Kognitif
Jurnal Riset HOTS Pendidikan Matematika
Volume- 5 No- 4 Page 1533 – 1549
ISSN 2776-9704 P-ISSN 2776-9984
https://doi.org/10.51574/kognitif.v5i4.3934

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How to cite: Noprisa, N., & Suryatul, A. A. (2025). Calculus Learning Using an Epidemiological Influenza Mathematical Model Based on STEM to Enhance Mathematical Literacy Skills. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *5*(4), 1533–1549. https://doi.org/10.51574/kognitif.v5i4.3934

To link to this artcle: https://doi.org/10.51574/kognitif.v5i4.3934

Opened Access Article

Published Online on 12 November 2025

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Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i4.3934 Volume 5, No 4, October - December 2025, pp. 1533– 1549

Calculus Learning Using STEM Based Epidemiological Influenza Mathematical Model to Enhance Mathematical Literacy Skills

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Article Info

Article history:

Received Oct 03, 2024
Accepted Nov 07, 2025
Published Online Nov 12, 2025

Keywords:

Calculus Learning
Mathematical Literacy Skills
Mathematical Model
STEM

ABSTRACT

Considering the growing importance of mathematical literacy in the 21st century, this study provides an initial insight into improving future STEM-based learning models in mathematics education. The research aims to describe students' mathematical literacy skills as a foundation for enhancing STEM-oriented instruction in higher education. The participants were students of the Mathematics Education Study Program enrolled in a Calculus course at a university in Lampung, Indonesia. Data were collected through a mathematical literacy test and a student response questionnaire. Data were analyzed using an independent sample t-test to identify students' strengths and weaknesses in mathematical literacy. The results show that students' mathematical literacy remains low. The average score was 20.67, with nearly half of the students (46.67%) scoring below the mean. The highest achievement was found in the problem formulation indicator (57.78%), followed by reasoning (49.33%), interpretation and representation (46%), and application (38.33%) as the lowest. These findings suggest that students are relatively capable of formulating mathematical problems but struggle to interpret, represent, and apply them in real-life contexts. Overall, students tend to focus on procedural calculations rather than meaningful connections between mathematics and real situations. Therefore, STEM-based learning innovations are needed to strengthen conceptual understanding and problem-solving skills. The positive student responses indicate that the approach used in this study successfully fostered engagement, motivation, and deeper mathematical literacy.

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Introduction

This research is motivated by the fact that Indonesian students' mathematical literacy scores are consistently below those of other countries (PISA, 2022; *PISA 21st-Century Readers: Developing Literacy Skills in Digital Word*, 2021). In fact, mathematical literacy is one of the key competencies that the Indonesian government seeks to develop in students (Anisa et al., 2020; Habibi & Suparman, 2020). The assessment indicators measured are: 1) understanding, which is classified as low; 2) creating mathematical models, using concept-fact-object, interpreting, and evaluating, which are in the very low category. Mathematical literacy is the ability of a person to use, interpret, and communicate mathematics in various everyday life contexts, not just about being able to calculate, but more about how a person understands real world problems and solves them using a mathematical approach (Hardianti & Desmayanasari, 2022a; Lestari et al., 2025). There are six indicators of mathematical literacy skills: formulation/assumption skills, interpretation skills, representation skills, calculation/reasoning skills, application/analysis skills, and communication skills. These six indicators support a person in developing mathematical literacy skills (Bolstad & Hedi, 2020; Gene & Kursat Erbas, 2019). This becomes an urgency in this research, because students who have good literacy skills can meet the demands of 21st-century skills and compete globally (Habibi & Suparman, 2020; Nugroho et al., 2024).

Based on preliminary studies, several problems were found, including: 1) students have difficulty applying the concepts of differentiation, facts, procedures, and reasoning from the concept of differentiation; 2) students have difficulty interpreting, using, and evaluating the results from the concept of differentiation; 3) students have difficulty applying the concepts of integration, facts, procedures, and reasoning from the concept of integration; 4) students have difficulty interpreting, using, and evaluating the results from the concept of integration; 5) students have difficulty formulating situations mathematically.The integration of STEM with contextual modeling is very close because STEM requires the practical application of concepts from science, technology, engineering, and mathematics, thus needing relevant real-world contexts for deep understanding. Contextual modeling provides a framework for students to construct and test mathematical and scientific models of real-world phenomena, helping to connect STEM theory and practice. This approach develops critical, analytical, and creative thinking skills in cross-disciplinary problem-solving. NCTM (National Council of Teachers of Mathematics) also explicitly emphasizes that STEM education must be built on a strong foundation in mathematics. They consider mathematics as the core of STEM education because students' success in STEM fields heavily depends on a deep mastery of mathematics and the development of mathematical thinking. The following Figure 1 is a diagram illustrating the integration of STEM, Calculus, and Mathematical Literacy.

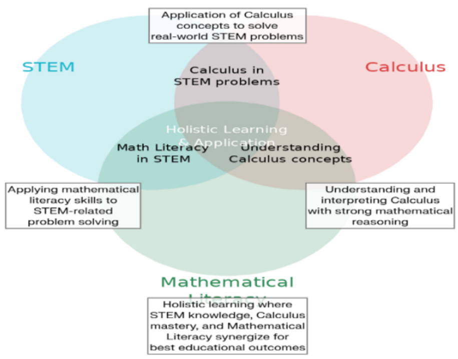

Figure 1. STEM, Calculus and Math Literacy Integration

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The overlap between STEM and Calculus represents the application of calculus concepts to solve real-world STEM problems. The intersection of Calculus and Mathematical Literacy highlights the deep understanding and interpretation of calculus through strong mathematical reasoning. The overlap between STEM and Mathematical Literacy reflects the use of mathematical literacy skills in STEM related problem solving. The central intersection where all three areas overlap shows the most holistic learning and application, where STEM knowledge, mastery of calculus, and mathematical literacy synergize for the best educational outcomes. The elements of science (S), technology (T), and engineering (E) in this research are integrated into the concept of calculus so that students who take calculus courses can identify and understand its applications in real life.

Innovation in learning is needed to teach calculus in a meaningful and enjoyable way, namely by using a STEM based epidemiological flu mathematical model supported by the Matlab numerical computing platform. Students can create interactive simulation applications using Matlab to understand the concept of flu epidemiology, display graphs of changes in the population of flu spread and can modify parameters and see the impact of flu disease spread. Learning with this model will be enjoyable because students can construct their understanding through contextual problems (Fathoni et al., 2020; Muslimah & Pujiastuti, 2020). This will show students that studying calculus is not only about mathematical concepts but is closely related to real-life problems. It can also create meaningful learning and become an opportunity for the development of knowledge in the fields of mathematics, technology, and mathematics education (A. Czocher et al., 2019; Hourigan & M. Leavy, 2020; Irma Novianti Davidi et al., 2021)

A mathematical model involves modeling real world problems or events encountered by society to represent these problems/events mathematically and then determine their solutions. Influenza spread model $SV1I1I2R$ by Ashrafur Rahman & Zou (2011) in Noprisa & Aryati (2018) where the population susceptible to the flu (S) against the first virus strain ($I1$) is given vaccination ($V1$), which results in the emergence of a second virus strain ($I2$) that is a genetic derivative of the first virus strain with a more severe virulence effect, and the recovered population (R).

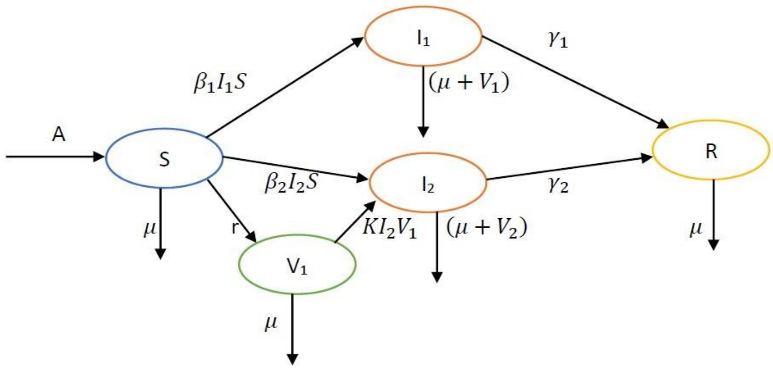

Figure 2. Mathematical Model of Influenza Epidemics $SV1I1I2R$

The mathematical model of flu epidemiology in Figure 2 is formulated into a system of differential equations to investigate the global dynamics of disease spread using concepts from calculus learning, namely the differential and integral concepts. Relevant research on mathematical literacy using mathematical models is still very limited. Previous research on mathematical literacy using epidemiological models has been successfully developed to evaluate HOTS abilities in the mathematics curriculum (Nkululeko Mazibuko & Maharaj, 2024). However, there has not been any research of this kind applied to calculus learning. This becomes a novelty of applying a real epidemiological model in a calculus classroom to develop mathematical literacy. Furthermore, although STEM research and mathematical literacy have been quite extensive, the specific focus on calculus as part of STEM remains very limited and constitutes a significant gap in current mathematics education literature. Therefore, this study aims to design and implement a STEM based learning environment using an epidemiological influenza model to enhance students' mathematical literacy in the context of calculus concepts such as differentiation and integration.

Method

Following the Table 1 is an explicit map of the integration of STEM components in calculus learning activities using the epidemic flu model: $SV_1I_1I_2R$.

Table 1. STEM Component Map of Student Engagement in Calculus Learning

STEM Components	Student Involvement in Calculus Learning	Activities
Science	Understanding the basic concepts of flu epidemic using differential and integral methods, which involves analyzing the virus incubation period, the rates of susceptible and infected populations, vaccine effectiveness, and the mortality rate	Reading flu disease spread models, calculating the incubation period, and discussing the effects of vaccines
Technology	Using mathematical software, specifically MATLAB for interactive simulations of applying derivatives and integrals	Running flu population dynamics simulations with MATLAB and visualizing changes in population graphs
Engineering	Graphical analysis using calculus with differentials and integrals to observe the dynamics of flu spread	Designing a phase diagram of flu spread, using graphs to identify the critical points in flu disease dynamics
Mathematics	Understanding the theory and techniques of differential and integral calculus: rules of derivatives and integrals, applications of derivatives and integrals, limit, and mathematical modeling related to the spread of flu	Constructing and solving mathematical models, learning derivative and integral formulas, performing analytical calculations

The scoring guidelines refer to the AAC&U (Association of American Colleges & Universities) rubric, focusing on the development of quantitative reasoning and mathematical literacy. The process of adapting the AAC&U rubric to the context of a calculus class involves the following Table 2.

Table 2. Adjustment of the AAC&U Rubric in calculus instruction

No	Indicator	Description
1	Formulation	Transforming the context of an influenza epidemic into a mathematical model
2	Interpretation	The ability to interpret the dynamics of mathematical models (reading diagrams, population changes, identifying variables and parameter values)
3	Representation	Transforming mathematical models into differential and integral concepts
4	Calculation	Perform differential and integral mathematics operations
5	Application	Presenting and connecting mathematical results with policies or strategies for disease management clearly, both in writing and orally

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The stages of classroom learning implementation are: 1) apperception: the initial stage of learning to connect new material with the knowledge or experiences students already have before a pre-test; 2) rubric implementation: students complete calculus assignments (for example, mathematical modeling problems using integrals and derivatives from real-life contexts) with the help of Matlab; 3) reflection: the lecturer reviews the results and discusses what has been done and what needs improvement; 4) Assessment: the lecturer evaluates the students' work using the rubric. The timeline for the implementation of calculus learning in the classroom can be seen in Table 3.

Table 3. Implementation on Timeline

Week	Activities
1-2	Lecturers develop & adapt the rubric
3	Apperception and giving the pretest questions
4-5	Reinforcement the material and doing calculus assignments
6-7	Reinforcement of materials and completion of calculus assignments using Matlab
8	Self-assessment/post-test and group reflection

Type of Research

This research employed a quasi-experimental design with a non-equivalent pretest-posttest control group design using pre-test data (test before treatment) and post-test data (test after treatment) (Arikunto, 2021; Rachman et al., 2024). The treatment in the experiment class used STEM based epidemiological flu mathematical model supported by the numerical computing platform Matlab, while the control class used conventional learning.

Table 4. Research Design

Group	Pre-test	Treatment	Post-test
Experiment Class	O_1	X	O_2
Control class	O_1		O_2

Description:
O1 = Initial test before the learning begins (pre-test)
O2 = Final test after the learning is completed (post-test)
X = Given treatment using STEM based epidemiological flu mathematical model $SV_1I_1I_2R$

Samples

The sample of this research consists of students from mathematics education study program who are enrolled in calculus courses at a university in Lampung. The population in this research consisted of 55 students. The sample was selected using purposive sampling with the number of students in the control group being 11 students and the experimental group being 15 students. The control group and the experimental group were equivalent at the beginning of the study based on the students' prior knowledge, meaning that students must have a basic understanding of algebraic concepts, functions, and the real number system.

Instruments

The instruments in this research consist of test instruments and student response questionnaire instruments. The mathematical literacy test instrument consists of 5 items containing mathematical literacy indicators on the concepts of differential and integral. Empirical validation of the test item instruments was conducted through trials with students who had taken calculus courses, particularly on differential and integral material, as the criteria for respondents. The results of the empirical validation and reliability of the test item instruments can be seen in Table 10 and Table 11.

The mathematical literacy indicators refer to the quantitative literacy rubric: AAC&U (American Colleges Universities, 2025). Then, they are tested with the taught learning indicators as well as the accuracy of the content to measure mathematical literacy skills. Suggestions from the validators are used as a basis for improving the instruments. Then, the questions are tried out on students who have completed differential and integral material in order to calculate validity scores, reliability, question discrimination power, and question difficulty level. Scoring is done using the modified AAC&U with the maximum score for each item being 2 (score 0 if unable to provide a response, score 1 if able to respond but with errors, and score 2 if able to respond correctly). The grid of the mathematical literacy test instrument is presented in Table 5.

Table 5. Mathematical Literacy Grid

Question Element	**Mathematical Literacy Indicator**	**STEM Learning**	**Epidemic Flu Mathematical Model $SV_1I_1I_2R$**	**Question Number**
Function defined by the domain	Formulation/Assumption Interpretation Representation Reasoning/Calcuation Application/Analysis	Mathematics Science	$SV_1I_1I_2R$	1
General solution of the rate of change of the population infected with the first virus strain	Formulation/Assumption Interpretation Representation Reasoning/Calcuation	Mathematics Science	$SV_1I_1I_2R$	2a
Calculate the population infected with the first virus strain over a certain period	Formulation/Assumption Interpretation Representation Reasoning/Calcuation Application/Analysis	Mathematics Science	$SV_1I_1I_2R$	2b
Interactive simulation of an epidemic flu model using Matlab	Interpretation Representation Reasoning/Calcuation Application/Analysis	Mathematics Science	$SV_1I_1I_2R$	3a
How is that mathematical model applied in infection management?	Interpretation Representation Reasoning/Calcuation Application/Analysis	Science Technology Engineering Mathematics	$SV_1I_1I_2R$	3b

The student response questionnaire consists of 50 questions covering interest, opinions, and perceived benefits after participating in calculus learning using STEM based epidemiological flu mathematical model $SV_1I_1I_2R$, supported by the Matlab numerical computing platform. The questionnaire, once prepared, was subsequently validated by experts.

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The questionnaire uses a likert scale. The developed questionnaire follows the guidelines outlined in Table 6.

Table 6. Questionnaire Grid for Student Responses

No	Student Behavior	Indicator
1	Regarding learning	• Showing interest in attending lectures • Expressing opinions about lectures
2	Regarding content material	• Showing interest in the course material • Shows the benefits of the course material
3	Regarding the question	• Expressing opinions on lecture/course questions • Showing the benefits for college assignments

Procedures and Analysis

The data collection technique used a testing method (Arikunto, 2021; Rachman et al., 2024). The test was carried out using research instruments consisting of a mathematical literacy test and a questionnaire on students' responses to learning. The data analysis technique used independent sample t-test (Arikunto, 2021; Rachman et al., 2024). This aims to determine the significance of the improvement in students' learning outcomes from before using the learning innovation implemented in the research to after the learning innovation was carried out. The data is said to show a difference if p-value < α (0,05). The t-test is conducted after meeting the assumptions of normality and homogeneity. The normality test is carried out using the Shapiro-Wilk test with the criterion of rejecting H_0 if p-value ≥ α (0,05) and the homogeneity test was conducted using Levene's test with the criteria to reject H_0 if p-value ≥ α (0,05). Furthermore, to see the extent of the improvement in each student's learning outcomes, an analysis was conducted on the score improvement in the form of the difference between the pre-test and post-test scores using the N-Gain test, calculated with the following equation.

$$\mathrm{N-Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}}$$

The interpretation of N-Gain values can be seen in Table 7.

Table 7. N-Gain Interpretation

N-Gain	Interpretation
0,70 ≤ G ≤1,00	High increase
0,3 ≤ G < 0,70	Medium increase
G < 0,3	Low increase

The analysis of student response questionnaire data was conducted using descriptive statistics (Arikunto, 2021; Rachman et al., 2024). Next, the percentage of student response was identified, categorizing them as very positive, positive, somewhat positive, or not positive. The scoring guidelines for the student response questionnaire refer to Table 8.

Table 8. Guidelines for Scoring Student Responses on the Questionnaire

Response	Criteria
85% ≤ Response	Very Positive
70%≤ Response< 85%	Positive
50% ≤Response< 70%	Somewhat Positive
Response< 50%	Not Positive

To determine the extent of the effect of learning calculus using the epidemic flow model, further testing was carried out, namely by determining the effect size value using Cohen's D - formula as follows.

$$D = \frac{\bar{x}_{Eksperimen} - \bar{x}_{Kontrol}}{S_{Pooled}}$$

The criteria for testing effect size in social and humanities research typically refer to the standards of Cohen with the effect size categories as follows Table 9.

Table 9. D-value Interpretation

D value	Interpretation
0,00 ≤ D ≤ 0,20	Small effect
0,21 ≤ D ≤ 0,50	Small effect to Medium effect
0,51 ≤ D < 1,00	Medium effect
D ≤ 1,00	Large effect

Results

Analysis of Students' Mathematical Literacy Test Items

Mathematical literacy ability is illustrated based on students' answers to the mathematical literacy ability test questions. The mathematical literacy ability test questions were developed from the indicators of mathematical literacy ability as described in the research method. The development of the mathematical literacy ability test questions was adjusted to the material being taught at the time the research was conducted, namely differential and integral material. The test questions consist of 5 essay questions that had previously been trialed. The test questions are piloted to ensure that the developed items meet the criteria of a good test, namely being valid and reliable.

Then, they are administered in alignment with the taught learning indicators and content accur acy to measure mathematical literacy skills. The test items are tried out on students who have covered differential and integral material to determine the validity and reliability of the questions. An item is considered valid if it meets the test criteria, namely if $r$count ≥ $r$table (Arikunto, 2021; Rachman et al., 2024). Table 10 shows the results of the validity test of the mathematical literacy ability test items.

Table 10. Results of the Validity Test of Mathematical Literacy Questions

Question Number	r Count	r Interpretation	r Table	Information
1	0,61	Medium		Valid
2a	0,94	Very High		Valid
2b	0,72	High	0,44	Valid
3a	0,89	High		Valid
3b	0,94	Very High		Valid

The item analysis results in Table 10, show that the mathematical literacy test items that were trialed are valid and can therefore be used to assess students' mathematical literacy skills. All items are considered valid because the item total correlation (r) exceeds the criterion threshold $r$table = 0,04. The scores indicate that 3b and 2a are the highest, 2b and 3a are at a high level, and 1 is at a medium level. This means that the questions already have a balanced distribution of difficulty levels. There are basic items to confirm concept mastery, and there are items that encourage higher order reasoning. Reliability test of the questions was conducted

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using the test criteria proposed by Guilford in (Arikunto, 2021; Rachman et al., 2024). The calculation results of the reliability coefficient are presented in Table 11.

Tabel 11. Results of the Reliability Test of Mathematical Literacy Questions

r	r Table	r Interpretation	Information
0,72	0,44	High	Significantly reliable

Based on Table 11, the tested mathematical literacy questions are reliable and meet high reliability criteria. This means that these questions can yield consistent measurement results over time. Due to their high reliability, the tested mathematical literacy questions can be used to assess students' mathematical literacy skills.

Analysis of Students' Mathematical Literacy Skills

The results of the normality test in Table 12, indicate that the N-Gain data for both classes are normally distributed, as the significance values (Sig.) for the experiment class is 0.066 and for the control class is 0.072, which are higher than the set significance level, α = 0.05.

Tabel 12. Test of Normality

Shapiro-Wilk		
	Class	**Sig**
N-Gain	Exsperiment	0.066
	control	0.072

Next, to examine the similarity of variance between groups, a homogeneity test was conducted using Levene's test, which is presented in Table 13.

Tabel 13. Test of Homogenity

Levene Statistic		
	Class	**Sig**
N-Gain	Exsperiment and Control	0.991

The results of the Homogenity test in Table 13, indicate that the N-Gain data for both classes homogeneous variance, as the significance values (Sig.) is 0.991, which are higher than the set significance level, α = 0.05. Further analysis using an independent sample t-test is justified (Arikunto, 2021; Rachman et al., 2024).

Table 14. Independent Sample T-Test

		Sig(2-tailed)
N-Gain	Equal Variances Assumed	0.394
	Equal Variances Not Assumed	0.402

Based on Table 14, the results of independent sample t-test on students' N-Gain scores in the experiment class and the control class obtained a significance value (Sig. 2-tailed) of 0.394. These values are greater than the established significance threshold, which is α = 0.05. Therefore, it can be concluded that there is no difference class. Nevertheless, based on improvement in each student's learning outcomes, an analysis was conducted on the score increase in the form of the difference between the pre-test and post-test scores using the N-Gain test. Thus, an improvement in learning outcomes before and after the treatment can be seen in Table 15.

Table 15. N-Gain Criteria

Student code (S)	N-Gain	Information
S1	0.05	Low
S2	0.36	Medium
S3	0.33	Medium
S4	-0.17	Low
S5	0.07	Low
S6	0.16	Low
S7	0.17	Low
S8	-0.30	Low
S9	0.09	Low
S10	0.25	Low
S11	0.05	Low
S12	0.31	Medium
S13	0.10	Low
S14	0.32	Medium
S15	0.24	Low

Students' mathematical literacy skills in Table 15 are dominated by low and medium levels, and there are no students who truly master mathematical literacy skills at a high level. The average N-Gain is 0.13, which is classified as low. Students do experience improvement from the pre-test to the post-test, but the increase is not significant. This is supported by an effect size of 0.33, categorized as having a small effect. This means there is an increase, but it is not significant. Meanwhile, the achievement of students' mathematical literacy skills for each mathematical literacy skill indicator can be seen in Table 16.

Table 16. Students' Mathematical Literacy Indicator Achievement

No	Indicator	Achievement	Maximum	Percentage of Achievement
1	Mathematical formulation	52	90	57.78
2	Interpretation	69	150	46.00
3	Representation	69	150	46.00
4	Mathematical reasoning	74	150	49.33
5	Application	46	120	38.33

Based on Table 16, the average score for students' mathematical literacy indicators is 47.49%. This shows that students' mathematical literacy ability is still in the low category. Students are more proficient in the formulation aspect compared to the applicative and reflective aspects (interpretation, representation, and realworld application). The mathematical formulation indicator, the achievement is 57.78%, the highest among all other indicators. This indicates that students are more capable of formulating problems in mathematical terms than in other aspects. Additionally, the achievement in the mathematical reasoning indicator is 49.33%. Mathematical reasoning reflects students' ability to think logically, construct arguments, and draw conclusions. The indicators of interpretation & representation have the same achievement level of 46%. This indicates that students still have difficulty interpreting the results of solutions and transforming ideas into mathematical representations (graphs, tables, diagrams). Meanwhile, the application indicator shows the lowest achievement, at 38.33%, which is a major problem in mathematics education at the university level.

The data shows that although students are fairly good at formulating mathematical problems, they are still weak in interpreting results, representing mathematical concepts, reasoning, and especially applying mathematics in real-life situations. Students tend to stop at

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calculations but rarely connect them back to real-world contexts. Relevant research indicate a similar trend (Rahmawati et al., 2022).

This is caused by many assignments/problems still being theory based or abstract, so students are not accustomed to connecting mathematics with everyday life situations (Riezky Pratiwi et al., 2022; Slamet Kusumawardana & Dintarini, 2021). Students are given calculation problems (formulations), but few are asked to interpret the results in realworld contexts or to convert the forms of representation into graphical, verbal, and diagrammatic forms (Aldi Hidayatulloh et al., 2025).

Meanwhile, the results of the student response survey in Table 17 showed an average score above 80. This indicates that students responded very positively to the learning, materials, and questions provided. Affectively, students demonstrated very positive interest, motivation, and acceptance toward learning activities using STEM based epidemiological flu mathematical model, supported by the Matlab numerical computation platform.

Table 17. Questionnaire Grid for Student Responses

No	Student Behavior	Indicator	Score
1	Regarding learning	• Showing interest in attending lectures	85,16
		• Expressing opinions about lectures	84,25
2	Regarding content material	• Showing interest in the course material	87,81
		• Shows the benefits of the course material	84,06
3	Regarding the question	• Expressing opinions on lecture/course questions	86,67
		• Showing the benefits for college assignments	82,5

Discussion

Based on the results of relevant research (Mujib et al., 2020; Rahmawati et al., 2022), STEM based learning is more effective than nonSTEM learning in enhancing students' mathematical literacy skills. Other research (Rahmawati et al., 2022) demonstrate that STEM based learning improves performance in reasoning and formulation indicators, yet innovation is still needed to optimize its application in real-world contexts. This is further confirmed by the results of this research in Table 15, with the average N-Gain is 0.13 dan value of effect size is 0,33. Which show an increase in students' mathematical literacy skills, although it is not significant. In Table 16, students who learned calculus through a STEM based epidemiological flu mathematical model, the achievements in the reasoning and formulation indicators are better than the other three indicators (interpretation, representation, and application). Reasoning dan formulation ability is greatly influenced by the understanding of basic mathematical concepts and the skill to model realworld problems in the form of equations or mathematical symbols. The abilities of representation, interpretation and application depend on students' experience and practice in relating mathematical concepts to various visual forms and contexts.

The pattern of increasing mathematical literacy is consistent with findings that the STEM approach is generally effective in developing students' mathematical literacy skills. This approach enhances critical thinking, problem-solving, and mathematical communication skills, which are important dimensions of mathematical literacy (Nur Savitri et al., 2024). The improvement of mathematical literacy is also related to students' ability to connect mathematical concepts with real-world phenomena (such as the spread of the flu) and to use technology (simulation/modeling) that reinforces conceptual and applicative understanding of calculus and motivates them to learn more actively (Rahmawati et al., 2022).

The $SV_1I_1I_2R$ mathematical model is a model that utilizes a system of differential equations to predict the dynamics of the simultaneous spread of two influenza virus strains within the human population. The $SV_1I_1I_2R$ mathematical model helps in understanding how a single vaccination affects the spread dynamics of both new and old virus strains simultaneously and guides towards more effective control strategies (Noprisa & Aryati, 2018). Therefore, it requires an understanding across mathematical concepts, which poses a challenge for students in formulating and solving these problems which is one of the main processes in mathematical literacy. Thus, mathematics is not seen as an empty abstraction but rather as a tool for solving real problems.

The STEM approach in this model integrates science (flu diseases and epidemiological processes), technology (simulation and modeling using MATLAB), engineering (control and vaccination strategies), and mathematics (differential, integral, and systems of differential equations). This helps students develop multidisciplinary skills and see the connections between fields, which is an important aspect of mathematical literacy involving the integration of knowledge and systemic thinking. This process involves high-level mathematical competencies such as understanding functions, variables, and change, so the mathematical literacy process occurs at both operational and conceptual levels. The flu epidemiology mathematical model does not stop at mathematical problem-solving but also extends to interpreting simulation results for disease control and mathematical decision-making. Students are trained to communicate mathematical understanding in an applied context, enhancing communication skills and conceptual understanding in mathematical literacy.

Difficulty in understanding the basic concepts of differential calculus and integral calculus is a major obstacle to achieving mathematical (Aini Asyhara et al., 2025). The researchs (Nurlaili et al., 2022; Silvia et al., 2020) highlight the importance of strengthening differential calculus skills as a foundation before moving on to integral calculus and multivariable calculus to ensure a significant improvement in student learning outcomes. Mastery of differential calculus concepts is a key requirement before students begin studying integral calculus, as integration is theoretically the inverse process of differentiation (Fundamental Theorem of Calculus). Therefore, a strong understanding of limits, derivatives, and their applications is a very important foundation. The necessary mathematical literacy skills involve mastering the concepts of functions, limits, continuity, as well as the ability to formulate problems, apply derivative concepts and techniques, and interpret results in the context of real-world problems.

Students with a strong command of differential calculus achieve better learning outcomes in integral calculus and multivariable calculus. Conversely, weaknesses in differential calculus can hinder the understanding of integral and advanced concepts (Silvia et al., 2020). Mathematical literacy, which includes the ability to design mathematical models, solve problems, and interpret results, is an indicator of a high level of proficiency. Difficulties in mastering complex mathematical models can obstruct the achievement of mathematical literacy indicators at an advanced level (Diantari Telaumbanua et al., 2024; Nurlaili et al., 2022). Therefore, mastery of the learning outcomes in differential and integral calculus simultaneously makes a significant contribution to the success in learning multivariable calculus or advanced calculus, making these three courses interconnected and prerequisites for one another.The initial competency requirements of students in differential calculus, integral calculus, and multivariable calculus encompass not only basic mathematical conceptual knowledge but also mathematical literacy skills to connect, apply, and interpret these concepts in more complex contexts during advanced calculus learning.

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Students' initial mathematical literacy significantly influences the improvement of their mathematical literacy achievements (Hardianti & Desmayanasari, 2022b; Muslimah & Pujiastuti, 2020). Students' initial abilities affect the learning process and final outcomes. Students who already have a strong foundation in mathematical literacy will find it easier to understand new material, and their improvement in mathematical literacy will be more significant compared to those with low initial abilities (Kurnia Putri Sepdikasari et al., 2025; Nurlaili et al., 2022). The interaction of these factors must be taken into account when designing effective learning strategies to ensure successful enhancement of students' mathematical literacy. Mathematical literacy skills are abilities that require a fairly deep learning process and continuous practice. Therefore, practice and learning that integrate complex mathematical models contextually can improve mathematical literacy by honing critical thinking, reasoning, and the application of mathematical concepts (Kurnia Putri Sepdikasari et al., 2025; Nur Savitri et al., 2024).

Nevertheless, the pedagogical implications of innovating calculus learning using a STEM-based epidemiological flu mathematical model show that STEM integration significantly facilitates the enhancement of students' mathematical literacy. Based on studies on the effectiveness of STEM learning, the reported effect sizes for creative and critical thinking abilities range from 0.935 to 1.074 (large effect category), indicating a very positive impact on learning outcomes and mathematical skills (Rahmawati, 2022). Furthermore, there is a positive perception among students towards this method because the STEM approach makes learning more contextual, interactive, and integrated, which motivates active engagement and critical as well as reflective (metacognitive) thinking during the learning process. Although there are limitations, such as the need for a relatively high level of cognitive readiness among students to understand complex epidemiological mathematical models, as well as time and resource constraints in implementing STEM-based learning. In addition, not all students have a strong STEM background, so support needs to be strengthened.

The researchs (Diantari Telaumbanua et al., 2024; Intan Putri & Widi Wardani, 2024) show that although there is a positive correlation between attitude or motivation and mathematical literacy skills, this does not necessarily mean that a significant improvement in these skills will be seen in a short time because these abilities are complex cognitive and functional skills. If students start with low initial abilities, even if the response results are positive, the improvement will appear small statistically. Therefore, students' responses in the questionnaire, which reflect a very positive attitude towards the learning process, materials, and given questions, do not directly result in a significant increase in mathematical literacy skills.

Conclusion

Innovation in learning calculus using a STEM based epidemic flu mathematical model has great potential to enhance students' mathematical literacy through contextual, integrative, and reflective learning, provided it is supported by appropriate learning design in accordance with the latest learning theory framework. Calculus learning using the epidemiological flu mathematical model naturally integrates STEM elements (Science, Technology, Engineering, Mathematics). The flu epidemic model contains aspects of science (the disease and its spread), technology (modeling and simulation using MATLAB software), engineering (system analysis and practical solutions), and mathematics (application of calculus and differential equations). The epidemiological flu mathematical model used as an innovation in calculus learning involves mathematical modeling activities that align with the mathematical process cycle of PISA. The PISA process cycle emphasizes several important stages: formulating real-world problems into mathematical forms, using mathematical concepts and procedures to solve these problems, and interpreting the results in real-world contexts. The flu epidemic model provides a concrete and relevant context as a real-world problem that is then formulated into a mathematical model (differential equations), solved using calculus concepts, and the results are interpreted to understand the spread of the disease. This reinforces the learning process in mathematics that is not merely procedural but based on applied contexts and deep mathematical reasoning, as emphasized in the PISA 2022 mathematical literacy framework.

Practically, the implemented learning innovation shows an improving trend. There is an increase in students' mathematical literacy abilities, although it has not yet risen significantly. This study provides an initial insight into refining the STEM based learning model in the future. The learning innovation in this study is a new adaptation that still requires reinforcement so that it can renew or revolutionize the learning process and promote the creation of more effective interventions by providing new approaches and tools in mathematical literacy learning. Therefore, STEM integration must be designed to connect mathematical concepts with other complex contexts, thereby strengthening the mathematical literacy essential for 21st-century problem-solving. Recommendations for further research include: 1) the development of HOTS instruments using the STEM based mathematical model $SV_1I_1I_2R$ to enhance students' mathematical literacy skills; 2) analysis of other variables related to students' mathematical literacy concerning learning innovations using the STEM based mathematical model $SV_1I_1I_2R$ to improve students' mathematical literacy skills such as aspects of character development, so that learning innovation is not limited only to cognitive aspects; 3) Further Didactical Design Research (DDR) at the university level as part of curriculum and modern pedagogy development; 4) Conduct multi-cohort or cross-institutional replication, for example using different student groups or in different institutions; 5) Examine long-term retention and transfer of literacy skills to assess the long-term effectiveness of learning and the practical impact of the literacy taught; 6) Employ qualitative inquiry to explore students' reasoning processes during modeling to gain an in-depth understanding of how students think, organize concepts, and solve problems as they engage in mathematical modeling, using data collection techniques such as in-depth interviews, participatory observation, and case studies that allow researchers to observe and explore students' cognitive processes in detail as they go through the stages of mathematical modeling, from understanding the problem, constructing a mathematical model, to interpreting and reflecting on the solutions found.

Acknowledgments

We would like to express our gratitude to the Directorate of Research and Community Service, Directorate General of Research and Development, Ministry of Higher Education, Science, and Technology of the Republic of Indonesia for providing financial assistance and support in the preparation of this research in 2025.

Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

N. understood the research ideas presented, collected data, analyzed the data, discussed the results, and approved the final version of the work. S.A.A. actively participated in the development of methodological theory and instruments. All authors declare that the final

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version of this paper has been read and approved. The total percentage contribution for conceptualization, drafting, and revising of this paper is as follows: N.: 70%, and S.A.A.: 30%.

Data Availability Statement

The authors state that the data supporting the findings of this study will be made available by the corresponding author, [N], upon reasonable request.

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