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Design and Validity of STEM Integrated Physics Electronic Teaching Materials to Improve New Literacy of Class XI High School Students

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Abstract *- The 21st century education demands the integration of STEM into learning to improve technology skills, and students' literacy skills can be increased. One of the ways teachers should guide students to face the challenges of the 21st century is by updating the learning resources used. However, in reality schools still use printed teaching materials, have not integrated STEM well, and students' knowledge and literacy are still low. One solution to this problem is to develop STEM-integrated electronic teaching materials (ETMS) to increase new literacy for class XI high school students. This research uses R&D method with the Ploom development model. The research carried out is only limited to the development and prototype stages. The analytical technique used is the use of Aiken's V formula. The results of the first study were in the form of an ETMS design. The results of the second study are valid ETMS with an average value of 0.94. Based on the results of the study, two conclusions can be drawn. First, ETMS contains STEM development activities related to the facts of real world problems, technology and working principles, as well as mathematical concepts of physics. Second, the results of the prototype stage consist of self-evaluation and expert review. ETMS is valid based on five indicators of validity assessment, namely material substance, visual communication display, learning design, software utilization, and STEM assessment. This ETMS can be an alternative learning resource to improve students' new literacy.*

Keywords: *Electronic Teaching Matherials; New Literacy; STEM*

I. INTRODUCTION

Changes in technology and information around the world take place very quickly, especially in the 21st century. The 21st century is closely related to the era of revolution 4.0 (Reaves, 2019). The era of industrial revolution 4.0 is an era where the development of technology and information is growing rapidly (Lase, 2019). Humans must be able to adapt to these technological developments and create quality human resources, especially in the world of education. This era also demands the 21st century skills and student' literacy skills

(Aoun, 2020; Li & Liu, 2018). One of the efforts to answer the challenges of the 21st century is to organize education (Asrizal et al., 2022). Therefore, educational institutions must be able to prepare students who can master technology, have 21st century skills, and have literacy skills.

The use of technology in the learning process is very important. The use of technology can help the interaction between students and teachers. Students are encouraged to study independently and get additional information from various sources using technology (Hashim, 2018). Technology in education is usually a tool to support the implementation of learning (Prayudi et al., 2021). Some examples of technology used in education are usually E-Books, Google Classroom, cellphones, laptops, and others (Abed, 2019; Baker et al., 2012). Thus, it can support the encouragement of students' abilities, especially literacy skills.

The importance of literacy in life is to support one's success in dealing with various problems. Through literacy skills, a person not only gains knowledge but can also document a piece of experience that becomes a reference in the future (Laar et al., 2020). Literacy is closely related to competence in a field. The importance of literacy for students because literacy skills greatly affect student learning outcomes. Good literacy skills will help students understand various learning resources (Asrizal, 2020). Literacy is important to survive in the era of the industrial revolution 4.0, the goal is that humans can function well in their environment and can understand interactions with humans. One of the literacy skills that can prepare students to face the era of the industrial revolution 4.0 is the new literacy. Thus, new literacy skills in education need to be improved to create a new generation that can adapt to technological and educational developments along with the times.

In reality, schools still have some problems that are contrary to the expected ideal conditions. This problem was found in one of the high schools in the city of Padang, namely SMAN 3 Padang. First problem, schools still use printed teaching materials. Second, the integration of STEM in learning has also not been well integrated. Third, student learning outcomes both in terms of knowledge and literacy are still low. Thus, learning must be carried out using appropriate learning resources so that students' abilities can be improved.

One of the learning resources that can be used to improve students' knowledge and new literacy skills in learning Physics is electronic teaching materials. Electronic teaching materials are teaching materials that are displayed in electronic form and can be accessed through current technology including cellphones or laptops (Asrizal et al., 2022; Yulaika et al., 2020). Electronic teaching materials contain pictures, videos, gifs, links, and animations that can generate student interest in studying and understanding Physics material (Sriwahyuni et al., 2019). Electronic teaching materials are useful for making it easier for teachers to bring out the competencies and abilities of students (Yunita & Hamdi, 2019). By using electronic teaching materials, learning can take place effectively and efficiently (Rusnilawati & Gustiana, 2017; Serevina et al., 2018; Said et al., 2015). Therefore, these electronic teaching materials are very much needed in the learning process to see student success both in terms of competence and literacy.

One of the educational innovations to increase students' literacy and knowledge skills is by applying STEM to learning. STEM is a combination of Science, Technology, Engineering, and Mathematics (Nugroho & Nurcahyo, 2018; Winarni et al., 2016). STEM focuses on solving problems in everyday life (Gülen, 2019; Gülen & Yaman, 2019). STEM can be integrated into learning resources, one of which is electronic teaching materials (Niam & Asikin, 2021). By integrating STEM into electronic teaching materials, students can understand the four interrelated aspects of STEM so that students can solve problems and improve their thinking skills, especially literacy skills (Phungsuk et al., 2017). Therefore, STEM should be well integrated into learning especially Science.

Ideally, STEM integrated physics electronic teaching materials are suitable for use if they are in the valid category. The validity of this Physics electronic teaching material is measured through a product validity test. A Product validity test is a feasibility test of a product that is assessed according to predetermined standards. The product validity test has several criteria, in terms of the substance of the material, in terms of visual appearance, in terms of design, in terms of software use, and the STEM assessment.

This research has two problem formulations. First, how to design STEM integrated electronic teaching materials?. Second, how do determine the validity of STEM-integrated electronic teaching materials?. Based on the two problem formulations, the research objectives can be known. The purpose of this research consists of two objectives. First, designing/developing STEM integrated physics electronic teaching materials. Second, determine the validity of STEM integrated physics electronic teaching materials. By doing this research, it is hoped that the two research objectives can be achieved.

II. METHODS

The method in this research is the R&D research method with the Ploom Development model. Ploom's model is divided into three research phases. The three phases are preliminary research (preliminary research), development & prototyping phase, and assessment phase (Plomp, 2013). The prototyping stage carried out consists of five steps. The five steps are self-evaluation, expert review, one-to-one, small group, and field test. The stages that have been carried out are self-evaluation and expert review. The self-evaluation stage is carried out to assess products that have been developed independently. After that, the product is validated by an expert (expert review). The stages carried out in this study in the form of expert review results can be seen in Figure 1.

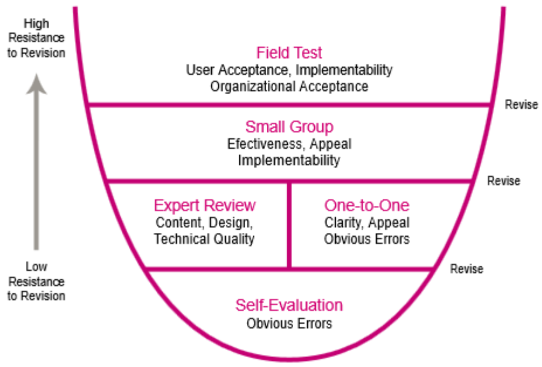


Figure 1. Stages of the Prototype Phase (Tessmer, 1993, in Ploom, 2013)

The data obtained in this study are self-evaluation data and expert review data in the form of product validity. The validity instrument used is a validation sheet. This validation sheet is in the form of a questionnaire consisting of several indicators that are guided by the development of ICT-based teaching materials in 2010. These indicators include material substance, visual communication display, learning design, software utilization, and STEM assessment. The validation sheet is filled out by three UNP Physics education master lecturers with the criteria provided.

The product assessment that has been filled in by the expert is analyzed to determine the feasibility of the product being developed. The validity analysis used is Aiken's V formula. The steps in assessing the validity of the product are to score each answer between 1-4, add up the total score of each validator, then give the validity value using the Aiken's V formula. The Aiken's V formula used is as follows:

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

Where S = r - lo

Information :
lo = The lowest value of the validity assessment (in this case =1)
c = The highest validity rating score (in this case =4)
r = Number given by validator

The grading scale used to determine the validity of electronic teaching materials is with a range of "V" numbers obtained between 0 to 1.00. The validity assessment interval for the range of ≥ 0.6 can be interpreted as a fairly high coefficient, so it can be categorized that its validity is in the "valid" category. While the validity interval <0.6 can be interpreted as a low coefficient and can be categorized in the "invalid" category (Azwar, 2015). The validity category of electronic teaching materials can be seen in Table 1.

Table 1. Validity Category

Score	Criteria
≥ 0,6	Valid
< 0,6	Invalid

III. RESULTS AND DISCUSSION

RESULTS

The results of this study focus on the second phase of the Ploom development model, namely the development phase and prototyping. Before the electronic teaching materials enter the prototype-making phase, the teaching materials are designed in such a way as to suit their needs. The development of electronic teaching materials is based on the STEM component and aims to increase new literacy for class XI high school students. The design of teaching materials is designed as attractive as possible and describes the content of the expected teaching materials. The teaching materials developed to consist of three chapters, namely the chapter on sound and light waves, optical instruments, and global warming. These electronic teaching materials are designed with STEM activities that can trigger an increase in students' abilities, especially students' new literacy skills consisting of data literacy, technological literacy and human literacy. The design of ETMS that have been designed can be seen in Table 2.

Table 2. STEM Integrated Electronic Teaching Material Design

Teaching Material Design	Information
	Cover Contains the title, author's identity, class, pictures related to the content of teaching materials, and materials

KEGIATAN PENGEMBANGAN STEM PADA SONAR

Science

Luasnya lautan Indonesia memberikan tantangan tersendiri baik segi pemanfaatan sumber daya laut maupun keamanan. Bagaimanakah cara kita menjaga keamanan sumber daya laut tersebut? Apakah ada alat untuk memantau dan menjaga kekayaan sumber daya laut yang berada jauh di kedalaman laut? Untuk mendeteksi keberadaan suatu objek dibawah laut digunakan suatu metode navigasi yang disebut sonar.

Sonar merupakan kependekan dari *Sound Navigation and Ranging*. Sonar merupakan teknik yang digunakan untuk menentukan posisi (jarak) dan navigasi dengan menggunakan gelombang suara (akustik). Sonar sendiri terbagi atas dua jenis yaitu sonar pasif dan sonar aktif. Sonar pasif merupakan sonar yang hanya bias menentukan arah objek dan terkadang dipakai untuk mendeteksi suara hewan laut. Sedangkan sonar aktif merupakan system sonar yang bisa mengukur jarak objek dan kedalaman laut. Sonar memanfaatkan suara frekuensi tinggi atau ultrasionik. Frekuensi yang digunakan umumnya sebesar 50 KHz karena pada rentang frekuensi tidak bisa terdengar oleh manusia dan panjang gelombang dan pada ultrasionik gelombangnnya sangatlah kecil.

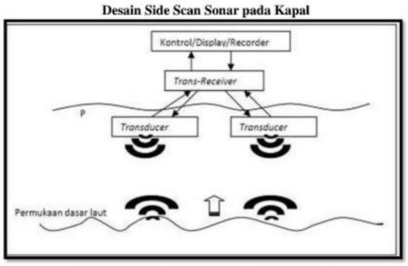
Technology

Perhatikan cuplikan video berikut!

Video 10.7 Teknologi Side Scan Sonar pada Kapal
Sumber: https://www.youtube.com/watch?v=E322xK7IfnY

Engineering

Desain Side Scan Sonar pada Kapal



Gambar 10.32 Desain Side Scan Sonar pada Kapal
Sumber: https://identitasku.wordpress.com

Mathematics

Teknologi side scan sonar pada kapal menerapkan prinsip sonar. Teknologi ini berguna untuk mengukur kedalaman laut dan mencari benda seperti kapal KRI Nanggala 402 yang hilang di dasar laut dengan menggunakan pancaran gelombang ultrasonik. Adapun rumusan yang terkait dengan side scan sonar ini dapt dituliskan sebagai berikut:

$$s = \frac{v \times t}{2} \quad (10.38)$$

Section of STEM development activities

1) Science
   Contains knowledge about sonar and its distribution and work activities
2) Technology
   Contains the latest technology related to the science that has been described
3) Engineering
   Contains the components and working principles of the technology that has been described
4) Mathematics
   Contains Physics concepts related to science, technology, and engineering written mathematically

Based on Table 2, the design of ETMS can be described. The cover of the electronic teaching material already describes the entire contents of the teaching material. The electronic learning materials developed to consist of activities that are the integration of STEM in teaching materials. STEM activities are arranged in a single unit and are located in the work activities section. There are three STEM development activities in a sound and light waves, namely STEM development activities on sonar, ultrasound, and fiber optics. STEM development activities in the optical instruments chapter consist of two activities, namely STEM development activities for cameras and telescopes. STEM activities in the global warming chapter are STEM on solar panels. With these STEM development activities, STEM can already be well integrated into the developed teaching materials.

After the development phase that describes the design of electronic teaching materials, then a series of activities are carried out in the prototype phase. The prototype phase carried out in this study focused on the self-evaluation and expert review stages. The first stage is self-evaluation. At this stage, the researcher reads and checks the completeness of the design of the teaching materials that have been developed. Following the results of the self-evaluation, it was found that the design of ETMS that had been designed was complete both in terms of structure and STEM components. The structure of electronic teaching materials developed is by the structure of ICT-based teaching materials in 2010 which consists of titles, study instructions, competencies to be achieved, supporting information, work activities, assignments, and evaluations (Depdiknas, 2010).

The second stage is expert review. At this stage, expert validation was carried out by three lecturers of the Master of Physics Education UNP. The validation of electronic teaching materials consists of four assessment indicators. The four indicators are material substance, visual communication display, learning design, software utilization, and STEM assessment. The description of the research results for each indicator is as follows.

Material substance indicator

The result of the first research is the validation of electronic teaching materials based on the indicators of the substance of the material. The material substance indicator contains four sub-indicators. The four sub-indicators are truth, material coverage, current, and readability. The results of the validation of ETMS for material substance indicators can be seen in Table 3.

Table 3. Electronic Teaching Material Validation Results for Material Substance Indicators

No	Sub Indicator	Aiken's V	Criteria
1	Truth	0.97	Valid
2	Material Coverage	0.86	Valid
3	Contemporary	0.97	Valid
4	Legibility	0.86	Valid
	Average	**0.92**	**Valid**

Based on Table 3, it can be explained the results of the validation of electronic teaching materials based on the indicators of the substance of the material. All sub-indicators both in terms of truth, material coverage, current, and readability are in the valid category with a value range of 0.86 to 0.97. The average validation result based on the material substance indicator is 0.92 with a valid category. Thus, the results of the validation of ETMS based on indicators of material substance are in the valid category.

Visual communication display indicator

The result of the second study is the validation of electronic teaching materials based on visual communication display indicators. The visual communication display indicator contains six sub-indicators. The six sub-indicators are navigation, font, media, color, animation, and layout. The validation results for visual communication display indicators can be seen in Table 4.

Table 4. Electronic Teaching Material Validation Results For Visual Communication Display Indicators

No	Sub Indicator	Aiken's V	Criteria
1	Navigation	1.00	Valid
2	Letter	0.94	Valid
3	Media	0.94	Valid
4	Color	0.89	Valid
5	Animation	1.00	Valid
6	*Layout*	0.94	Valid
	Average	**0.95**	**Valid**

Based on Table 4, the results of the validation of electronic teaching materials can be described based on visual communication display indicators. All sub-indicators in terms of navigation, fonts, media, color, animation, and layout are in the valid category with a value range of 0.89 to 1.00. The average validation result based on the visual communication display indicator is 0.95 with a valid category. Thus, the results of the validation of ETMS based on visual communication display indicators are in the valid category.

Learning design indicators

The third research result is the validation of electronic teaching materials based on learning design indicators. The learning design indicator contains nine sub-indicators. The nine sub-indicators are titles, KI and KD, learning objectives, materials, sample questions, exercises, work steps, compilers, and references. The results of the validation of ETMS for learning design indicators can be seen in Table 5.

Table 5. Results of Validation of Electronic Teaching Materials for Learning Design Indicators

No	Sub Indicator	Aiken's V	Criteria
1	Title	0.94	Valid
2	KI and KD	1.00	Valid
3	Learning objectives	1.00	Valid
4	Theory	1.00	Valid
5	Problems example	0.94	Valid
6	Exercise	0.78	Valid
7	Work steps	0.78	Valid
8	Compiler	1.00	Valid
9	Reference	1.00	Valid
	Average	**0.94**	**Valid**

Based on Table 5, it can be explained the results of the validation of electronic teaching materials based on learning design indicators. All sub-indicators both in terms of titles, KI and KD, learning objectives, materials, sample questions, exercises, work steps, compilers, and references are in the valid category with a value range of 0.78 to 1.00. The average validation result based on learning design indicators is 0.94 with a valid category. Thus, the results of the validation of ETMS based on learning design indicators are in the valid category.

Software utilization indicators

The fourth research result is the validation of electronic teaching materials based on indicators of software usage. The software usage indicator contains three sub-indicators. The three sub-indicators are interactivity, supporting software, and originality. The validation results for indicators of software utilization can be seen in Table 6.

Table 6. Results of Validation of Electronic Teaching Materials for Software Utilization Indicators

No	Sub Indicator	Aiken's V	Criteria
1	Interactivity	1,00	Valid
2	*Software* Supporter	1,00	Valid
4	Originality	0,89	Valid
	Average	**0,96**	**Valid**

Based on Table 6, the results of the validation of electronic teaching materials can be described based on indicators of software utilization. All sub-indicators both in terms of interactivity, supporting software, and originality is in the valid category with a value range of 0.89 to 1.00. The average validation result based on indicators of software utilization is 0.96 with a valid category. Thus, the results of the validation of ETMS based on software utilization indicators are in the valid category.

STEM assessment indicators

The fifth research result is the validation of electronic teaching materials based on STEM assessment indicators. The STEM assessment indicator contains four sub-indicators. The four sub-indicators are science, technology, engineering, and mathematics. The results of the validation of electronic teaching materials for STEM assessment indicators can be seen in Table 7.

Table 7. Electronic Teaching Material Validation Results for STEM Assessment Indicators

No	Sub Indicator	Aiken's V	Criteria
1	Science	0,89	Valid
2	Technology	0,94	Valid
3	Engineering	0,94	Valid
4	Mathematics	0,89	Valid
	Average	**0,92**	**Valid**

Based on Table 7, the results of the validation of electronic teaching materials can be described based on the STEM assessment indicators. All sub-indicators in terms of science, technology, engineering, and mathematics are in the valid category with a value range of 0.89 to 0.94. The average validation result based on the STEM assessment indicator is 0.92 with a valid category. Thus, the results of the validation of ETMS based on STEM assessment indicators are in the valid category.

From the four validation results based on each indicator, the overall average can be calculated. The average validation of ETMS can be seen in Table 8.

Table 8. Validation Results of ETMS

No	Sub Indicator	Aiken's V	Criteria
1	Material Substance	0,92	Valid
2	Visual Communication Display	0,95	Valid
3	Learning Design	0,94	Valid
4	Software Utilization	0,96	Valid
5	STEM Assessment	0,92	Valid
	Average	**0,94**	**Valid**

Based on Table 8, the results of the validation of electronic teaching materials can be described based on five indicators. The five indicators both in terms of the coverage of visual communication display material, learning design, software utilization, and STEM assessment are in the valid category with a value range of 0.92 to 0.96. The average validation result based on five indicators of electronic teaching material validation is 0.94 with a valid category. Thus, the results of the validation of ETMS are in the valid category and are suitable for use in learning.

DISCUSSION

The research results obtained in this study consisted of two. First, the design of STEM-integrated electronic teaching materials to improve students' new literacy. The teaching materials that have been developed contain STEM components that are interrelated and related to real-world concepts. Second, the results of self-evaluation and expert review. The expert review carried out was to validate STEM-integrated electronic teaching materials. The teaching materials were validated by three lecturers of Master of Physics education based on five indicators. The five indicators are material substance, visual communication display, learning design, software utilization, and STEM assessment.

STEM development activities on electronic teaching materials consist of science, technology, engineering, and mathematics. The science section of teaching materials contains facts about sonar and work activities to prove the concept of sonar through activities in the crocodile physics application with a sonar theme. Science is knowledge or information that contains facts about a real-world problem and contains work activities to solve problems (Sudarsono et al., 2020; Suwarma et al., 2015). The technology section of the teaching materials contains sonar technology, for example, side-scan sonar technology. Technology in STEM is a technological innovation that utilizes knowledge to find technological innovations to meet human needs (Anggraini & Nurita, 2021; Ring-Whalen et al., 2018). The engineering section of teaching materials describes the working principle of side scan sonar technology. Engineering in STEM is a way of designing technology from economical materials and incorporating engineering concepts in the manufacture of the technology (Aninda et al., 2019; Ellis et al., 2020). The mathematics section of the teaching materials contains physics concepts in sonar which are written mathematically. The meaning of mathematics in STEM is the pattern of analysis of a concept that contains numbers and related formulations (Ardianto et al., 2019). Of the four STEM components that have been described later, they can train students' new literacy skills. (Aninda et al., 2019; Ellis et al., 2020).

The test results of the validity of the ETMS at the expert review stage have been categorized in the valid category. Electronic teaching materials have been designed as attractive as possible and revised according to the validator's suggestions so that the developed teaching materials are suitable for use. The design of valid teaching materials is caused by the average value on all indicators of the validity assessment which is also valid. The results of the validation of electronic teaching materials on each indicator can be described as follows.

The first indicator of the feasibility of electronic teaching materials that need to be measured is the substance of the material. In the substance of the material can be seen the truth, the scope of the material, the present, and its legibility (Depdiknas, 2010). The truth in question is the truth of the matter, symbols, and formulating equations, and must be adapted to the facts found in everyday life (Nurhasnah et al., 2020; Tharmar & Kalidasan, 2019). The scope of the material in question is the completeness of the presentation of the material, the effort achieved after studying the material, and the integration of STEM in teaching materials. Now, what is meant here is having an update both in terms of the appearance of teaching materials, integrating models in teaching materials, connecting software with teaching materials, and of course the demands of the latest curriculum (Sriwahyuni et al., 2019). So, physics electronic teaching materials can be said to be feasible if the truth, completeness of the material, updates, and the rules of writing teaching materials are valid.

Electronic teaching materials must be developed with the help of some software so that the appearance of teaching materials is even more attractive. The software must have clear navigation buttons, animations, and media that can support the display of teaching materials (Jannah et al., 2020). These features can create an interactive and interesting learning atmosphere (Nida et al., 2021). The existence of an animation effect when flipping through electronic teaching materials, makes students feel like opening a real book (Saputra & Musafanah, 2017). Thus, the electronic teaching materials developed are feasible to use if the visual communication display is valid.

Learning design must be considered to develop quality teaching materials. The learning designs in question include titles, Core Competencies and Basic Competencies, learning objectives, materials, sample questions, exercises, work steps, compilers, and references (Depdiknas, 2010). The electronic teaching materials developed have met these criteria. Thus, electronic teaching materials are suitable for use in learning.

Software that can be used in developing electronic teaching materials varies widely. The types of software commonly used in the manufacture of electronic teaching materials, especially physics, are Flip Pdf Professional, Lectora, Adobe Flash, Macromedia Flash, AutoRun, and many more (Pratiwi & Jasril, 2020). Electronic teaching materials developed using the right software can support the learning process, support student interactivity, and can improve students' abilities, especially their literacy skills (Usmeldi, 2017). Electronic teaching materials developed must be the result of their work and if there are images or videos, they must include the link as proof of the authenticity of the teaching materials. Following the validation results, electronic teaching materials are suitable for use based on indicators of software utilization.

The integration of STEM in teaching materials is one of the advantages of current research. STEM needs to be integrated into the developed electronic teaching materials. STEM is a combination of science, technology, engineering, and mathematics (Nugroho & Nurcahyo, 2018). The four STEM components cannot be separated, but are interrelated (Krajcik & Delen, 2016). With the integration of STEM in teaching materials, it can support students' mindsets and students' literacy skills, especially new literacy skills (Adnan et al., 2016; Yildirim & Selvi, 2015). The electronic teaching materials developed have integrated STEM as expected. Thus, ETMS can be said to be feasible to use to improve students' new literacy.

The research results that have been obtained at this time can have good implications for the world of education, especially Physics. The results of the validation of ETMS show that the developed teaching material products are valid and can be used as alternative teaching materials by teachers and students of class XI SMA/MA. This STEM integrated electronic teaching material can be carried out by further research in testing the practicality and effectiveness of teaching materials in order to improve students' new literacy.

IV. CONCLUSION AND SUGGESTION

Based on the results of the study, two conclusions can be drawn. First, the results of the development phase of ETMS contain STEM development activities related to facts of real-world problems, technology and working principles, and mathematically written physics concepts. Second, the results of the prototype phase consist of self-evaluation and expert review. ETMS were valid based on five indicators of validity assessment, namely material substance, visual communication display, learning design, software utilization, and STEM assessment. This STEM integrated electronic teaching material can be carried out further research to test its practicality and effectiveness so that this STEM integrated electronic teaching material can be an alternative learning resource to improve students' new literacy (data literacy, technologi literacy, and human literacy).

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