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The Effectiveness of Integrity of the Electronoc Module Based STEM Approach on Students Mathematical Literacy Abilities

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Abstract

This study aims to identify the effectiveness of STEM strategies combined with digital modules to develop junior high school students' mathematical literacy skills. These skills are vital competencies in the contemporary era that need to be strengthened to equip students to face the dynamics of the modern era. The method used was a *pre-experimental one-group pretest-posttest* design on 30 students of class VII D of SMP Negeri 14 Yogyakarta in the 2024/2025 academic semester. Data were collected using a 4-item mathematical literacy test instrument that measures three indicators: *formulate, employ*, and *interpret & evaluate.* Data processing was carried out through normality testing with the *Shapiro-Wilk method* and *paired sample t-test testing.* The research findings indicate that the STEM approach based on electronic modules is effective in improving students' mathematical literacy skills. There was a significant increase from an average pretest score of 35.227 to 77.557 in the posttest with an *n-gain value* of 0.636 (moderate category). Statistical tests showed a highly significant difference with a t-count of -9.644 and *a p-value* <0.001. The highest increase was in the *interpret & evaluate indicator* at 73.58%, followed by *employ* at 57.57%, and *formulate* at 34.11%. The integration of STEM in electronic modules successfully bridged abstract mathematical concepts with real-world applications through meaningful and contextual multidisciplinary learning. This approach not only optimizes academic achievement but also fosters crucial 21st-century skills. The study recommends the adoption of an electronic module-based STEM approach as a superior learning strategy for transforming mathematics learning toward an innovative approach that integrates technology.

Keywords: *Effectiveness; Electronic Module; Mathematical Literacy Skills; STEM Approach*

Introduction

In this modern era, the development of 21st-century competencies is a fundamental aspect that needs to be instilled in students, especially in the cognitive aspect (Rafianti et al., 2018). In line with the acceleration of the development of science and technology, a generation with creative thinking, the ability to analyze problems, and the capacity to produce solutions to various contemporary challenges is urgently needed (Arisoy & Aybek, 2021). Within the spectrum of 21st-century skills, students need to master various competencies including the ability to communicate appropriately, collaborate, solve problems with a systematic approach, analyze critically, and produce quality work (Redhana, 2019).

In the contemporary digital landscape, 21st-century non-technical capabilities are manifested in six fundamental elements identified as the 6Cs, including: critical thinking, collaboration, communication, creativity, social aspects (culture*)*, and networking (connectivity*)* (Aktaş, 2022; Anugerahwati, 2019; Kirbas & Bulut, 2024; Nadiroh et al., 2021). All elements of these 21st-century capabilities have a significant correlation with strengthening mathematical literacy. In practice, mathematical mastery requires analytical capacity to evaluate problems, the ability to innovate in formulating alternative answers, the clear delivery of mathematical ideas, and coordination in handling complex problems (De Lange, 2006). This phenomenon indicates that the cultivation of 21st-century capabilities plays a strategic function in strengthening students' mathematical mastery to face the dynamics of the digital era.

The concept of literacy in this dimension is not limited to the ability to recognize and understand mathematical functions in an elementary way. More complex than that, mathematical literacy emphasizes a person's ability to interpret and express mathematics in dealing with a spectrum of more complex and heterogeneous problems (Kolar & Hodnik, 2021; Umbara & Suryadi, 2019). Mathematical literacy skills play a crucial role in helping individuals recognize the relevance of mathematics in real life and utilize it as a basis for wise decision-making for a constructive, caring, and reflective society (Muzdalipah et al., 2021).

Based on empirical observations, Indonesian students' mathematical literacy skills still show suboptimal results. This is reflected in various international evaluations in which Indonesia has participated, particularly in the PISA study coordinated by *the* OECD. Indonesia's achievements in PISA mathematics have varied but tend to be inferior. The minimum achievement was recorded in PISA 2003 with a score of 360 compared to the international average of 500, while the maximum achievement occurred in PISA 2006 with a score of 391, still below the international standard of 498. In the most recent PISA 2022 evaluation, Indonesia scored 366, while the international average is 472 (OECD, 2023).

Referring to the Guidelines from the Indonesian Ministry of Education and Culture Decree No. 22/2016 regarding procedural benchmarks for elementary and secondary educational activities, one aspect discussed is the principle of learning that optimizes technology and communication to optimize learning effectiveness. According to the perspective Daryanto (2016), learning instruments include all learning resources that support educational interactions between educators and students. In line with technological progress, the transformation of conventional modules into digital format, known as electronic modules (e-modules), offers various advantages in the educational process.

Productive learning using digital platforms requires the support of precise instructional methodologies. Currently, innovation in digital mathematics modules has progressed with the implementation of various learning methods and approaches.

Optimizing the learning process is highly dependent on the approach used. Research has shown that Tiona Pasaribu et al (2020) learning success is determined by the appropriate alignment of media and learning strategies. In the context of strengthening mathematical literacy, *the Science, Technology, Engineering, and Mathematics* (STEM) approach presents a comprehensive solution by integrating four scientific domains: Science, Technology, Engineering, and Mathematics. Referring to research conducted bySaputri & Herman (2023) It is known that there have been many studies that integrate the STEM approach and provide a positive contribution to the mathematics learning process which can be carried out continuously from preschool to college level, without having to be tied to a particular class level.

Based on research Tati et al. (2017), the implementation of STEM in the educational process has the potential to strengthen various dimensions of student literacy including scientific literacy, mathematical literacy, technological literacy, and engineering literacy. Meanwhile, Siswandari (2021) it is stated that a number of empirical study results indicate that the superiority of the STEM approach produces a positive influence on student abilities, including mathematical literacy competencies. Modules can act as appropriate media to be used in implementing learning activities and are suitable for integration with the STEM approach (Rahmawati & Juandi, 2022; Salsabila et al., 2023).

Integration of electronic instructional resources focused on STEM disciplines has demonstrated effectiveness in developing students' mathematical literacy skills. Studies have shown Megiana et al (2025) that the use of e-modules has a positive impact on the learning process. E-modules present material that integrates mathematical, scientific, technological, and engineering aspects, allowing students to observe concrete applications of mathematical concepts in real-world contexts. The use of multimedia elements, such as graphical representations, animated simulations, and interactive visualizations, facilitates students' understanding of abstract mathematical concepts and strengthens conceptual understanding. Furthermore, activities in E-modules encourage group collaboration, discussion, exchange of ideas, and articulation of mathematical understanding. Students' mathematical communication capabilities are cultivated through interaction and sharing of insights. E-modules also provide direct feedback mechanisms and formative evaluation, enabling students to receive constructive input and identify areas of development. This formative evaluation process allows educators to adjust learning and support the continuous strengthening of students' mathematical literacy.

This study aims to determine the effectiveness of the STEM approach based on electronic E-modules in improving students' mathematical literacy. The combination of the STEM approach with E-Modules specifically focused on improving mathematical literacy is still limited, in contrast to previous studies that examined STEM or E-Modules separately, this study integrates both as a strategic whole. By adopting the STEM approach based on E-modules, students can improve their mathematical literacy competencies through active participation and application of concepts in relevant contexts. Student-centered learning supported by technological innovation has the potential to prepare a generation with comprehensive STEM literacy and the capacity to face the complexities of the 21st century. Therefore, the integration of STEM based on E-modules is a strategic combination to strengthen mathematical literacy and facilitate the development of 21st-century skills, which is still limited to the literature on the condition and development of mathematics education in Indonesia.

Methods

The research approach used in this study was pre-experimental without a comparison group, with initial and final measurements on one group of students. The design was selected based on its suitability to the research objective, namely analyzing the transformation of students' mathematical literacy competencies by comparing the initial conditions before the implementation of the treatment (pretest) with the final conditions after the treatment (posttest).

The population focused on in this study consisted of all seventh-grade students of SMP Negeri 14 Yogyakarta. The sample selection technique used was cluster random sampling, where the sample was determined based on accessibility, appropriate learning time, class type homogeneity, and suggestions from the seventh-grade mathematics teacher. The study participants were 30 seventh-grade D students of SMPN 14 Yogyakarta in the 2024/2025 academic year. The data collection instrument consisted of four mathematical literacy test items. Table 1 displays the mathematical literacy indicators used in this study.

Table 1. Mathematical literacy indicators

Process	Indicator
Formulate	Constructing mathematical representations of problems in a variety of contexts
Employ	Applying mathematical concepts to solve problems in various situations
Interpret & Evaluate	Interpreting and evaluating mathematical results

To analyze the data, a normality test using Shapiro-Wilk will be performed, followed by a paire Data examination will involve conducting a Shapiro-Wilk normality assessment, subsequently followed by paired sample t-testing to evaluate the efficacy of STEM-integrated electronic learning materials. The effectiveness benchmark employed in this research was determined by statistically significant improvements in post-intervention assessment results relative to pre-intervention measurements. The paired sample t-test statistical computation utilized the subsequent equation:

$$t = \frac{\bar{D}}{SD/\sqrt{n}}$$

The dependent samples t-test hypotheses are structured as follows H_0: No significant variance exists between average pre-intervention and post-intervention mathematical literacy assessment scores, H_1 : A significant variance exists between average pre-intervention and post-intervention mathematical literacy assessment scores. The final determination will be derived from computational outcomes generated through JASP/R-studio software.Where if the p-value $<\alpha$ then H_0rejected or Reject H_0if $t_{hitung} < -t_{tabel}$ means there is a difference in the average *pretest* and *posttest scores of students'* mathematical literacy skills after using the electronic module-based STEM approach. The final test conducted is the calculation of the increase (gain) value, namely by comparing the test scores before and after learning using the electronic module-based STEM approach. The *n-Gain* score is calculated using the following equation with the standard gain formula as follows:

$$n - Gain = \frac{Final\ Score - Initial\ Score}{Maximum\ Score - Initial\ Score}$$

The scores obtained can be categorized into low, medium, and high categories adapted from (Hake, 1998) those shown in Table 2.

Table 2. Standards Interpretation against the N-Gain Value

n-Gain Category	**<g> Value Range**
High	<g> > 0.7
Medium	0.3 <g> ≤ 0.7

Results and Discussion

Results

The implementation of electronic module-based STEM was conducted in five meetings in grade VII, with two meetings for *pretests* and *posttests*, and three meetings for implementing learning activities using the electronic module-based STEM approach. The results showed that the electronic module-based STEM approach was effective for junior high school students in improving mathematical literacy skills. A description of the results is presented in Table 3 below.

Table 1Description of Students' Mathematical Literacy Abilities Results

Percentage (%)	**Results**	
	Pretest	***Posttest***
Average value	35,227	77,557

Descriptive analysis showed progress and improvement in student test results. During the initial measurement, the average score for students' mathematical literacy was only 35.227. However, after special treatment was implemented, significant progress occurred, with the average percentage of students' mathematical literacy scores increasing to 77.55. Before conducting the hypothesis test, a normality test was run using *the Shapiro-Wilk test* at a significance level of 0.05. The results of the normality test can be seen in Table 4 below.

Table 2Normality Test Results

Category	**Statistics**	**Decision**
Pretest	0.232	Normal
Posttest	0.077	Normal

Table 4 presents the normality test data for *the pretest of* mathematical literacy ability with a significance value obtained of 0.232 > 0.05, and *the posttest* with a significance value obtained of 0.077 > 0.05, so it can be concluded that *the pretest-posttest data* for mathematical literacy ability comes from a normally distributed population.

After the normality assumption test was met, a hypothesis test was conducted. The hypothesis test was conducted with the aim of determining the effectiveness of the electronic module-based STEM approach on students' mathematical literacy skills. hypothesis implemented using *paired sample t-test*, the results test shown in Table 5.

Table 3Paired Sample t-Test Results

***t* count**	***p* -value**	**Decision**
-9,644	< 0.001	H_0rejected

Referring to table 5, the t - count value obtained from analysis *paired sample t-test* is -9.644, which is the value more low compared to t- table amounting to 1,717. In addition that is , the p-value obtained is not enough of 0.001. Because the p- value more small from 0.05, then hypothesis The null hypothesis (H0) is rejected. Based on these results, the conclusion that can be drawn is that learning using the STEM approach based on electronic modules has a significant influence on students' mathematical literacy skills. To assess the extent to which learning is effective, an n-Gain analysis was conducted, with the results shown in Table 6.

Table 4Results of n-Gain Calculation

Average *Pretest Score* (%)	**Average *Posttest Score* (%)**	***n-Gain***	**Interpretation**
37.17	77.55	0.636	Currently

Table 6 shows an increase in the average percentage of posttest scores compared to the average percentage of pretest scores, and an n-Gain score of 0.636 is obtained, which is in the moderate category. This indicates that STEM learning based on electronic modules is effective. quite effective in improving students' mathematical literacy skills.

Comparison of average pretest scores and posttest per indicator of mathematical literacy ability can be seen in Figure 1 below.

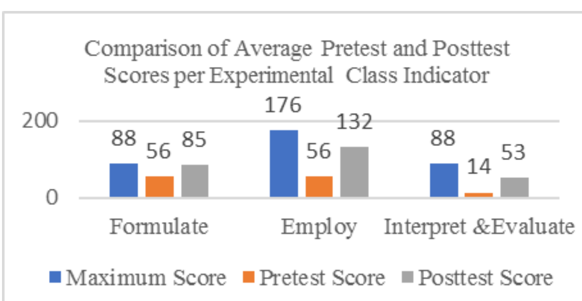

Figure 1. Comparison of the Average Pretest and Posttest Scores for Each Indicator

Based on the diagram above, it is known that all indicators have increased. After implementing the STEM Approach learning based on electronic modules, the average student score on the *formulate indicator* increased by 34.11%. For the *employ indicator,* the average student score increased by 57.57%. Furthermore, for the *interpret &* The average student *evaluation* increased by 73.58%. This indicates that the use of an electronic module -based STEM approach to learning has proven effective. Table 7 explains the STEM integration used in the study.

Table 5Integration of Module-Based STEM Approaches

	Integration
Science	Explaining the process of paper decay scientifically, a scientific explanation of how acidic conditions damage the structure of paper. Addition and subtraction are used to calculate the total number of books damaged.
Technology	Integrating digital mathematics modules which also include explanatory videos on algebraic forms so that students can explore independently.
Engineering	Students create simple scenarios in a classroom environment such as: counting the number of books on a shelf, counting the total number of stationery on a desk.
Mathematics	Applying algebraic forms to solve contextual problems.

Discussion

The implementation of STEM (*Science, Technology, Engineering, and Mathematics*) learning in the context of the problem of library book decay demonstrates comprehensive integration across the four disciplines. From a scientific perspective, learning integrates chemical concepts about the scientific process of paper decay, specifically an in-depth explanation of the hydrolysis of Al^3 ions that form acidic conditions and damage the structure of paper fibers. These chemical concepts are not only learned as abstract theories, but are exemplified through real phenomena encountered by students in their daily activities, thus providing a more meaningful understanding of how science plays a role in explaining problems around them. The technological component in this learning is realized through the use of digital mathematics modules equipped with interactive videos explaining algebraic forms of material. This digital platform allows students to explore the material independently according to their respective learning rhythms, while increasing *engagement* through engaging multimedia. This learning technology supports learning differentiation and provides flexibility for students to repeat material that has not been well understood.

engineering aspect is implemented through hands-on activities in a classroom setting, where students create simple scenarios such as counting the number of books on a shelf or counting the total number of stationery items on a desk. This *hands-on experience* facilitates students in honing their critical thinking and problem-solving skills using real-world data they collect themselves. Through this hands-on exploration and investigation, students develop a stronger understanding of the application of mathematical concepts in practical situations. The mathematical component serves as a common thread connecting all aspects of this learning, as students apply algebraic forms to solve contextual problems relevant to their lives. Integration with electronic modules not only strengthens students' understanding of algebraic concepts but also enhances students' mathematical literacy through an approach that combines digital literacy with analytical thinking skills. This holistic approach allows students to understand the relevance of mathematics in everyday life while developing essential skills in today's digital age.

The biggest improvement occurred in the *interpret & evaluate indicator* in learning using electronic module-based STEM. This shows the effectiveness of this approach in optimizing students' mathematical literacy skills, especially in the aspects of mathematical interpretation and evaluation. The following will show some of the students' answers during the pretest on the first question. The question is: P and Q each store a number. The numbers P and Q are negative integers. The product of the numbers P and Q is 50 While the difference between the numbers P and Q is 23. What is the sum of the numbers P and Q.

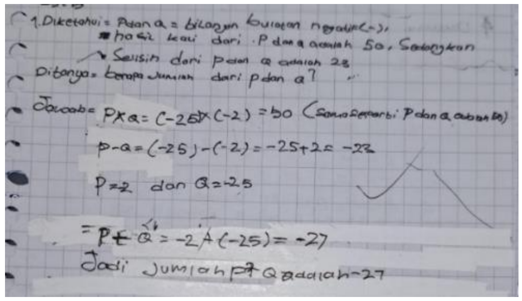

Figure 2. Students' pretest answers

During the pretest, a large number of students were unable to model contextual problems mathematically. This was evident in their answers to item 1, which indicated that they were able to understand the content of the problem well but were unable to formulate the situation mathematically by sequentially writing down the information learned from the problem.

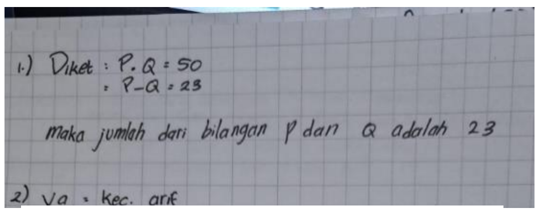

Figure 3. Students' pretest answers

In the image above, we can see that the student's answer has formulated a mathematical problem using the symbols P and Q, but the student has not yet written down all the information known in the problem. Furthermore, the student has not been able to apply the correct mathematical formula to solve the problem.

After the learning treatment, *a posttest was administered* to reassess students' mathematical literacy skills. Nearly all students were able to answer the *posttest questions* correctly. This indicates an increase in students' understanding of algebraic shapes, enabling them to better complete the *posttest questions. Below are some student responses to the posttest questions.*

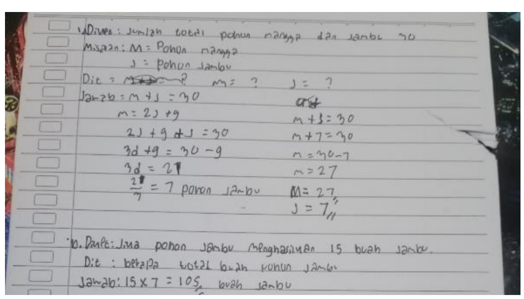

Figure 4. Students' Posttest Answers

The image above shows that students have been able to formulate mathematical problems by writing down various known information and representing it in the form of m and j. Students have also used mathematical calculation strategies to solve the problem correctly, and have also interpreted the problem they have worked on. This is in accordance with a study conducted by(Mujib et al., 2020) which explains that the STEM approach can increase awareness of everyday life problems and develop students' abilities to produce various alternative answers or solutions to problems accompanied by logical arguments for various events in the surrounding environment related to the principles of mathematical literacy .

A comparison of pretest and *posttest results* revealed significant transformations in students' cognitive abilities. In the pretest, the majority of students experienced difficulty formulating contextual problems into mathematical representations, as evidenced by their inability to comprehensively represent information. This reflects the findings of theVebrian et al. (2021) which highlights that there are obstacles in students' abilities to analyze and process information presented in question format, and difficulties in detecting problems which ultimately result in students also having difficulty when determining the appropriate calculation method to overcome the problems faced.

The improvement in interpretation and evaluation skills seen in *the posttest* can be explained by the characteristics of electronic module-based STEM learning. This is in line with research Mohd Shahali et al. (2016) that states that the use of the STEM approach in the context of mathematics learning allows for a shift from conceptual things to more concrete representations. This type of learning is an example of an activity that combines theoretical and empirical elements simultaneously, namely learning modules (Rahmadhani et al., 2023). The implementation of digital modules can support students' autonomous mastery of material, both in the context of face-to-face learning and distance learning, and students become less reluctant to participate in learning activities (Hadiyanti et al., 2021; Susanto & Susanta, 2022).

Students' ability to write information systematically and use appropriate problem-solving strategies on *the posttest* indicates significant metacognitive development. This is supported by research Ijirana et al., (2022) that found that the STEM approach increases students' metacognitive awareness in the mathematics learning process, enabling them to be more aware of the problem-solving strategies they use. The transition from the inability to formulate mathematical models on *the pretest* to the ability to formulate, apply, and interpret on *the posttest* indicates a holistic development in mathematical literacy. In line with (Riani et al., 2022; Yıldırım & Sidekli, 2018) the research, it states that STEM learning creates a conducive environment for the development of high-level mathematical skills because it integrates various disciplines that encourage students to see mathematics as a useful tool in solving real-life problems and has the potential to make a positive contribution to students' mathematical literacy abilities.

The highest increase in the " *interpret & evaluate* " indicator can be explained through the constructivist learning perspective, because in this approach, students independently develop their personal knowledge through experience, exploration, and reflection. Specifically, Saleh and Malone (2019) argue that digital media such as e-modules facilitate the construction of knowledge through active exploration and reflection, which are crucial for developing evaluation and interpretation skills. In this teaching module, elements of experience, exploration, and reflection are clearly visible through the comprehensive STEM learning approach. Experience emerges when students are invited to confront real-life or contextual problems, such as the story of Mr. Hasan's orange orchard or the Mira space mission, which provides them with a starting point for understanding the application of algebraic concepts. Exploration occurs when students are invited to gather information, develop ideas, plan solutions, and try to realize their ideas, whether through group activities, modeling tasks, or simple experiments provided in the learning activities. The element of reflection emerges when students are asked to evaluate their work, correct errors through the *redesign stage,* and communicate the results or solutions they have developed to classmates or the teacher. This entire flow is intentionally designed to build deeper understanding, going beyond simply memorizing concepts, but also linking learning to everyday experiences and honing students' critical reasoning and mathematical literacy skills.

One of the beneficial effects of technological advancements in education is the creation of participatory learning (active *learning)*. Various technological devices can facilitate students in the process of verifying and evaluating data obtained through digital systems and can be accessed practically (Raja & Nagasubramani, 2018; Sulistiawati et al., 2021). The findings of this study are also in line with research by (Dewi & Maulida, 2023) which shows that integrated digital learning approaches such as STEM with the help of technology media are positively correlated with improvements in mathematical literacy skills, including interpretation and evaluation. Thus, the significant improvement in students' mathematical interpretation and evaluation skills through electronic module-based STEM learning can be understood as the result of a pedagogical approach that integrates technology, multidisciplinary contexts, and meaningful learning experiences. This approach creates a learning environment that supports the development of high-level mathematical literacy skills, which are essential for students' success when facing challenges in the contemporary era.

Conclusion

This study provides strong empirical evidence that the integration of the STEM approach based on electronic modules is a very effective learning strategy in improving the mathematical literacy skills of junior high school students, proven through its implementation which resulted in a significant increase from an average score of 35.227 to 77.557 with an n-gain value of 0.636 in the medium category and statistical tests showed a very significant difference (t-count = -9.644; p-value <0.001). The success of this approach is seen in all indicators of mathematical literacy with the highest achievement in the interpretation and evaluation aspect (an increase of 73.58%), followed by the ability to apply concepts (57.57%), and formulate mathematical problems (34.11%), which shows a fundamental cognitive transformation from the inability to model contextual problems to the ability to formulate, apply, and interpret mathematical problems correctly. Theoretically, this study strengthens the constructivism paradigm in mathematics learning where the integration of electronic module technology with the STEM approach successfully bridges abstract mathematical concepts with real applications through meaningful and contextual multidisciplinary learning, thus not only improving academic abilities but also developing essential 21st-century skills to face the complexities of the modern world. Therefore, this study strongly recommends the adoption of the electronic module-based STEM approach as a superior learning strategy for the transformation of mathematics learning from conventional methods to innovative approaches that integrate technology, with suggestions for further research to explore its effectiveness at different educational levels and analyze its influence on affective and psychomotor aspects for a more comprehensive understanding of the impact of technology-based STEM learning.

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