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Enhancing students' mathematical literacy ability through the implementation of the Needham learning model assisted by GeoGebra

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Abstract.
This study investigates the impact of limited learning models, conventional instructional methods, and minimal utilization of interactive technology on low mathematical literacy. It highlights a research gap in integrating the Needham model with GeoGebra for teaching linear equations. The study's objective was to compare the mathematical literacy improvement of students taught with the Needham model supported by GeoGebra versus those receiving conventional instruction. Additionally, it aimed to assess the implementation of the Needham model assisted by GeoGebra. A quasi-experimental design with a nonequivalent pretest–posttest control group was employed. The study's population comprised 124 eighth-grade students at State Junior High School 8 Singkawang. Purposive sampling was used to select class VIII A (25 students) as the experimental group and class VIII B (25 students) as the control group. Data analysis techniques utilized included normalized gain, t-test, and implementation percentage. The results revealed that the experimental group (N-Gain = 0.65) outperformed the control group (0.32), demonstrating a statistically significant difference ($t_{count} = 3.243 > t_{table} = 2.01$, $p < 0.05$). This indicates that students taught with the Needham model supported by GeoGebra exhibited greater improvement in mathematical literacy compared to those taught with conventional methods. The implementation of the Needham model assisted by GeoGebra was categorized as very good, exceeding the 90% threshold. Specifically, 92.37% of students achieved the desired level in the first session and 96.85% in the second session. The study concludes that the Needham model assisted by GeoGebra significantly enhances students' mathematical literacy in learning systems of linear equations in two variables.

Keywords:
GeoGebra; mathematical literacy; Needham; system of linear equations in two variables

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INTRODUCTION

Mathematical literacy encompasses a comprehensive skill set that encompasses the formulation, application, and interpretation of mathematical concepts across diverse contexts. It also involves the ability to reason and connect these concepts to real-life situations (OECD, 2023). Mathematical literacy is a crucial aspect of mathematics education as it emphasizes students' capacity to analyze, reason, and effectively communicate ideas when confronted with mathematical problems. This competence is essential for all students, as it provides tangible benefits in comprehending, interpreting, and applying mathematical concepts to solve problems encountered in daily life.

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Despite the Programme for International Student Assessment (PISA) data from 2006 to 2022, which indicate a consistent decline in Indonesian students' mathematical literacy, the situation remains concerning. In the most recent assessment conducted in 2022, Indonesia ranked 70th out of 81 participating countries, with a score of 366 (OECD, 2023). This finding is further corroborated by the research conducted by Kurniawan and Djidu (2021), which revealed students limited mathematical literacy in various domains, including conceptual understanding, factual knowledge, procedural skills, reasoning, and the ability to interpret, apply, and evaluate mathematical outcomes. Similarly, Farida et al. (2021) reported the results of this study indicate that high-ability students are able to demonstrate good mathematical literacy skills, namely students are able to fulfill all three aspects of the mathematical process, namely formulate, employ and interpret well. Students with moderate abilities are only able to meet two indicators in the mathematical process aspect, namely formulate and employ. Low-ability students cannot fulfill all indicators in the mathematical process aspect, low-ability students only meet one aspect of the mathematical process, namely formulate.

Furthermore, preliminary research conducted through an initial aptitude test revealed that students' average mathematical literacy score was only 34.79, placing them in the low category. In this assessment, mathematical literacy was evaluated based on five indicators: (1) communication, which pertains to students' capacity to articulate mathematical concepts both verbally and in written form; (2) mathematizing, which involves the ability to translate real-world scenarios into mathematical models or concepts; (3) representation, which encompasses the skill of presenting mathematical information in various formats, such as tables, graphs, or diagrams; (4) reasoning, which entails the capacity to provide logical arguments in problem-solving; and (5) devising strategies for problem-solving, which includes the utilization of symbolic, formal, and technical language, mathematical operations, and appropriate mathematical tools. These findings underscore the fact that students continue to encounter challenges in multiple facets of mathematical literacy, encompassing the ability to communicate ideas, model situations, and represent data, as well as the capacity to reason logically and construct effective problem-solving strategies.

One of the primary factors contributing to students' low mathematical literacy is the absence of teachers' inclination to provide literacy-based mathematical problems. Interviews with mathematics educators revealed that the exercises provided predominantly emphasize procedural patterns and the memorization of formulas, without establishing a connection to the indicators of mathematical literacy. This condition has a detrimental impact on students' inadequate mastery of the five indicators of mathematical literacy, namely communication, mathematizing, representation, reasoning, and devising strategies. Consequently, it impedes the overall development of students' mathematical literacy skills.

Rahmawati et al. (2023) posited that the low level of students' mathematical literacy is attributed to the limited availability of literacy-based problems and the absence of learning modules that explicitly incorporate mathematical literacy indicators. Kurniawan and Anwar (2022) further emphasized that instructional materials not designed with a literacy orientation hinder students' comprehension of mathematical concepts in real-life contexts. Similarly, Zhang et al. (2023) affirmed that the integration of literacy indicators into learning materials has a significant impact on enhancing mathematical literacy skills across various educational levels. In light of these challenges, there is an urgent need to address the issue of low mathematical literacy among students by implementing appropriate, engaging, and enjoyable learning models that can effectively support the development of literacy-oriented mathematical competencies.

One of the learning models that can be applied is the Needham model, which emphasizes students' active engagement in constructing knowledge, with the teacher serving as a facilitator (Gardenia, 2016). This approach is student-centered Handayani et al. (2023)and consists of five stages orientation, idea generation, idea restructuring, application of ideas, and reflection. Each stage is designed to foster students' mathematical communication skills through discussion and the articulation of ideas. Furthermore, the model assists learners in translating real-life situations into mathematical concepts (mathematizing) and in employing diverse forms of mathematical

representation (representation) in an active manner. The reflection process also cultivates logical reasoning skills (reasoning) and supports the development of problem-solving strategies using symbolic language and mathematical tools (devising strategies), thereby enabling a deeper and more meaningful understanding of the material.

The Needham model is effectively applied to the topic of systems of linear equations in two variables, which serves as a fundamental concept in mathematics and its real-life applications. To support the learning process, the GeoGebra application is utilized as a tool capable of visualizing linear equations in two variables through graphical representations (Siregar et al., 2024). GeoGebra enhances students' mathematical representation skills and facilitates the development of problem-solving strategies using symbolic language and visual aids. This view is further supported by research conducted by Khotimah (2018), which revealed that students' mathematical literacy significantly improved after the integration of GeoGebra into the learning process.

This study presents a novel contribution by integrating the Needham instructional model with the GeoGebra application in the teaching of systems of linear equations in two variables. This integration aims to enhance students' mathematical literacy. Previous research suggests that while various innovative learning models have been implemented, most remain limited to conventional approaches or the isolated use of technology. To date, no study has specifically integrated the Needham model with GeoGebra in the context of teaching systems of linear equations in two variables at the junior high school level. Furthermore, studies that compare the Needham model assisted by GeoGebra with conventional learning while simultaneously evaluating its classroom implementation are still scarce. This gap underscores the urgency of the present research, which seeks to provide empirical evidence on the integration of Needham and GeoGebra in improving junior high school students' mathematical literacy.

METHOD

This research employed an experimental method with a quantitative approach to investigate the enhancement of students' mathematical literacy following instruction through the Needham instructional model, facilitated by the GeoGebra application. As per Sugiyono (2019), an experimental method seeks to ascertain the impact of a specific intervention on other variables under controlled conditions, while a quantitative approach is employed to analyze numerical data processed statistically to test hypotheses. This approach is corroborated by Creswell (2014), who asserts that the quantitative experimental method is the most suitable design for investigating cause-and-effect relationships with stringent control over intervention variables. The research design employed in this study was a Quasi-Experimental Design of the Nonequivalent Pretest Posttest Control Group type. The design of this study is presented as follows:

Eksperiment	:	O_1	x	O_2
Control	:	O_1	x	O_2

Description
O1 : Pretest (Mathematical Literacy Ability)
O2 : Posttest (Mathematical Literacy Ability)
X : Needham learning model assisted by GeoGebra

This research was conducted at State Junior High School 8 Singkawang during the odd semester of the 2024/2025 academic year. The population comprised all eighth-grade students, totaling 124 individuals. The selection of eighth graders was based on the consideration that students at this age are generally at the formal operational stage, as proposed by Piaget (1970). The sampling technique applied was purposive sampling, which involves selecting participants according to specific considerations or criteria relevant to the objectives of the study (Sugiyono, 2013). This approach is also supported by Patton (2015), who emphasized that purposive sampling is effective in experimental research requiring participants with particular characteristics suited to

the research purpose. Based on the preliminary findings, class VIII A was designated as the experimental group, while class VIII B served as the control group. This study recognizes certain limitations, particularly regarding the relatively small number of respondents. Such limitations may restrict the generalizability of the findings to a broader population. Therefore, the results are most applicable to the specific context of State Junior High School 8 Singkawang.

In this study, data collection techniques employed included tests and observations. The test comprised five essay questions administered during both the pre-test and post-test to assess students' mathematical literacy skills. Additionally, observations were conducted to evaluate the implementation of the learning model within the experimental class. In accordance with the perspective of Lestari and Yudhanegara (2017), data collection techniques are defined as systematic procedures for acquiring information that subsequently serves to address the research objectives.

The research instruments comprised mathematical literacy test items and an observation sheet for evaluating the implementation of learning. Prior to their utilization, the instruments underwent thorough examination for both content validity and construct validity. Content validity was established through evaluations conducted by three mathematics education experts to ensure that the instruments aligned with the designated competency indicators, adhering to the standard validation procedures outlined by Arikunto (2013). A concise summary of the instrument validity results is presented in Table 1.

Table 1. Recapitulation of content validity results

Instruments Validated	Validator			Total	Average	category
	1	2	3			
Lesson Module, Meeting 1 (Experimental)	4,2	4,3	4,4	12,9	4,3	Highly Valid
Lesson Module, Meeting 2 (Experimental)	3,8	4,2	4	12	4,0	Valid
Lesson Module, Meeting 1 (Control)	3,9	3,7	4,5	12,1	4,0	Valid
Lesson Module, Meeting 2 (Control)	3,9	3,8	4,5	12,2	4,0	Valid
Post-test Items	4,1	4	4,3	12,4	4,1	Valid
Pre-test Items	3,8	4	4,3	12,1	4,0	Valid
Observation Sheet of Learning Implementation 1	4,2	4,5	4,8	13,5	4,5	Highly Valid
Observation Sheet of Learning Implementation 2	4,3	4,4	4,2	12,9	4,3	Highly Valid

Based on the analysis presented in Table 1, it was determined that the teaching modules for the initial and subsequent meetings in both experimental and control classes achieved an average validation score of 4.1, which falls within the valid category according to the criteria for the feasibility of instructional instruments. Furthermore, the results of the content validity test for the pre-test and post-test items demonstrated an average score of 4.0, also classified as valid, indicating that the test items were appropriate for measuring students' mathematical literacy skills. Additionally, the validation results for the observation sheets assessing the implementation of the learning model yielded an average score of 4.4, which is categorized as highly valid. This demonstrates that the instruments were highly suitable for observing the implementation of classroom learning. These findings are consistent with Rahmawati et al. (2023), who emphasized the importance of instrument validation to ensure the accuracy of data in mathematics literacy-based research.

Furthermore, to assess the construct validity of the test items, a correlation was computed between the score of each item and the total score using Pearson's Product Moment formula. This trial was conducted on a numeracy literacy test administered to eighth-grade students at State Junior High School 16 North Singkawang, comprising a total of 20 respondents. The recapitulation results of the construct validity test for each test item are presented in Table 2.

Table 2. Recapitulation of construct validity results

Item Number	Correlation Coefficient (Pre)	Category	Correlation Coefficient (Post)	Category
1	0,58	Moderate	0,67	Moderate
2	0,66	Moderate	0,68	Moderate
3	0,57	Moderate	0,52	Moderate
4	0,59	Moderate	0,64	Moderate
5	0,55	Moderate	0,43	Moderate

Based on the analysis presented in Table 2, the five test items designed to assess students' numeracy literacy skills demonstrated moderate validity, both in the pre-test and post-test. Specifically, items number 1, 2, 3, 4, and 5 each obtained construct validity coefficients that fall within the moderate interpretation range, as outlined by Arikunto (2013). This finding indicates that every item accurately measures the intended numeracy literacy skills, thereby confirming that the research instrument is valid in terms of both content and construct.

Furthermore, a reliability test was conducted to determine the extent to which the instrument consistently produced stable results under the same conditions. The reliability analysis employed the Alpha Coefficient formula (Cronbach's Alpha) as suggested by Siregar (2017). The calculation results revealed that the reliability score of the test instrument for assessing students' numeracy literacy skills at Public Elementary School 85 Singkawang was 0.68 for the pre-test and 0.62 for the post-test. According to the criteria proposed by Lestari and Yudhanegara (2018), these values fall within the moderate category, indicating that the instrument possesses an adequate level of reliability for use in this study.

In addition, a discrimination power test was conducted to assess the extent to which the items effectively distinguished between students with high and low ability levels. The results revealed that the average discrimination index was 0.53 for the pre-test and 0.57 for the post-test, both of which fall within the acceptable range based on the item discrimination interpretation guidelines (Lestari & Yudhanegara, 2018). Concurrently, the difficulty index of the items indicated an average of 0.55 for the pre-test, categorized as moderate, and 0.68 for the post-test, which also falls within the moderate category. Consequently, the trial analysis of the five items in this study demonstrated that the questions possessed good validity, moderate reliability, discrimination power ranging from adequate to very good, and item difficulty at the moderate level. Therefore, all items utilized in this research instrument were deemed feasible and appropriate for evaluating students' literacy skills.

The data analysis techniques employed in this study were derived from Sugiyono (2019), which involved statistically processing the collected data to ensure the validity and reliability of the results. The analysis commenced with prerequisite tests, commencing with the normality test. This test aimed to ascertain whether the sample data exhibited a normal distribution, thereby fulfilling the assumptions of parametric statistics. Subsequently, a homogeneity test was conducted to verify the equality of variances among groups, ensuring the accurate interpretation of the results of parametric tests. Once the prerequisites were met, a t-test was applied to compare the mean scores of students' mathematical literacy skills before and after the implementation of the Needham learning model facilitated by the Geogebra application. This comparison was intended to examine the improvement in literacy ability as a consequence of the intervention. Additionally, the N-Gain calculation was utilized to quantify the magnitude of students' literacy improvement, both individually and in groups, following the treatment. Finally, percentage analysis was conducted to assess the implementation level of the Needham learning model facilitated by GeoGebra within the learning process of Grade VIII students at State Junior High School 8 Singkawang.

RESULTS AND DISCUSSION

This study was conducted at State Junior High School 8 Singkawang, involving eighth-grade students divided into two groups: Class VIII A (experimental group) and Class VIII B (control group). The experimental class was taught using the Needham learning model, supplemented by the Geogebra application. In contrast, the control class received instruction through the direct

learning model. The primary objective of this research was to evaluate the effectiveness of the Needham model, supported by GeoGebra, in enhancing students' literacy skills in the subject of systems of linear equations in two variables. Furthermore, the study aimed to assess the extent to which the implementation of the Needham model, integrated with GeoGebra, was effectively carried out throughout the teaching and learning process.

Enhancement of Students' Literacy Skills through the Needham Learning Model Assisted by GeoGebra in the Topic of Systems of Linear Equations in Two Variables

The data utilized in this research were derived from students' mathematical literacy test results, encompassing both pre-tests and post-tests. The test instruments, comprising five items, had previously undergone validation through content and construct validity tests, reliability analysis, item difficulty, and discrimination index, ensuring their appropriateness for measuring students' mathematical literacy skills. Data collection commenced with the administration of a pre-test to both groups: the experimental class, which implemented the Needham learning model assisted by GeoGebra, and the control class, which applied direct instruction. Subsequently, both groups participated in several sessions of teaching according to their respective models. Subsequently, both groups were administered the same post-test to assess students' mathematical literacy performance. The average scores from the pre-test and post-test in both the experimental and control classes on the topic of Systems of Linear Equations in Two Variables are presented in Figure 1.

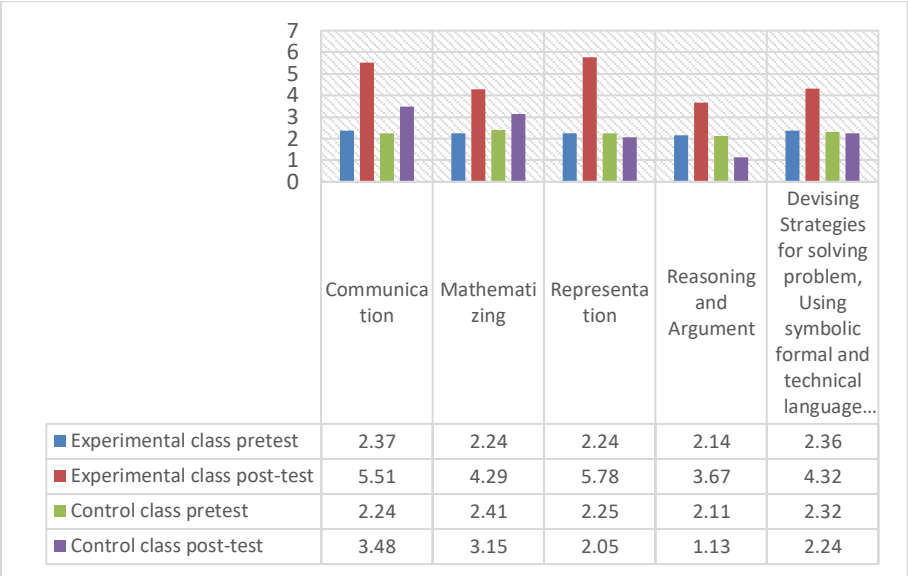

Figure 1. Average pre-test and post-test scores of mathematical literacy in the experimental and control classes

Figure 1 presents a comparative analysis of students' average scores in mathematical literacy across five domains: communication, mathematical modeling, representation, reasoning and argumentation, and problem-solving strategies employing symbolic, formal, and technical language. The data were collected from two groups: the experimental class and the control class, each subjected to pre-test and post-test assessments. Notably, the experimental class exhibited a significant improvement in all domains, with the highest post-test score recorded in the representation domain at 5.78. This was followed by communication at 5.51, mathematical modeling at 4.29, problem-solving strategies at 4.32, and reasoning and argumentation at 3.67. Conversely, the control class demonstrated relatively modest gains or even declines, particularly in the reasoning and argumentation domain, which experienced a decrease from 2.11 in the pre-test to 1.13 in the post-test. Consequently, descriptively, the mathematical literacy proficiency of students in the experimental class surpassed that of the control class across all indicators.

Furthermore, Figure 2 illustrates the pre-test and post-test scores of students' mathematical literacy in the experimental group, which was instructed using the Needham model augmented by the GeoGebra application, and the control group, which received direct instruction.

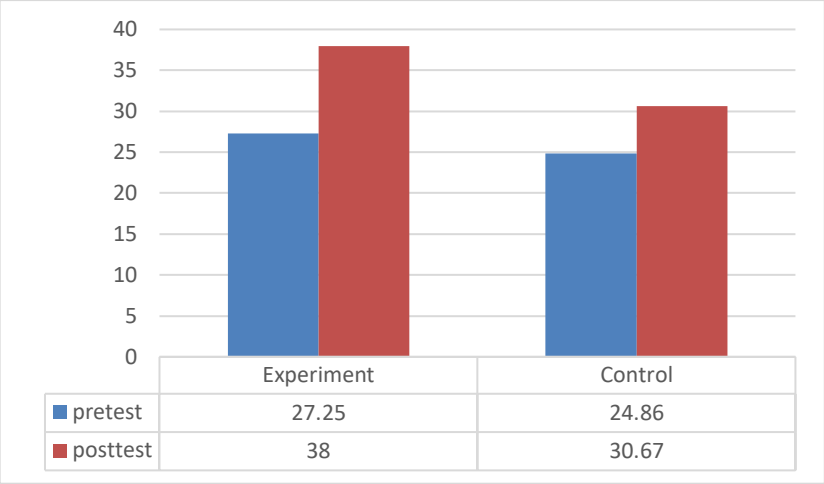

Figure 2. Average pre-test and post-test scores of mathematical literacy skills

Based on Figure 2, the average pre-test score of the experimental group was 27.25, while the control group achieved an average score of 24.86. Following the implementation of the learning process, the experimental group's average post-test score increased to 38, whereas the control group's score rose to 30.67. The improvement observed in both groups suggests a disparity in mathematical literacy skills, with the experimental class demonstrating superior results compared to the control class. Descriptively, it is evident that the average pre-test scores of mathematical literacy between the experimental and control groups were distinct, and the same holds true for their average post-test scores, which also exhibited notable variations. Consequently, a test of mean similarity was subsequently conducted.

Normality Test of Mathematical Literacy Skills

In this study, the normality test was conducted using the Chi-Square test. The results of the normality test for the pretest data on students' mathematical literacy skills in the experimental and control classes are presented in Table 3.

Table 3. Recapitulation of normality test results

Description	Class	
	Experimental	Control
$x^2 count$	8,10	2,60
Number of students (N)	25	25
Significance level	5%	5%
$x^2{}_{table}$	11,07	

Based on Table 3, the obtained x^2_{count} value for the experimental class was 8.10, while the x^2_{table} value was 11.07. Since $x^2_{count} < x^2_{table}$, the null hypothesis ($H_0$) is accepted, indicating that the data are normally distributed. Similarly, in the control class, the x^2_{count} value was 2.60, with the same x^2_{table} value of 11.07. As $x^2_{count} < x^2_{table}$, H_0 is accepted, confirming that the data are normally distributed. Furthermore, the Kolmogorov Smirnov test was also conducted, and the results are presented in Table 4.

Table 4. Test of normality of mathematical literacy skills

			Kolmogorov-Simornov[a]		
		Class	Statistic	df	Sig.
Mathematical Literacy Skills		Experimental	.119	25	.200*
		Control	.092	25	.200*

Based on Table 4, the significance value obtained was p (0.200) > α (0.05). This indicates that the mathematical literacy skills of students in both the experimental and control classes follow a normal distribution.

Homogeneity Test of Mathematical Literacy Skills

A homogeneity test was conducted on the data from both the experimental and control classes to ascertain whether the variance of the data was homogeneous or not. In this study, the F-test was employed to investigate homogeneity. The summary of the homogeneity test results is presented in Table 5.

Table 5. Recapitulation of homogeneity test calculations

Description	Class	
	Experimental	Control
Variance	47,97	46,72
F_{count}	0.225	
Number of Students	25	25
Significance Level	5%	5%
Degrees of Freedom	24	24
F_{table}	1,98	

Based on the calculations presented in Table 5, it was determined that the homogeneity test employing the F-test formula revealed a variance of 47.97 for the experimental class, which was the highest variance, and a variance of 46.72 for the control class, which was the lowest variance. This resulted in a calculated F value of F_{count} = 0.225. Conversely, from the F_{table} at a 5% significance level with 24 numerator degrees of freedom and 24 denominator degrees of freedom, the F_{table} value was F_{table} = 1.98. Since F_{count} (0.225) < F_{table} (1.98), the null hypothesis (H_0) is accepted, indicating that the data variance is homogeneous. Table 6 presents the results of the Test of Homogeneity of Variances for mathematical literacy skills, conducted using Levene's test.

Table 6. Test of homogeneity of variances for mathematical literacy ability

Levene Statistic	df1	df2	Sig.
.225	1	25	.615

Based on Table 6, the Levene test significance value, p (0.615), exceeds the significance level (α) of 0.05. This suggests that, at a 5% significance level, the mathematical literacy scores of the students originate from a homogeneous population.

N-gain ternormalisasi (N-Gain) Kemampuan Literasi Matematis

To ascertain the efficacy of the Needham learning model, augmented by the GeoGebra application, in enhancing students' mathematical literacy, particularly in the domain of systems of linear equations in two variables, the N-Gain formula was employed. The results of the N-Gain computation are presented in Table 7.

Table 7 indicates that the N-Gain index for the experimental class was 0.65, placing it within the moderate range. Conversely, the control class achieved an N-Gain index of 0.32, also categorized as moderate. The normalized N-Gain diagram illustrating students' mathematical literacy levels in the experimental and control classes is depicted in Figure 3.

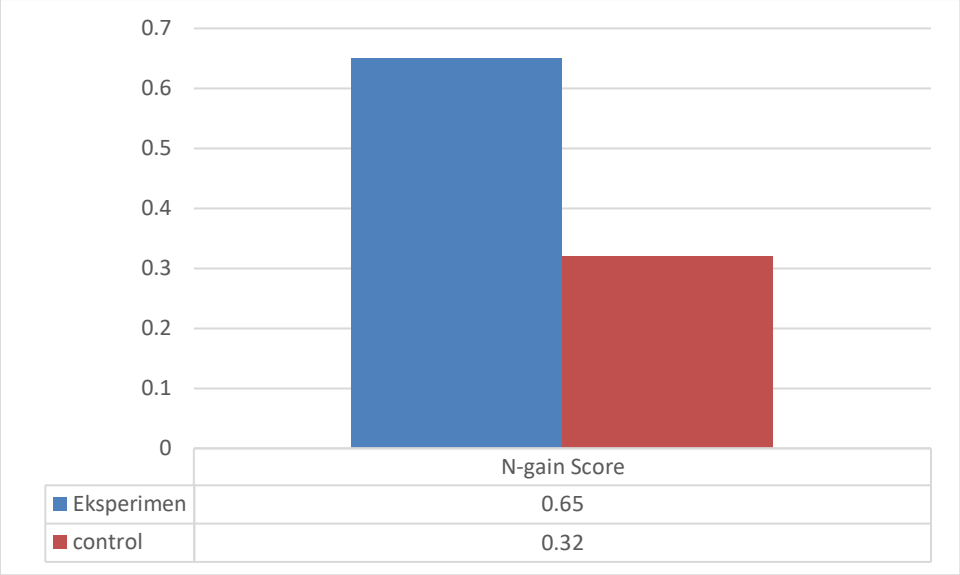

Figure 3. Normalized n-gain of mathematical literacy skills in the experimental and control classes

Figure 3 demonstrates a discernible enhancement in students' mathematical literacy proficiency following the implementation of the Needham learning model, augmented by the GeoGebra application, in the context of systems of linear equations in two variables for eighth-grade students at State Junior High School 8 Singkawang.

Table 7. Recapitulation of n-gain calculation results

Class	N-Gain Score	Category
Experiment	0,65	moderate
Control	0,32	moderate

Independent Two Sample t-Test of Mathematical Literacy Skills

Based on the normality and homogeneity tests, it is evident that the post-test scores of the experimental and control classes are normally distributed and exhibit equal or homogeneous variances. Consequently, to ascertain the equality of the mean scores of the two classes, an independent two-sample t-test was conducted, as illustrated in Table 8.

Table 8. Independent t-test of mathematical literacy skills

Description	Class Experiment and control
dk	48
α	5%
t_{count}	3.243
t_{table}	2.01

Table 8 presents the results of an independent two-sample t-test, indicating a calculated t-value of 3.243 and a t-value from the t-distribution table of 2.01. Since the calculated t-value exceeds the t-value from the t-distribution table (3.243 > 2.01), the alternative hypothesis is accepted, and the null hypothesis is rejected. Table 9 provides the processed data of pretest and posttest scores of mathematical literacy skills for both the experimental and control classes. Based on Table 9, the obtained two-tailed significance value (sig) is 0.002, which is less than the alpha level (α) of 0.05. Consequently, the null hypothesis (Ho) is rejected at the 5% significance level. Therefore, the improvement in mathematical literacy achieved through the Needham model, facilitated by the GeoGebra application, demonstrates a statistically significant difference. This suggests that the enhancement in students' mathematical literacy proficiency through the

Needham model, supplemented by the GeoGebra application, surpasses that of students taught using the direct instruction model.

Table 9. Independent samples test of mathematical literacy skills

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig.(2-tailed)
Mathematical Literacy	Equal variaces assumed	.225	.615	3.243	48	.002
	Equal variances not assumed			3.277	47.249	.002

The Implementation of the Needham Learning Model Assisted by the GeoGebra Application on the Topic of Systems of Linear Equations in Two Variables

The observation sheet for the Needham learning model assisted by the GeoGebra application in this study aims to ascertain the extent of implementation of the Needham learning model supported by GeoGebra in the experimental class. The observation was conducted by an observer, a mathematics teacher at SMP Negeri 8, with the primary focus on the application of the Needham learning model during two sessions in the experimental class. The observed aspects encompassed the stages of learning activities in accordance with the Needham model syntax, students' level of engagement, teacher involvement in the guidance process, and the utilization of the GeoGebra application as a supporting learning medium. The results of the percentage calculation of the implementation of the Needham learning model assisted by GeoGebra can be found in Table 10.

Table 10. Summary of the percentage of implementation of the needham learning model facilitated by the GeoGebra application

Needham's Teaching Model	Lesson		Category
	1	2	
	92,37%	96,85%	Excellent

As evidenced by the data presented in Table 10, the implementation of the Needham learning model facilitated by the GeoGebra application achieved a remarkable 92.37% proficiency in the initial session, subsequently improving to 96.85% in the subsequent session. Both outcomes were deemed exceptional. This notable increase signifies enhanced student engagement, streamlined learning processes, and a more effective utilization of the GeoGebra application. Consequently, it can be conclusively asserted that the application of the Needham model in the teaching of Systems of Linear Equations in Two Variables within the experimental class demonstrated exceptional success.

Improvement of Students' Literacy Skills through the Needham Learning Model Assisted by the GeoGebra Application on the Topic of Systems of Linear Equations in Two Variables

The findings of this study indicate that students taught using the Needham learning model, supported by the GeoGebra application, exhibited a higher improvement in their mathematical literacy skills compared to those taught through direct instruction. Consequently, the Needham learning model, when complemented by GeoGebra, can effectively enhance students' mathematical literacy. These findings align with the study conducted by Khotimah (2018), which demonstrated that the Metacognitive Guidance approach, supported by GeoGebra, significantly improved students' mathematical literacy compared to conventional instruction. This study employed a pretest-posttest design with a non-equivalent control group and revealed that students who received the treatment demonstrated a greater improvement in mathematical literacy.

In accordance with the findings of Fitriani et al. (2023) it was observed that students taught using the Problem-Based Learning (PBL) model, supported by GeoGebra, exhibited a greater improvement in mathematical literacy compared to those taught through conventional instruction. Data analysis using the Mann-Whitney U test revealed a statistically significant difference between the two groups. These results are further corroborated by the study of Widyawati et al. (2023), which indicated that the implementation of the 7E learning cycle model, supported by GeoGebra, had a positive impact on students' conceptual understanding in mathematics. While the primary focus of that study was conceptual understanding, the improvement in this aspect correlated with the overall enhancement of mathematical literacy. Furthermore, these findings are supported by the research of Puspita et al. (2022), which found that the integration of GeoGebra in problem-solving-based learning had a positive impact on students' mathematical literacy and conceptual visualization skills.

This study further corroborates previous findings suggesting that the utilization of GeoGebra within constructivist-based learning models can facilitate students' enhanced comprehension of abstract mathematical concepts in a visually and interactively engaging manner, thereby positively influencing the enhancement of mathematical literacy (Puspita et al., 2022; Yuliana et al., 2023). Consequently, the implementation of the Needham learning model augmented by the GeoGebra application demonstrates a substantial contribution to the improvement of students' mathematical literacy skills, as it provides avenues for concept exploration through the Needham syntax while leveraging GeoGebra's interactive visualization to facilitate students' understanding of abstract mathematical concepts, particularly the subject matter of Systems of Linear Equations in Two Variables.

Furthermore, the findings of this study indicate that the Needham learning model supported by GeoGebra not only augments students' mathematical literacy but also broadens perspectives on constructivist learning theory, which positions students as active participants in the learning process. Additionally, this study offers a significant contribution to the body of research on technology-assisted mathematics learning models, demonstrating that interactive technology can effectively enhance mathematical literacy skills at the junior secondary level, particularly in the instruction of Systems of Linear Equations in Two Variables.

Despite its valuable contributions, this study acknowledges certain limitations that warrant attention. The research exclusively focused on two classes at State Junior High School 8 Singkawang, resulting in a relatively small sample size. Consequently, the external validity of the findings cannot be fully assured. The contextual characteristics of the school, such as the availability of technological facilities, learning culture, and teachers' proficiency in integrating technology-based learning, may significantly influence the success of the model's implementation. Consequently, its application in schools with varying conditions may yield divergent results. As elucidated by Cohen et al. (2018), research findings derived from a specific context are inherently contextual and necessitate replication across diverse settings to validate their consistency. Therefore, the generalization of this study's results should be approached with caution and remain restricted, considering the alignment of target school conditions with the context of this research. To enhance external validity, future studies are recommended to involve a larger number of schools with diverse characteristics, employ a multi-site experimental design, and control external variables such as student readiness, teacher competence, and technological support. Through these measures, the Needham learning model augmented by GeoGebra can be tested in a broader range of educational contexts, enabling its outcomes to be more widely recognized.

Implementation of the Needham Learning Model Assisted by the GeoGebra Application on the Topic of Systems of Linear Equations in Two Variables

The implementation of the Needham learning model, facilitated by the GeoGebra application, was observed in the context of Systems of Linear Equations in Two Variables during this study. An observation sheet was utilized to assess the extent to which the model adhered to the prescribed syntax. The observations were conducted by a mathematics teacher at State Junior

High School 8 Singkawang, who served as the observer during two sessions in the experimental class. The observed aspects encompassed the execution of the learning stages in accordance with the Needham model syntax orientation, exploration, restructuring of ideas, application of ideas in novel situations, and reflection, along with students' active participation in learning activities. The teacher's involvement in providing guidance and the utilization of GeoGebra as a supporting tool to enhance mathematical literacy skills were also noted.

The observation results indicated that the implementation of the Needham learning model assisted by GeoGebra in the first session achieved 92.37%, classified as excellent, and increased to 96.85% in the second session, which also met the excellent criterion. This outcome was attributed to the alignment between the learning model and classroom activities, enabling the Needham model to be implemented effectively. Furthermore, during the learning process, improvements were evident in the optimization of the model stages, the augmentation of students' active participation, and the optimal utilization of GeoGebra to support students' mathematical literacy skills. These findings are consistent with the study conducted by Ramadhani et al. (2024), which demonstrated the effective implementation of the Needham learning model in the topic of fraction multiplication operations.

The theoretical implications of this study suggest that the high level of implementation of the Needham learning model, facilitated by the GeoGebra application, on the topic of Systems of Linear Equations in Two Variables reinforces constructivist learning theory. This theory posits that students are active subjects in the learning process. The syntax of the Needham model, comprising five stages: orientation, exploration, restructuring of ideas, application of ideas in novel situations, and reflection, has been demonstrated to foster a participatory learning environment and encourage students to construct knowledge through direct interaction with GeoGebra and group discussions. These findings align with those of Safitri et al. (2021), who reported that the application of technology-assisted constructivist learning significantly enhances student engagement and conceptual understanding in mathematics. Furthermore, this study expands the perspective of interactive digital learning theory, as elucidated by Kusumah et al. (2020), who emphasized that the utilization of GeoGebra enhances students' visualization skills in comprehending abstract mathematical concepts. Consequently, this research not only reinforces existing theories but also contributes a novel perspective by effectively integrating the Needham model with GeoGebra in mathematics learning, particularly at the junior secondary level. This integration can serve as a reference for developing interactive technology-based learning strategies aimed at improving students' mathematical literacy.

CONCLUSIONS

This study demonstrates that the implementation of the Needham learning model, supported by the GeoGebra application, can enhance students' mathematical literacy skills in the topic of Systems of Linear Equations in Two Variables. Students taught using the Needham learning model, assisted by GeoGebra, exhibited superior mathematical literacy skills compared to those taught through direct instruction, as evidenced by the test value $t_{count} > t_{table}$ 3.57 > 2,01. The improvement was further reflected in the N-Gain score of 0.65 in the experimental class, which falls within the medium category. The integration of Needham's learning phases orientation, exploration, idea restructuring, idea application, and reflection with the interactive visual media of GeoGebra effectively facilitated the transformation of abstract concepts into more concrete and meaningful understanding for students. The model's implementation was also categorized as very good, achieving a score of 92.37% in the first meeting and increasing to 96.85% in the second, indicating its feasibility for classroom application in similar contexts. These findings reinforce the application of constructivist theories proposed by Piaget (1970) and Vygotsky (1978), as well as Mayer's (2009) Cognitive Theory of Multimedia Learning, emphasizing that adapting Needham's (1987) model in combination with GeoGebra serves as cognitive scaffolding to enhance students' mathematical literacy.

Nevertheless, the study has limitations in terms of scope and participant numbers, as it only

involved two classes in a single school. Therefore, generalizing the findings should be approached with caution, considering contextual factors such as technological infrastructure, learning culture, and teacher competencies. The practical implication of this study is that mathematics teachers are encouraged to integrate instructional phases that promote students' knowledge construction with interactive visual media to clarify abstract concepts. The application of the Needham model supported by GeoGebra should be adapted to students' readiness, available technological resources, and the characteristics of the subject matter to ensure optimal learning outcomes.

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