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THE EFFECT OF THE SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) LEARNING MODEL ON STUDENTS' NUMERACY LITERACY SKILLS

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ABSTRACT
This study aims to determine the effect of the STEM learning model on students' numeracy literacy skills. The STEM (Science, Technology, Engineering, and Mathematics) learning model is an interdisciplinary instructional approach that integrates concepts and practices from science, technology, engineering, and mathematics to solve real-world problems. This model emphasizes inquiry-based learning, critical thinking, and problem-solving skills, encouraging students to apply knowledge across disciplines in a cohesive and meaningful way. STEM education aims to enhance students' cognitive engagement and prepare them for future academic and career challenges in a rapidly advancing technological world. The study was conducted at SMP Darussalam with a sample size of 27 students. A quantitative approach was employed, utilizing data analysis techniques such as normality and homogeneity tests. Subsequently, a t-test was conducted to assess the influence of the STEM model in mathematics learning. The results of the study indicate a significant effect on students' numeracy literacy skills, as evidenced by the average test scores, which increased from 18,852 on the pretest to 30,704 on the posttest. This finding suggests that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted.
Keywords: Learning Model , STEM, Numeracy Literacy Skills.

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PRELIMINARY

Education is a critical process in the comprehensive development of students' potential, encompassing knowledge, skills, attitudes, and life values (Maysarah et al., 2023). In the implementation of the 2013 Curriculum (K-13), mathematics instruction is designed to foster student competencies across these three domains (Fatihah & Yahfizham, 2024). Mathematics serves not only as a subject but also as a vital instrument for cultivating logical and scientific thinking patterns and for enhancing the quality of human resources (Siswondo & Agustina, 2021). The importance of early mathematics education is further emphasized by the National Council of Teachers of Mathematics (NCTM) and the National Association for the Education of Young Children (NAEYC), both of which state that children aged 3 to

6 years must have access to high-quality and challenging mathematics learning as a foundational component of their development (Ulfah & Felicia, 2019). This highlights the urgency of designing numeracy-oriented learning models to support the development of 21st-century thinking skills (Sutama et al., 2022).

This condition aligns with the findings of international assessments such as the Programme for International Student Assessment (PISA), initiated by the OECD, which aims to evaluate students' readiness to face future challenges by measuring reading, mathematics, and science literacy (Santos & Del Rosario, 2024). According to the 2022 PISA report published by the Indonesian Ministry of Education, Culture, Research, and Technology (Kemendikbudristek), Indonesian students' numeracy literacy scores declined from 379 in 2018 to 366 in 2022, indicating a 13-point decrease (Nasuha & Ammamiarihta, 2023). This decline reflects the persistently low quality of human resources and the suboptimal standard of education (Masjaya & Wardono, 2018). Epran et al., (2025) further emphasize that students with low numeracy skills tend to struggle with fundamental mathematical concepts, including interpreting information from word problems, identifying relationships among variables, and performing calculations.

Despite several revisions to the national curriculum up to 2024, classroom practices have not fully aligned with curricular expectations (Lubis et al., 2023). Most teachers still rely on lecture-based methods, delivering content in a one-way manner that fails to promote active student participation (Aminah et al., 2023). Such methods are increasingly outdated in the context of current advancements in science and technology and are ineffective in nurturing critical thinking, curiosity, and creativity. In addition to pedagogical approaches, the quality of test items also significantly influences students' numeracy literacy, particularly when questions are not contextual or fail to intellectually challenge learners. This study is grounded in a humanistic approach, which emphasizes the holistic development of learners, including intellectual, emotional, and social dimensions (Sumadi et al., 2023). In this context, it is essential to explore and implement more effective and relevant instructional models to address the low levels of numeracy literacy and to enhance the overall quality of mathematics education.

Based on observations conducted by the researchers at SMP Darussalam Medan, it was found that students exhibited limited numeracy literacy skills. This phenomenon is primarily attributed to the use of lecture-based methods in classroom instruction, which hinder students' ability to apply numeracy literacy in solving given problems. This issue was evidenced through an assessment involving 10 randomly selected students who were given

a problem related to the System of Linear Equations in Two Variables (SPLDV). The problem presented was as follows: “The price of 2 kg of apples and 3 kg of oranges is Rp44.000,-. The price of 3 kg of apples and 2 kg of oranges is Rp41.000,-. If Mrs. Ani buys 5 kg of apples and 4 kg of oranges, how much should she pay?”. Based on the results, most students made errors in both the calculation process and the sequencing of problem-solving steps, leading to incorrect final answers. These mistakes indicate a lack of precision and are closely associated with students’ weak numeracy literacy skills as demonstrated in the pre-test on SPLDV. Out of the 10 students, only 3 were able to answer correctly. This outcome led the researchers to conclude that there is a need for implementing a more effective instructional model to enhance students' numeracy literacy.

In response to this condition, the researchers propose the use of the Science, Technology, Engineering, and Mathematics (STEM) learning model as an alternative strategy to improve instructional quality and strengthen students’ numeracy skills (Muliyana & Jailani, 2023). STEM represents an interdisciplinary learning approach that integrates four core domains—science, technology, engineering, and mathematics. These domains are interconnected within a problem-based learning framework, which facilitates active learning and helps bridge understanding across abstract concepts in each discipline (Siahaan et al., 2020). The STEM learning model incorporates various essential skills such as reading, writing, mathematical reasoning, and deep conceptual understanding. This approach is in alignment with the principles of the 2013 Curriculum, which emphasizes students’ active participation in the learning process as a means to increase their competitiveness in an ever-evolving technological era (Faizah et al., 2022). Therefore, mathematics instruction should be oriented toward hands-on activities such as observation and experimentation to support concrete conceptual development. This underscores the importance of selecting a teaching model that is both appropriate and relevant to the demands of the current era.

The learning model adopted should not merely assist students in answering questions but should also equip them with the ability to understand and solve problems effectively. In the context of the Fourth Industrial Revolution (Industry 4.0), individuals are expected to possess adaptive skills and technological proficiency. To address this challenge, various models have been developed to support the cultivation of 21st-century competencies, commonly known as the 4C^{s}: Creative Thinking and Innovation, Critical Thinking and Problem Solving, Communication, and Collaboration. Accordingly, this study aims to evaluate the effectiveness of the STEM model in enhancing students' numeracy literacy by focusing on three key indicators:

1. the ability to comprehend relevant information within contextual problems,
2. the ability to explain problem-solving processes and present logical answers through mathematical reasoning, and
3. the ability to utilize technology as a tool in formulating and presenting solutions (Darmastuti et al., 2024).

The STEM learning model has previously been implemented in several studies, such as those conducted by Karlina et al., (2023), Dewita & Witarsa, (2023), and Yuniar & Hadi, (2023), all of which demonstrated a significant positive effect on student learning outcomes. Although the topic of this study may appear straightforward, investigations specifically examining the impact of the STEM learning model on students' numeracy literacy remain relatively scarce in the existing literature. This indicates a relevant research gap that warrants further exploration. In the present study, the researchers employed the GeoGebra application as a supporting tool to enhance students' numeracy literacy, particularly in the context of the System of Linear Equations in Two Variables (SPLDV) topic. The application was not used as the central focus of the intervention but rather served as a technological aid to support the implementation of the STEM model.

Given this context, a more in-depth investigation is necessary to specifically examine "The Effect of the Science, Technology, Engineering, and Mathematics (STEM) Learning Model on Students' Numeracy Literacy." This study is expected to contribute to the development of adaptive, technology-based instructional strategies aimed at improving the quality of mathematics education in schools.

METHODS

Figure 1. Research Methods

This study was conducted at SMP Darussalam Medan, located at Jalan Darussalam No. 26A, Kelurahan Sei Sikambing D, Kecamatan Medan Petisah, Kota Medan, Sumatera Utara 20119. The research was carried out during the even semester of the 2024/2025 academic year, specifically in April 2025. The focus of the study centered on the topic of Systems of Linear Equations in Two Variables (SPLDV) and was implemented over the course of four instructional sessions. The initial phase of the research began with an observation stage, aimed at identifying problems that emerged during the teaching and learning process. This study employed a quantitative approach using a quasi-experimental method, specifically the one-group pretest-posttest design. The quantitative approach is characterized by the use of numerical data, which is analyzed through statistical techniques. Azwar (2010) explains that quantitative research emphasizes the analysis of numerical data processed through statistical procedures. Similarly, Sugiono (2013) states that quantitative research is grounded in a positivistic paradigm and is used to study specific populations or samples through the collection of data using research instruments, with the data analyzed quantitatively for the purpose of testing formulated hypotheses. The one-group pretest-posttest design involves administering a pretest to a single group, implementing an intervention, and subsequently administering a posttest (Hananto & Melini, 2023).

The population in this study consisted of clusters (i.e., groups of individuals), which led to the use of the cluster random sampling technique for sample selection. This technique involves selecting members from homogeneous groups. Based on this method, the eighth-grade students at SMP Darussalam Medan were divided into several groups, and one class—Class VIII-1—was selected as the research sample. This class served as the experimental group in which the Science, Technology, Engineering, and Mathematics (STEM) learning model was implemented.

To collect the necessary data, the researcher utilized several instruments designed to ensure the validity and reliability of the findings. These included observation sheets, numeracy literacy tests (in the form of pretests and posttests), and validation sheets.

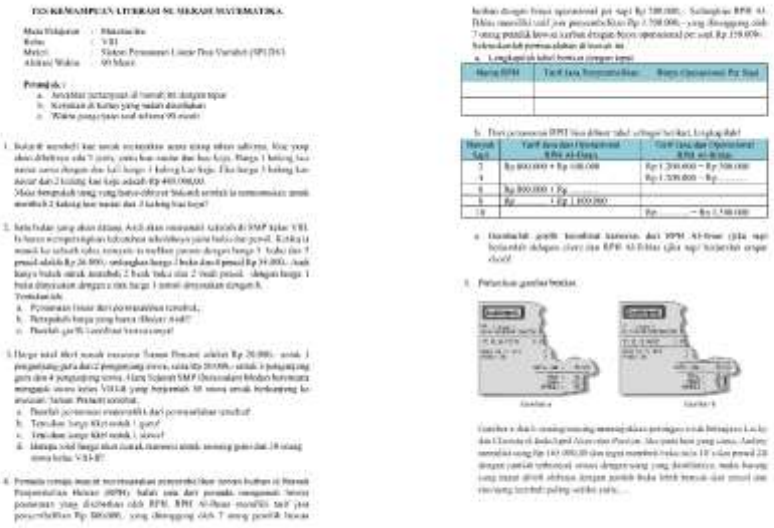

Figure 2. Numeracy Literacy Test Questions

In this study, the Android version of the GeoGebra application was utilized due to its wide array of interactive features that support STEM-based mathematics learning. GeoGebra was employed as a supporting tool to strengthen students' understanding of the topic Systems of Linear Equations in Two Variables (SPLDV). Several key features of the application were integrated into the learning process, including:

1. Algebra Input and Dynamic Graphing

   GeoGebra enables students to input linear equations in algebraic form (e.g., 2x + 3y = 44), which are then automatically displayed as straight lines on a coordinate plane. This visualization helps students better understand the relationship between two variables and identify the point of intersection (i.e., the solution) of the system of equations.

2. Drag and Object Manipulation Tools

   Students can drag lines or points on the graph and immediately observe how the corresponding algebraic expressions change. This interactive feature enhances their conceptual understanding of variable relationships and bridges symbolic and visual representations of mathematical concepts.

3. Intersect and Point Tools

   These tools are used to identify the intersection point of two lines, which represents the solution to the system of equations. By using this feature, students can visually verify their answers and grasp the geometric meaning behind the solution of a linear system.

4. Automatic Calculation

GeoGebra automatically computes and displays the coordinates of the intersection point, facilitating faster answer verification without the need for manual calculation. This feature also provides immediate feedback to students, helping them identify and correct computational errors efficiently.

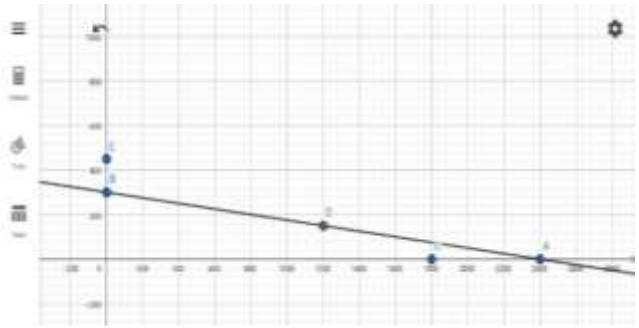

Figure 3. Implementation of GeoGebra Android Application

The data obtained were analyzed using descriptive and inferential statistical techniques. Students' numeracy literacy skills were described based on test scores, which were then categorized according to assessment criteria established by (Arikunto, 2018). After describing students' mathematical concept mastery, the next step involved hypothesis testing using the independent sample t-test. This statistical test was conducted following the fulfillment of normality and homogeneity assumptions. The purpose of the hypothesis test was to determine whether the null hypothesis (H_0) should be accepted or rejected. At this stage, a one-sample t-test was used to assess whether the sample mean differed significantly from a predetermined value.

The use of the GeoGebra application, with its interactive and visual features, provided students with a learning experience that differed markedly from traditional lecture-based methods. This approach is highly relevant to the instructional conditions observed at SMP Darussalam Medan, which, according to preliminary observations, is still largely dominated by conventional methods with minimal integration of technology. Students at this school demonstrated significant difficulties in solving context-based numeracy problems, particularly on the topic of SPLDV, as evidenced by their low performance on the initial assessment.

Through the integration of GeoGebra within the STEM learning model, students at SMP Darussalam Medan were not only given opportunities to practice solving mathematical problems but also encouraged to explore and visualize concepts. This approach has been found to foster learning interest, reduce procedural errors, and improve analytical skills.

Therefore, the use of GeoGebra in this context is not merely a technological aid, but a pedagogical strategy aimed at addressing the challenge of low numeracy literacy in a more structured and applicable manner.

RESULT AND DISCUSSION

Based on the results of the analysis of item validity from the trial test, calculations were carried out using the r Pearson Product Moment correlation formula with the assistance of Microsoft Excel software at a 5% significance level.

Table 1. Validity Test

Test Item	1	2	3	4	5
R Count	0,720	0,549	0,782	0,651	0,699
R Table	0,381	0,381	0,381	0,381	0,381
Results	Valid	Valid	Valid	Valid	Valid

The results of the validity analysis indicated that all five test items were valid, as shown by the following calculations:

Item 1: $r_{value}(0,720) > r_{table}(0,381)$

Item 2: $r_{value}(0,549) > r_{table}(0,381)$

Item 3: $r_{value}(0,782) > r_{table}(0,381)$

Item 4: $r_{value}(0,651) > r_{table}(0,381)$

Item 5: $r_{value}(0,699) > r_{table}(0,381)$

Based on the results, it can be concluded that all test items in the research instrument are valid and appropriate for use as measurement tools to assess students' numeracy literacy skills. After the validity testing was completed, the validated items were subsequently subjected to reliability testing to determine the level of internal consistency among the items representing the indicators of a given variable. In this study, the reliability test was conducted using the Cronbach's Alpha formula with the assistance of Microsoft Excel.

Table 2. Reliability Test

Test Item	1	2	3	4	5
Item Variants	1,462	1,538	1,635	0,909	1,430
Total Variance			16,063		
Cronbach's Alpha Value			0,707		
Results			Reliable		

The results of the reliability test for the assessment instrument yielded a value of 0,7073, which falls within the range of 0,6 to 0,8, thereby categorizing the instrument as reliable. Consequently, it can be concluded that the items in the instrument are appropriate for use in the study and can function consistently as a measurement tool. Subsequently, a

normality test was conducted to determine whether the data obtained in the study followed a normal distribution. This test aimed to ensure that the distribution of the random sample data conformed to the characteristics of a normal distribution. The decision criterion was based on a comparison between the calculated W-value and the critical W-table value. If the calculated W is greater than the W-table value, the data are considered normally distributed. Conversely, if the calculated W is smaller than the W-table value, the data do not follow a normal distribution.

Table 3. Normality Test

Total Results	829
Average ($\bar{x}$)	30,704
Total (b)	20,096
W_Numerator (b^2)	403,857
W_Denominator (SS)	417,63
W Value (b^2/SS)	0,967
W Table	0,923
$W_{value} > W_{table}$	**Normal**

Based on the results of the normality test calculation, the data from Class VIII-1, which was taught using the STEM learning model, exhibited a normal distribution pattern. This is indicated by the calculated W-value of 0,967, which is greater than the critical W-table value of 0,923. Accordingly, the data from this class satisfies the normality assumption and can be considered normally distributed, making it a valid sample for use in this study. Furthermore, to determine the equality of variances between the experimental and control groups, a homogeneity test was conducted on the post-test data using Bartlett's test, which is detailed as follows:

Table 4. Homogeneity Test

	Pre-test	***Post-test***
Variance Value (S^2)	23,9	16,063
Combined Variance	19,981	
Unit B Value	67,634	
Chi-square test Value (L_{value})	1,0187	
Table Chi-square Value (L_{table})	3,8415	

Based on the results presented in the homogeneity test table, the calculated F-value was 1,0187, which is smaller than the F-table value of 3,8415. Therefore, the null hypothesis (H_0) is accepted, indicating that the variances of the two groups—pre-test and post-test—are homogeneous, or have similar distributions. Furthermore, an analysis of the item difficulty levels was conducted, and the results are presented as follows:

Table 5. Difficulty Level Test

Test Item	1	2	3	4	5
Average	8,333	3	5,407	5,704	8,259
Maximum Test Score			10		
Difficulty Level Score	0,833	0,3	0,541	0,57	0,826
Results	Easy	Hard	Medium	Medium	Easy

The analysis of the difficulty level of the five test items showed that all items ranged from easy to difficult. This indicates that the test instrument possesses sufficient variation to comprehensively assess students' abilities. The t-test in this study was employed as an inferential statistical tool to determine whether there was a statistically significant difference between pretest and posttest scores. In this context, the t-test was used to evaluate the effectiveness of the instructional intervention-namely, the STEM learning model supported by GeoGebra—in enhancing students' numeracy literacy skills. Conceptually, the t-test assesses whether the mean scores of two related datasets (before and after the treatment) differ in a manner that is not due to random variation, but instead reflects a genuine effect of the intervention. The test was conducted at a significance level of $\alpha = 0,05$, meaning that the results are considered statistically significant if the probability of committing a Type I error (rejecting a true null hypothesis) is less than 5%. Therefore, the t-test not only serves to test the hypothesis but also provides a basis for drawing conclusions about the effectiveness of the instructional model implemented.

Table 6. T-test Results

	Pre test	***Post test***
Average	18,852	30,704
Variance	23,9003	16,0627
Respondance	27	27
Standard Deviation	4,888	4,0078
Correlation	0,6003	
T_{Value}	15,22	
T_{Table}	2,056	

Based on the results of the t-test calculation, it was found that the t-value = 15,22 was greater than the t-table value = 2,056 at a significance level of 0,05 with a degree of freedom (df) of 26. This result indicates a statistically significant difference between the pretest and posttest scores following the implementation of the STEM learning model. The average pretest score of 18,85 increased to 30,70 in the posttest, accompanied by a decrease in variance from 23,90 to 16,06, and a correlation coefficient of 0,6003 between pretest and posttest scores, indicating a moderate relationship. These findings suggest that the STEM-based instructional intervention, particularly when supported by the use of GeoGebra,

contributed meaningfully to the improvement of students' numeracy literacy skills. Consequently, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted, confirming that the STEM learning model had a statistically significant effect on enhancing students' numeracy literacy in the topic of systems of linear equations in two variables (SPLDV).

These results are in line with the findings of Nurwijaya (2024) in a study titled The Effect of STEM Learning Approach on the Numeracy Skills of Elementary School Students in the Kepulauan Aru. In that study, hypothesis testing was conducted using the Mann–Whitney test, which produced a significance value (2-tailed) of 0,000, indicating that H_a was accepted and H_0 was rejected (0,000 < 0,05). This confirms that the use of the STEM learning approach had a significant effect on the numeracy skills of students at SD Negeri 1 Dobo, Kabupaten Kepulauan Aru.

CONCLUSION

The results of the numeracy literacy assessment indicated that the average test score of Class VIII-1 increased from 18,85 in the pre-test to 30,70 in the post-test. Based on the item difficulty analysis, all five test items fell within the moderate to difficult category, with difficulty indices ranging between $0 < DI \leq 1$. Furthermore, the t-test analysis revealed a calculated t-value of 15,22, which exceeded the critical t-table value of 2,056 at a significance level of $\alpha = 0,05$. These results indicate that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted, suggesting a statistically significant difference between the pre-test and post-test results. Thus, it can be concluded that the application of the Science, Technology, Engineering, and Mathematics (STEM) learning model has a positive impact on improving students' numeracy literacy skills.

Based on the findings of this study, several recommendations are proposed to support future research and educational practices:

1. For Students:
   - Increase active engagement in the learning process, particularly when using digital tools such as GeoGebra, to foster visual and contextual understanding of mathematical concepts;
   - Develop habits of critical and reflective thinking—not only to solve problems but also to comprehend the underlying processes of mathematical reasoning;
   - Independently explore digital learning applications as part of adapting to 21st-century learning demands.

2. For Teachers:
   - Reduce reliance on teacher-centered lecturing and adopt STEM-based approaches that emphasize interdisciplinary integration and active learning;
   - Utilize GeoGebra or similar technological tools as visual aids to enhance student understanding of abstract mathematical concepts;
   - Participate in training or internal workshops focused on the effective use of interactive digital media in the classroom.
3. For Educational Institutions:
   - Support the integration of technology into the learning environment by providing adequate infrastructure, including ICT equipment and access to educational applications;
   - Encourage STEM-based instructional innovations within the school curriculum and teacher development programs;
   - Formulate adaptive and contextual teaching policies that promote the use of technology to enhance students' numeracy and literacy competencies.
4. For Future Researchers:
   - Extend the research to different educational levels or subject matter to broaden the applicability and validity of the STEM learning model;
   - Conduct qualitative investigations into students' learning processes during GeoGebra-assisted instruction to gain deeper insights into their mathematical thinking;
   - Explore and compare other technology-based STEM instructional models to evaluate their effectiveness in enhancing students' numeracy and literacy outcomes.

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