	There are many menus that make it easy to use teaching materials
4	Loads many interactive applications like googleform, kahoot and PhET
5	There are videos and pictures that can accelerate the understanding of the concept of elasticity material

a. Practical Results on the One to One Test

According to students at the one-to-one stage, the practicality test of electronic teaching materials was carried out at SMAN 2 Padang to three students with high, medium, and low ability levels. Practical results on the one-to-one Test can be seen in Figure 4.

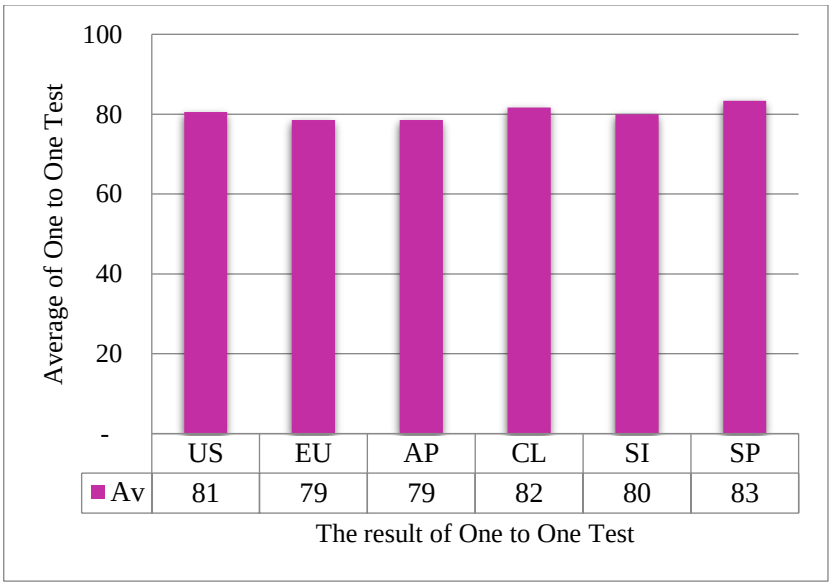

Fig. 4.Graph of Product Practicality Results in One to One Test

Based on Figure 4, the practical results of STEM integrated electronic teaching materials range from 79 to 83. The highest average score is 83 on the superior component of STEM integrated electronic teaching materials. Overall, the average practical result in the one-to-one test is 80.

Practical instruments in the One to One Test were given to three students. The functional analysis results on the one-to-one Test obtained an average value of 80 which means very good. The highest component value is the superiority of teaching materials. These advantages can be seen from the presentation of material that is clear and complete with sample questions. Teaching materials are also equipped with student worksheets based on virtual labs using PhET simulation. There are various HOTS questions to improve students' critical thinking, creativity, collaboration, and communication skills.

b. Practical Results on Small Group Test

According to students in the small group test, the practical test of STEM-interacted electronic teaching materials was given to the head of nine students. The nine students were taken from students with high, medium, and low abilities, three students. Practical results in the small group test can be seen in Figure 5.

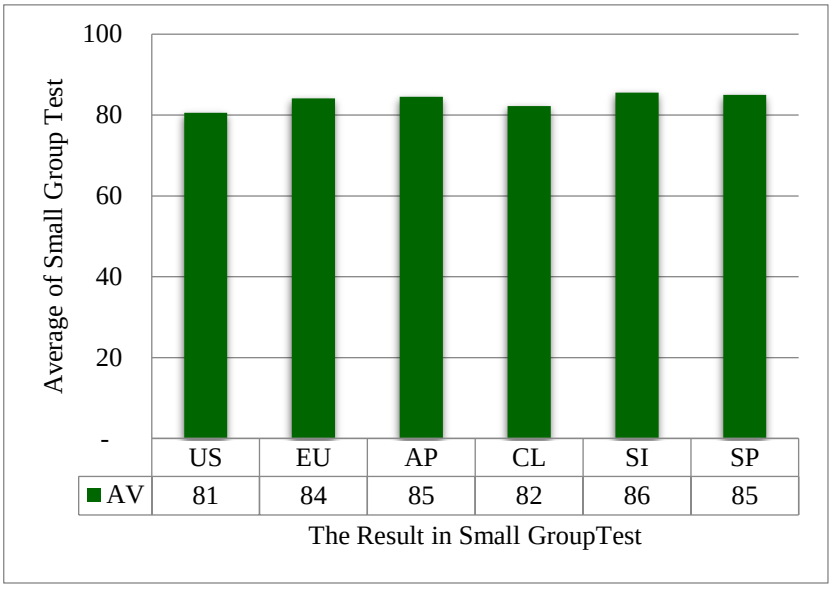

Fig. 5.Graph of Practicality Results on Small Group Test

Based on Figure 5, we can describe the practical results of teaching materials in the small group test ranging from 81 to 86. The STEM integration component got the highest score of 86. In comparison, the usefulness component got the lowest score of 81. Overall the average practicality result in the small group test was 84.

Practical instruments in the small group test were given to 9 students. Based on the results of data analysis, the average value of the practicality results was 84, with an excellent category. In the small group test, the STEM integration component obtained the highest score of 85. Based on the student's responses, integrated STEM in leaching materials increased students' mastery of learning materials. In the teaching materials, each aspect of STEM is described in detail so that students are easy to understand. In addition, the teaching materials are also given STEM-related quizzes that are able to provoke students' 21st-century skicanSTEM integrated electronic materials on elasticity materials are efficient to use in physics learning.

c. Practical Results on Field Test

According to students at the large group stage, a practical test of STEM-interacted electronic teaching materials was carried out at SMAN 2 Padang. The results of the practicality analysis are shown in table 1.

Table 2. Practical Results in Field Tests

Component	**-th Indicator**							**Average**
	1	**2**	**3**	**4**	**5**	**6**	**7**	
Usable	81	82	79	82	80	80		80
Easy to use	83	77	83	78	77	86	83	81
Appealing	87	85	85	86	81	85	83	84
Clarity	86	84	85	83	83			84
STEM Integration	83	82	80	80	85			82
Superioty	89	89	86	90	84			88

Based on table 2, it can be explained that the results of the practicality gain in the field test ranged from 80 to 88. The appealing and clarity components got the same value, namely 84. In comparison, the superiority component got the highest score, namely 88. All components received good responses from students so that the average score practicality is in a perfect category. Thus, the development of STEM integrated electronic teaching materials is efficient to use in learning.

The practicality of STEM integrated electronic teaching materials in the field test was given to the experimental class. Overall the results of practicality in the field test can be seen in Figure 6.

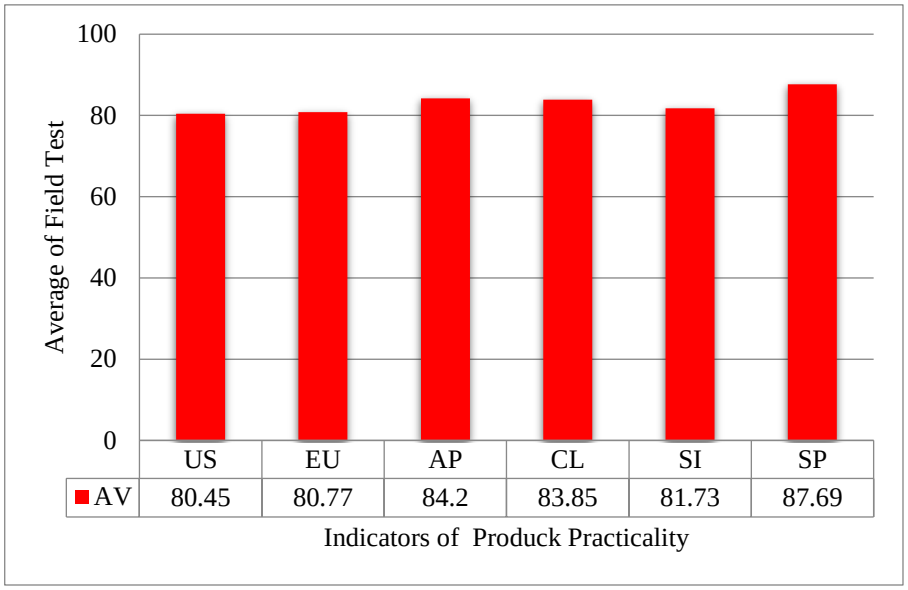

Fig. 6.Graph of Average Product Practicality Results in Field Tests

Based on Figure 6, it can be explained that the average practicality result in the field test is 83, with a perfect category. This shows that STEM integrated electronic teaching materials are efficient to use in physics learning. Based on student responses, several advantages of electronic teaching materials were developed.

The first reason is based on the usefulness component. The material presented in the teaching materials follows facts, concepts, and scientific rules. Students can benefit directly from these teaching materials. Students easily control and master the physics learning process by using this STEM-integrated electronic teaching material. Therefore, STEM integrated electronic teaching materials are practically used in physics learning.

The second reason lies in the ease of use component in learning. Electronic teaching materials that can be accessed via smartphones or computers without additional applications [27][28]. Students do not need to spend money to print out teaching materials. Students can repeat material and do assignments quickly at home and school.

The third reason lies in the attractiveness component of teaching materials. The developed STEM integrated electronic teaching materials provide real examples in students' lives. The teaching materials include several measures related to integrating STEM on elasticity materials so that students master learning materials quickly. Examples of STEM integration in the intended teaching materials include transportation, industry, technology, and sports. Therefore, by using STEM-integrated electronic teaching materials, students' curiosity is further increased.

The fourth reason refers to the material clarity component. STEM integrated electronic teaching materials have contained learning materials. In addition, experimental work steps have been systematically arranged so that students can efficiently conduct experiments related to learning materials. In addition, the teaching materials clearly describe physical phenomena such as the use of springs in motorized vehicles. Students are facilitated by the clarity of the structure of the teaching materials.

The fifth reason is based on the STEM integration component in teaching materials. The integration of STEM in teaching materials increases the mastery of learning materials for students [29]. In the teaching materials, each aspect of STEM is described in detail to understand it easily. In addition, the teaching materials are also given STEM-related quizzes that can provoke students' 21st-century skills. Thus, STEM integrated electronic materials on elasticity materials are very practical to use in physics learning.

The last reason is seen from the components of the superiority of teaching materials. The advantages of electronic teaching materials can be seen from the speed of access to teaching materials and interactive media. The teaching materials can be opened using a smartphone without having to download additional applications. The teaching materials are also equipped with various menus to make it easier for students to master the learning material. Then, mixed interactive media measures students' knowledge, skills, and attitudes, such as animation, video, Kahoot, and PhET.

One example of the application of elasticity material in everyday life is a ball kicking robot. The element of science in the robot is the spring used in the robot so that the robot can kick the ball forward like a football player. The element of technology can be seen from the robot itself which utilizes a combination of networks, electronic devices so that a robot is assembled. Likewise, engineering elements play a role in assembling the robot. Elements of mathematics include formulas used to calculate the constants of each spring used in the robot.

During the implementation of the research, there were several obstacles and limitations. The first limitation is that the development of STEM integrated physics teaching materials is still in one KD, namely KD 3.2 class XI elasticity material. This is due to the limited time of researchers in developing teaching materials. Furthermore, there are limitations to product trials. In this study, product trials were only carried out in one experimental class consisting of 37 students. The hope is that the test can be carried out on a large and comprehensive scale. The last limitation is the implementation of experimental activities. Research is conducted online, so it is less effective in conducting research. The solution is that the trial is carried out by performing experiments directly on students.

IV. CONCLUSION

The One to One test obtained an average value of 80, meaning that the STEM integrated electronic teaching materials are in the excellent category and practically applied in physics learning. Furthermore, the practical results in the small group test obtained an average value of 84, which means that the STEM integrated electronic teaching materials are in a perfect category and are practically applied in physics learning. Finally, the practical results in the field test obtained an average value of 83, which means that the STEM integrated electronic teaching materials are in a perfect category. They can be applied during the physics learning process. The results of this study become the basis for other researchers to develop electronic teaching materials on different topics. In addition, other researchers can also test the level of practicality of this product on a large scale and test the level of effectiveness.

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