STEM Integrated e-Teaching Material to Promote Students' Conceptual Understanding and New Literacy Skills

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Manuscript received August 25, 2024; revised September 20, 2024; accepted January 2, 2025; published April 18, 2025

***Abstract*—The demands of the Fourth Industrial Revolution require a focus on conceptual understanding and new literacies in education, especially in physics learning. However, in reality, students' understanding and new literacy skills are still low. Overcoming this challenge can be done by using electronic teaching materials integrated with Science, Technology, Engineering, and Mathematics (STEM). The purpose of this study was to promote students' conceptual understanding and new literacy by using STEM integrated electronic teaching materials. The research conducted included quasi-experimental research with a post-test only-design research design. The sampling method used cluster random sampling. Instruments in data collection using multiple-choice tests and performance assessments. The results showed that students' conceptual understanding and new literacy skills increased after using STEM integrated electronic teaching materials. Based on these findings, STEM integrated electronic teaching materials have a positive impact in promoting students' conceptual understanding and new literacy skills.**

***Keywords*—e-teaching material, concept understanding, Science, Technology, Engineering, and Mathematics (STEM), new literacy skills**

I. INTRODUCTION

Industry 4.0 has presented new challenges and opportunities across industries, especially revolutionizing the education sector [1]. The World Economic Forum reported that changes need to be made in education to develop talent to compete globally by utilizing technology [2]. The learning process can initiate change by embracing technology and aligning with the progress of industry 4.0 [3]. The utilization of technology aims to improve skills for the 4.0 era [4]. Equipped with 4.0 era competencies, it is expected that the educational goals of this era can be achieved [5].

The industrial era 4.0 aims to create quality human resources. Quality means having the ability to think creatively, learn efficiently, be innovative, and utilize technology [6]. Improved human resources can develop by integrating technology in learning [7]. Improving human resources can develop by utilizing technological tools in learning [8]. The empowering of technologies as education aids is intended to provide better results than traditional methods [9, 10]. Era 4.0 skills, also known as new literacy skills, are adaptations made by the government to improve era 4.0 skills.

Education in the fourth industry demands the development of new literacy competencies [11, 12]. The new literacies are data literacy, technology literacy and human resource literacy or humanism. Important new literacies for the Industry 4.0 era include data, tech and human literacy [13, 14]. The data literate involves analyzing data to improve understanding and expertise [15, 16]. Technological literacy is able to enrich insights because it is able to explore information [17]. In addition, it enables the ability to design learning by integrating technology [18, 19]. Human literacy aims to encourage people to function well in their environment and understand human interactions [20]. Thus, these three literacies are new literacies that are expected to answer the challenges of education in the 4.0 era.

The challenges of the revolutionary era require students to have skills. But in reality, the conditions in the field do not match the ideal conditions of era 4.0. Facts in the field found that the understanding of grade XI high school students in physics learning is still classified as moderate with an average score of 62.16. In addition, data literacy and technology skills in the same students are also still relatively low, with an average value of 49.34 and 39.31. Low student skills can have a significant impact on students' ability to adapt to technological developments [21, 22]. This problem will also make it difficult for students to evaluate relevant information [23]. This condition must be overcome so that students can face the challenges of era 4.0.

A potential solution to develop students' skills is through the adoption of STEM (Science, Technology, Engineering, and Mathematics) education. The STEM approach is a powerful strategy to build quality learning and prepare students for success in the digital age [24, 25]. STEM education is very much synonymous with the industrial revolution 4.0, where STEM incorporates technology in the in the process of learning [26, 27]. Thus, needs to be done to integrate STEM in learning.

One of the places to integrate STEM in learning is learning resources. The learning resources in question are teaching materials. Teaching materials serve as resources to improve learning [28]. Teaching materials are defined as systematically arranged materials that contain learning materials, topic materials, and details in accordance with applicable curriculum rules [29]. Teaching materials can be prepared by utilizing technological developments and are often referred to as e-teaching materials [30, 31]. E-teaching materials have several advantages, including: based on student characteristics, attracting student interest and motivation made the teacher easier to present the material, students become active learners because they are interested in teaching materials, students can learn it anytime and anywhere because it can be accessed without time limits [32, 33]. With digitized teaching materials, one of the learning resources is easy and organized in carrying out the learning process and students.

The utilization of digital teaching materials in learning is in line with the demands of era 4.0. However, the implementation of learning in the field is currently not in line with the expected conditions. Usage of teaching materials is not in line with student characteristics, namely attracting and motivating students and not utilizing technology properly. By utilizing technology in teaching materials, it will encourage the formation of student abilities, especially literacy skills in the era 4.0 and understanding of student concepts [34]. Based on a literature review, it reveals the scarcity of digital teaching materials for the Fourth Industrial Revolution [33, 35–38]. Apart from that, the availability of digital teaching, especially that integrated with STEM, is still limited [39]. The utilization of STEM integrated e-teaching materials is a potential solution to the challenge. The objectives of this study to promote students' new literacy competencies and conceptual understanding by using STEM integrated e-teaching materials.

II. Literature Review

E-teaching materials are interactive and stimulating learning tools suitable for the Fourth Industrial Revolution. Images and videos within e-teaching materials are designed to stimulate student interest [16, 40]. E-teaching materials are also designed with a display as interesting as possible and applied to everyday life so that it can encourage and shape students' mindset towards understanding the material [41, 42]. E-teaching materials can be opened using a smartphone or laptop so that they can be used at any time by students and teachers [43–46]. Furthermore, e-teaching materials provide access to interactive practical tasks, thereby promoting literacy development [47, 48]. Consequently, e-teaching materials are among the educational resources required by the fourth industrial revolution.

Learning continues to change with the times. One of the changes is to integrate STEM into learning [49]. STEM is standing for science, technology, engineering, and mathematics [50, 51]. STEM is a discipline that necessitates quantitative reasoning, data interpretation, and critical thinking grounded in science and mathematics [52]. STEM applies understanding and skills simultaneously to solve a learning challenge [53, 54]. The fourth definition of STEM aspects is that science is a concept that applies in nature so that students gain knowledge [50, 55]. Technology is the employment of man-made devices to facilitate work processes. Engineering is a way of designing a procedure and then operating it, which is expected to solve the problem. Mathematics is the discipline that explores quantities and spatial relationships through logical reasoning and empirical verification. By unifying STEM elements, it is hoped that the problems inherent in today's Industry 4.0 educational landscape can be resolved. Therefore, integrating STEM in learning is very important to provide the processing of the learning.

Process of learning is a process of activity from teaching that can make someone learn and get a change and new behavior. In the learning process, finally get a new understanding. Understanding is a person's ability to understand something that has been known. In other words, understanding is knowing and remembering something that has been learned from various points of view [56, 57]. Understanding will become a concept that is structured in the brain. Understanding the concept is able to express a material that has been given and explain it back into a form that is better understood [58, 59]. Conceptual understanding refers to the capacity to comprehend the essence of ideas, circumstances, and information within a specific scientific domain [60]. Therefore, conceptual understanding is the ability to obtain and analyze knowledge.

Literacy in the age of era 4.0 is very necessary in facing the challenges of the revolution 4.0 era. Literacy in the era of revolution 4.0 is known as new literacy [61]. The construct of new literacy is composed of three elements: data, technology, and human literacy [62, 63]. Humans must be able to process data and utilize technology, apply it to technology, and understand the use of technology [64]. Data literacy is an ability to analyze data sets and hone skills to gain knowledge [61]. Technological literacy is able to explore information and has the ability to integrate technology in the learning process [65]. Therefore, new literacy is one of the abilities to use data, be able to apply it in technology, and encourage the formation of students' thinking skills.

Integrating STEM into e-teaching materials is one way to promote conceptual understanding and new literacy skills. In the literature review, the effects of STEM integration in e-teaching materials in learning are analyzed based on the findings of other researchers. The findings in the literature review are the supporting basis for the research conducted. Komarudin *et al.* [66] explored how STEM integration affects students' conceptual understanding. Rahmawati *et al.* [67] and Hikmawati *et al.* [68] discussed how to integrate STEM into e-teaching materials so that it can improve students' new literacy skills. The positive impact of STEM integration in e-teaching materials is needed in promoting conceptual understanding and new literacy skills as important skills in 21st century learning.

III. Materials and Methods

A. Research Design

A quasi-experimental design was used in this research. Specifically, a posttest-only control group design was utilized. The research utilized an experimental design with two groups: an experimental and a control group. The experimental group students were given with STEM integrated e-teaching materials, whereas the control group employed regular classroom resources. The experimental group received STEM integrated e-teaching materials as the intervention. Post-test scores for the experimental and control groups are denoted as O_1 and O_2, respectively. Posttest-only control group design can be seen in Table 1.

Table 1. Posttest-only control group design

Class	Treatment	*Posttest*
Experiment	X	O_1
Control	-	O_2

B. Research Samples and Data

The population in this study was limited to all students of Senior High School 3 Padang. This school is one of the senior high schools located in the province of West Sumatra, Indonesia. The total number of students in this population was 280 students. The sample in this study used 2 classes, namely XI Science 7 as the experimental class and XI Science 5 as the control class. The experimental class consisted of 40 students, and the control class consisted of 39 students, with a total of 79 students. All samples were second-year students at the senior high school level. The average age of students was around 16–17 years. A cluster random sampling approach was adopted for this research, where classes with similar average student performance were grouped together. Both sample classes were tested for normality, homogeneity, and hypothesis testing.

C. Research Implementation

The experimental class was given treatment in the form of using treated in the form of using STEM integrated e-teaching materials. The STEM integrated e-teaching materials used in this study have been tested for validity and practicality. Before obtaining valid and practical STEM integrated e-teaching materials, the development of e-teaching materials has gone through a series of stages. The first stage is preliminary research. The results of the preliminary research will be an important foundation for the next stage, namely prototyping research. In this second stage, STEM integrated e-teaching materials are developed with repeated revision cycles to produce valid and practical e-teaching materials. The third stage is the assessment phase by applying STEM integrated e-teaching materials to experimental classes. The use of STEM integrated e-teaching materials in experimental classes aims to see the effectiveness of using STEM integrated e-teaching materials to promote students' conceptual understanding and new literacy skills.

STEM integrated e-teaching materials were applied to the experimental class for 9 meetings. The details of the meeting are 8 lessons using electronic teaching materials and 1 posttest to see the extent of student understanding. Each meeting is designed using STEM integrated e-teaching materials so that students can gain new experiences in learning. E-teaching materials can also guide students in expressing ideas and questions. This activity can encourage students' concept understanding and new literacy skills.

The STEM integrated material in this e-teaching material is sound waves and light waves. STEM integration consists of sonar, ultrasound, laser and hologram. STEM integration in sound wave material is found in sonar and ultrasound. Explanation of sound waves (science) on the side scan sonar (technology), its components and working principles (engineering), and formulations related to sound waves on the side scan sonar (mathematics). Explanation of sound waves (science) in vascular ultrasound (technology), its components and working principles (engineering), and formulations related to sound waves in vascular ultrasound (mathematics).

In addition to sound wave material, STEM integration is also found in light wave material. STEM integration in light material is found in lasers and holograms. In lasers and holograms, it is discussed from every aspect of STEM. An explanation of light waves (science) in lasers (technology), their components and working principles (engineering), and formulations related to light waves in lasers (mathematics). Explanation of light waves (science) on fiber holograms (technology), their components and working principles (engineering), and formulations related to light waves on fiber holograms (mathematics).

D. Research Instruments and Procedures

A two-sample t-test was conducted to compare the means of the two groups. The Mann-Whitney test is used if the parametric statistical requirements in the t-test are not met. Normality and homogeneity of variance assumptions were confirmed through statistical tests. The t-test results failed to show a significant difference between groups, suggesting that both groups had equivalent initial abilities before the intervention. Consequently, the control and experimental groups were randomly assigned.

The data taken in this study are the competence of understanding concepts and the competence of students' new literacy. Data were collected using instruments in the form of written multiple-choice tests to assess knowledge competence and non-test methods, such as scoring rubrics, to evaluate skill competence during experiments. The instrument used knowledge was assessed using a multiple-choice written test. In order for this test to be a good measuring tool, the following steps are taken: making a lattice of final test questions based on basic competence and existing indicators, compiling final test questions based on the grids that have been made, and conducting statistical tests, namely the validity test, difficulty test, differentiation index test, and reliability.

The instrument used for skills assessment is a performance assessment instrument. This instrument was developed to measure students' skills in applying the knowledge and skills they have learned through experimental activities. In this instrument there is an assessment rubric that contains a list of criteria that will measure student skills. In order for this instrument to become a good tool for measuring, the instrument is tested for validity, reliability, and practicality of use. Developing clear instruments can provide more accurate results in measuring student skills.

E. Data Analysis

The data analysis techniques include normality test, homogeneity test, hypothesis tests, and effect size tests. Mann-Whitney test. The normality test aims to see whether the sample is normally distributed or not. The study examined whether the sample groups had equal variances using a homogeneity test. Subsequent to normality and homogeneity testing, hypothesis testing commenced. A t-test was performed to compare group means, predicated on assumptions of normal distribution and same variance. Nonetheless, when the prerequisites for the parametric test were not fulfilled, the Mann-Whitney test is used. This alternative test is used in presenting a comparison of the means of two independent groups. This test is used when the parametric statistics of the t test are not met and the data does not follow a normal distribution.

Before using the Mann-Whitney test, the first step is to perform a normality test on the data of the two independent groups. The normality test is used to ensure that the data is normally distributed or not. In the second stage, a homogeneity test is carried out to ensure that the data is homogeneous or inhomogeneous. If the distribution of the data is normal and homogeneous, then it can be continued with the parametric test. The parametric statistic used is the comparison test of two independent sample means, namely the t-test.

Meanwhile, if the results show that the data is not distributed normally and is inhomogeneous, then further hypothesis test is the non-parametric Mann-Whitney. This test is carried out as a solution to sample data not normally distributed and not homogeneous. This test was carried out to test the results of the research hypothesis, namely to see significant differences in data between the two groups. The null hypothesis in this study states that the use of e-teaching materials integrated with STEM has no effect on increasing conceptual understanding and new literacy.

The effect size test was conducted to see how much influence the intervention applied in learning. The effect size test can show how effective the use of stem integrated e-teaching materials is in improving conceptual understanding and new literacy skills. The effect size test used in this study is Cohen's d effect size. The equation used in Cohen's d effect size is Eq. (1).

$$d = \frac{\overline{X_E} - \overline{X_C}}{S_{pooled}} \quad (1)$$

d: Effect size value, $\overline{X_E}$: Average of experimental class, $\overline{X_C}$: Average of control class, S_{pooled} : Combined standard deviation of experimental and control groups. The results of the effect size value can indicate the interpretation of the data obtained. The interpretation of d follows the following rules: $d < 0.4$ (small effect), $0.4 \leq d < 0.8$ (medium effect), and $d > 0.8$ (large effect) [69].

IV. Result and Discussion

The results showed that there was an impact on the aspects of understanding and literacy. Data on understanding of learning concepts were obtained from written test scores collected at the end of learning. Data on the skills aspect of this research includes data literacy and technology literacy skills, the data for each skill is obtained from the performance assessment instrument. The results of this research were obtained through data analysis.

A. *Effect of E-teaching Material on Conceptual Understanding*

The research data on this aspect of concept understanding came from a multiple-choice test sheet. The written test sheet was initially tested with 50 questions, and the data was analyzed to obtain 25 items that were good enough for the written test in the form of a post-test. The posttest was conducted at the end of the lesson. The statistical data description is shown in Table 2. The discussion is related to concept understanding and the new literacy skills of students who use e-teaching material. Based on the results that have been obtained, there are three discussions that will be elaborated, namely on concept understanding, new literacy skills of students where in the aspect of data literacy and technological literacy aspects of students.

Table 2. Conceptual understanding statistical analysis

Statistical Parameters	Experiment	Control
Average	81.00	70.00
Standard deviation	13.80	15.56
Variance	156.07	242.12
Normality Test	**Normal**	**Normal**
Homogeneity Test	**Homogeneous**	
t-Test	**2.27**	
Cohen's d Effect Size	**0.75**	

According to the data presented in Table 2, there is a disparity in conceptual learning outcomes between the two groups. The effect of E-Teaching Materials can be known by conducting hypothesis testing on the aspect of understanding the concept with a two-average comparison test. On the understanding of the concept, experimental and control classes are normally distributed and have homogeneous variances. The t-test obtained from Table 2 is presented, and the t_{count} value is 2.27, which is in the H_0 rejection area. Meanwhile, Cohen's d Effect Size data was obtained at 0.75. This results in a difference in conceptual understanding between students who use and not using STEM integrated E-Teaching Materials in Grade XI Science. Based on Cohen's d effect size, the effect of using STEM integrated e-teaching materials is in the moderate category.

The results obtained are also supported by qualitative data. Qualitative data in this study were obtained from feedback provided by students. Feedback was provided by students after using STEM integrated e-teaching material. Based on the feedback data, it was found that students felt they understood the learning material better after using STEM integrated e-teaching material. The integration of STEM in learning makes it easier for students to understand the concepts of the material. This supports the results of the study, which showed differences in conceptual understanding between students who used STEM integrated e-teaching material and students who did not use the teaching materials.

This first result is based on students' concept understanding, where there is an increase by using STEM integrated e-teaching materials. This finding is in line with the results of other studies showing that STEM integrated e-teaching materials can improve conceptual understanding [66]. Concept understanding is the process of being able to understand or comprehend what is learned [70, 71]. Understanding the concept is also a benchmark for students to master learning materials. STEM integrated e-teaching materials can increase student engagement and understanding, thereby increasing conceptual understanding [72]. E-teaching materials foster students' creativity and critical thinking, thus improving their conceptual learning [73]. Electronic teaching materials use videos and animated to promote students' conceptual understanding [74, 75]. The usage of videos in teaching materials may make students remember longer because they are interpreted in various senses [76]. Thus, STEM integrated e-teaching materials have significant influence on the conceptual understanding aspect of students.

B. *Effect of E-teaching Material on Data Literacy Skills*

Assessment of the data literacy skills aspect was carried out during the practicum using a performance assessment instrument. There are four skill indicators that are assessed during learning. The four indicators are: reading data (M1), collecting data (M2), analyzing data (M3), and concluding the results of data analysis (M4). Student data literacy skills were evaluated using a rubric and are presented in Fig. 1.

Data in Fig. 1 reveals that the two groups exhibited differing levels of data literacy skills across all indicators. The indicator that obtained the highest score was the data reading indicator, with the experimental and control class scores being 94 and 91, respectively. The lowest score was in the data analysis indicator, with the experimental and control class scores being 75 and 73, respectively. The experimental class obtained an average score of 85.05. The control class obtained an average of 80.20. The experimental class outperformed the control class in data literacy skills, as indicated by the higher average scores across all indicators.

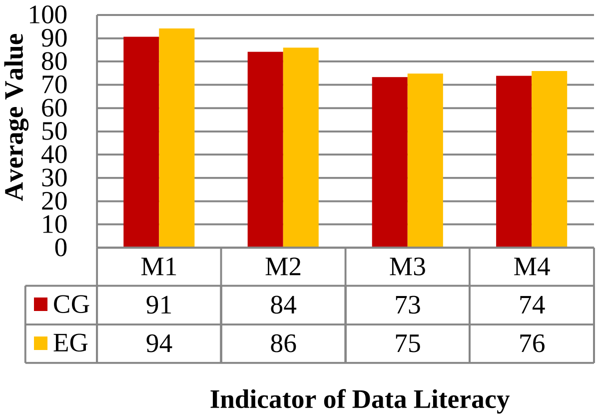

Fig. 1. Student data literacy skill scores per-indicator.

Data from data literacy skills obtained were processed using statistical analysis. Statistical analysis aims to see more deeply the differences in skills between the experimental group and the control group. Statistical analysis carried out includes calculating the average, standard deviation, and variance. In addition, normality tests, homogeneity tests, t-tests, and Cohen's d effect size were also carried out. Meanwhile, statistical analysis of data literacy can be seen in Table 3.

Table 3. Statistical analysis of data literacy

Statistical Parameters	Experiment	Control
Average	84.05	80.20
Standard deviation	6.00	5.51
Variance	36.00	30.42
Normality Test	**Normal**	**Normal**
Homogeneity Test	**Homogeneous**	
t-Test	**4.62**	
Cohen's d Effect Size	**0.69**	

According to data in Table 3, the experimental and control groups exhibit dissimilar levels of data literacy skills. The data in Table 3 indicates that both the experimental and control groups follow a normal distribution and exhibit equal variances. After that, the two-mean comparison test was carried out, and the t_{count} value was obtained at 4.62, which is in the H_0 rejection area. This means that there is a disparity in data literacy skills between Grade 11 Science students exposed to STEM integrated E-teaching materials and those without such exposure. The Cohen's effect size results obtained a value of 0.69. So, STEM integrated e-teaching materials have a medium effect on new literacy skills aspects, namely student data literacy.

Qualitative data were also obtained to support the research results. Student feedback after using STEM integrated e-teaching material became qualitative data supporting the research results. Based on student feedback, it was found that students felt better at analyzing data and could communicate data based on the results of the analysis. This was driven by the exposure of certain data in the STEM integrated e-teaching material. This finding supports the research results, which showed a difference between student data literacy between the experimental group and the control group.

These results focused on students' newly acquired data literacy skills, where there was an improvement by using STEM integrated e-teaching materials. These results are supported by other findings which state that data literacy skills can be improved through e-teaching materials [67]. Experimental activities are an important part of physics to understand physical phenomena and their characteristics [77]. The usage of a video in teaching materials may increase students' data literacy skills. The practical activities presented in this teaching material are in concordance with the problems discussed and the procedures for carrying out the experiment [78]. This practicum is a virtual laboratory. One of the advantages of using this virtual lab is that it saves costs in the use of tools and materials that will be provided, can be accessed anywhere, and makes it easier for teachers to conduct experiments [79]. Practical activities in virtual laboratories can improve students' abilities, both in student learning activities such as reinforcing the material learned and developing the skills needed [80]. Therefore, practicum activities significantly improve students' data literacy skills.

C. Effect of E-teaching Material on Technology Literacy Skills

Assessment of technological literacy skills aspects using performance assessment instruments is carried out during the practicum process. There are four skill indicators that are assessed during learning. The four indicators are: using virtual lab/experiment equipment (M1), using technology (laptop, mobile phone, laser) (M2), using the internet (M3), and using digital learning resources (digital-based teaching materials) (M4). Student learning outcomes in the aspect of technological literacy skills are obtained through a scoring rubric and can be described in Fig. 2.

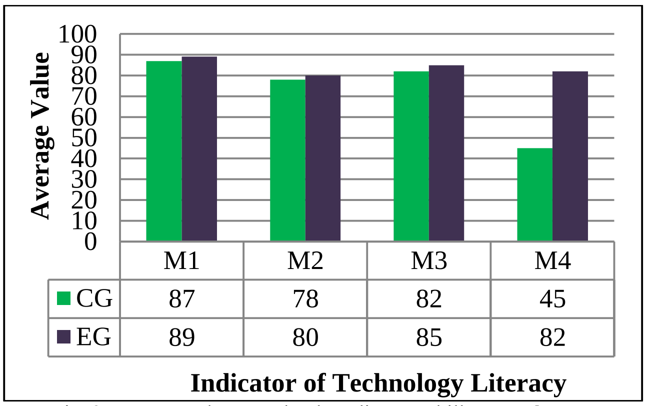

Fig. 2. Assess students' technology literacy skills per-indicator.

Fig. 2 indicates significant differences in technological literacy skills between the two groups across all indicators. The group exposed to the treatment consistently outperformed the control group, although the effect size was small. This observed difference is attributed to the differential treatment conditions. The average score of each indicator from the experimental group was always higher than the control group. The largest difference was seen in the indicator using digital learning resources, where the experimental group scored 82, while the control group only scored 45. This indicates a difference in the results obtained between the group that used e-teaching materials and the group that did not use them.

Data from technology literacy skills obtained were processed using statistical analysis. Statistical analysis aims to see more deeply the differences in skills between the experimental group and the control group. Statistical analysis conducted includes calculating the average, standard deviation, and variance. In addition, normality tests, homogeneity tests, the Mann-Whitney test, and Cohen's d effect size were also carried out. The statistical analysis of literacy data can be seen in Table 4.

According to Table 4, the data shows that the technological literacy for experimental and control groups do not adhere to normal distribution or equal variance assumptions. For hypothesis testing conducted, the Mann-Whitney test. The Z-count value obtained is −4.89, which is obtained outside the H_0 acceptance area, so H_0 is rejected. There is a clear difference in technological skills between students who used and did not use STEM integrated e-teaching materials in Grade XI Science classes in Padang. Meanwhile, Cohen's effect size analysis shows a value of 1.43 with a large effect category. So, STEM integrated e-teaching materials have a strong impact on technological literacy skills.

Table 4. Assess students' technology literacy skills per-indicator

Statistical Parameters	Experiment	Control
Average	79.93	69.63
Standard deviation	8.45	5.64
Variance	71.51	31.90
Normality Test	**Abnormal**	**Abnormal**
Homogeneity Test	**Inhomogeneous**	
Mann-Whitney Test	**−4.89**	
Cohen's d Effect Size	**1.43**	

The impact of STEM integrated e-teaching materials can also be seen based on qualitative data. This qualitative data can support the findings of the quantitative data obtained. Based on qualitative data from feedback provided by students, it can be stated that students are more effective in using, understanding, managing, and evaluating technology in various contexts. The presence of STEM aspects in teaching materials that apply technological literacy supports students to understand the basics of technology and how it works. Students also find it easier to access information independently to support the skills needed. This is certainly in line with the results of research that shows differences in students' technological literacy skills between groups that use STEM integrated e-teaching materials and groups that do not use them.

The third result is based on students' new literacy skills in the aspect of technological literacy that has increased by using STEM integrated e-teaching materials. The same findings were also found by other researchers who stated that the use of STEM integrated e-teaching materials can improve technological literacy [68]. Technological literacy is a new literacy in era 4.0 skills that students should have today [81]. The application of digital teaching aids using technology has a positive impact so that students' thinking skills increase and can utilize technology in learning and others [82, 83]. Various studies show that there is an increase by using digital teaching materials [84]. In addition, in the e-teaching materials there are skill experiments with virtual laboratories that can be opened through links. With the link, it is easier for students to conduct experiments directly as long as they have internet quota to access the link [85]. Virtual laboratory learning is more efficient because it is executed faster than learning in a real laboratory. Virtual labs use simulations of applied physics concepts that serve for engaging physics learning [86]. Engaging learning with digital teaching materials can improve students' new literacy in the technological literacy aspect of students [56, 74]. Thus, e-teaching materials significantly promote students' technological literacy skills.

V. Conclusion

Based on the analysis, three conclusions were obtained. The analysis shows that STEM integrated e-learning materials improve students' conceptual understanding, data literacy, and technology. There is a significant correlation between the use of STEM integrated e-teaching materials and students' conceptual mastery, data literacy, and technological literacy. STEM integrated e-teaching materials can be used as an effective learning resource for physics learning. STEM integration can be done in other subjects. The STEM approach is able to encourage various skills, involve technology in supporting the learning process, and encourage collaboration with various fields of science. Therefore, STEM integration is recommended for other subjects.

The first research limitation is the material contained in the teaching materials. The material contained is limited to sound and light waves. It is expected that in the future for other physics materials. In order to produce more complete teaching materials. Integration in future teaching materials can also be done for material in other subjects.

The second limitation is that the integration of STEM into sound and light waves in teaching materials is still limited. STEM integration consists of sonar and ultrasound in sound wave materials. STEM integration in laser and hologram material for light wave material. This STEM integration is still limited to a few topics. In the future, STEM integration can be added and deepened in the material.

The third research limitation is the observation aspect. In this study, what was observed was concept understanding and new literacy in the aspects of data literacy and technological literacy. In the future, other researchers can measure other new literacies in the human literacy section that emphasizes other 21st century skills. Human literacy includes critical thinking, creative, collaboration and communication skills needed in 21st century life.

The fourth limitation is that the implementation of STEM integrated electronic teaching materials is limited to a group of student populations at Senior High School 3 Padang. Exploration of the impact of these teaching materials on different student groups can also be done in the future. In addition, other researchers can also examine the impact of implementation on different academic subjects. Researchers who are interested in implementing STEM integrated e-teaching material in different academic subjects can study STEM aspects and adapt them to the material.

The fifth limitation is that this research still focuses on the short-term impact of implementing STEM integrated e-teaching materials. Future research exploration can be carried out to see the long-term impact of implementing STEM integrated e-teaching materials. Long-term impact exploration can be carried out on conceptual understanding and literacy skills. By conducting research on long-term impacts, research results have an important function that contributes both theoretically and practically, especially to student skills and the world of education.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors made significant contributions to the completion of this research. A played a role in designing the research and writing the article. RA played a role in designing the instrument. AN participate in analyzing the research data. VU plays a role in collecting data in the field. H and H played a role in validating the research instrument. All authors have approved this final paper.

Funding

This research was funded by the Institute for Research and Community Service (LPPM) of Padang State University. The funding scheme for this research is included in the Overseas University Collaborative Research (PK-PTLN). Funding through a contract numbered 1689/UN35.15/LT/2024. This funding support encourages the development of quality research and can carry out research optimally. We express our appreciation to those who have supported the funding of this research.

Acknowledgment

The author would like to thank The Research and Community Service, Universitas Negeri Padang, which funded this research. The author would also like to thank the rector of Universitas Negeri Padang, the head of the Research and Community Service, the principal, and the teachers who have helped and facilitated the implementation of the research.

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