



STEM-based Digital Media Oriented Towards Numeracy and Self-regulated Learning in Linear Equation System

Geni Puspita^{1*}, Wahyu Setyaningrum²

^{1*,2}Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

E-mail*: geniuspita.2023@student.uny.ac.id

Abstract

The numerical ability in Indonesia is still low and has an influence on students' academic achievement, including student's problemsolving ability. The purpose of this research was to produce STEM-based digital learning media which can develop students' numeracy and self-regulated learning in the subject of Two-Variable Linear Equation System (SPLDV) for VIII grade and its validation, practicality and effectiveness. The research adopted Research and Development (R&D) model through ADDIE with five main processes including arrays: analyze, design, develop, implement and evaluate. Subjects The subjects of this research were 22 eighth graders at a MTsN in Sleman Regency in the odd semester of academic year 2024/2025. Data were collected using a questionnaire and numeracy test, then analyzed by paired sample t-test and N-gain formula. Results indicated that learning media which was a form of smartphone application was appropriate, feasible and effective with the average numeracy score increase from 36.91 to 79.27 and for self-regulated learning test was from 44.95 to 74.09. The integration of the STEM approach with the self-regulated learning strategy was proven to improve students' numeracy and self-regulated learning. Future study is required to develop the interactive learning media can improve its content and interface and has effectiveness on a wider sample and school level.

Keywords: digital media; numeracy; self-regulated learning; STEM



INTRODUCTION

In order to develop capable students who are prepared to compete at a high level, mathematics education is essential. In addition to helping students master science, learning mathematics fosters the problem-solving abilities needed to keep up with scientific, technological, and innovative advancements (Suratno, Wahono, Chang, Retnowati, & Yushardi, 2020; Utami, Aulia, Permatasari, Taqiyuddin, & Widodo, 2022). One of the key skills gained from studying mathematics is numeracy, or the capacity to apply mathematical knowledge and abilities in daily situations (Minikutty & Mohan, 2021; Palomar, Ramis-Salas, Močnik, Simonič, & Hoogland, 2023). According to this study, Goos, Geiger, Bennison, & Roberts (2015) and Wake (2015), numeracy is the capacity of pupils to apply mathematical ideas, methods, and resources to solve practical issues, analyze data, and reach logical conclusions. The Minimum Competency Assessment (AKM), which ranks numeracy as one of the primary literacy competences, highlights the significance of numeracy in Indonesian education (Ridlo, Ngabekti, Peniati, Isnaeni, & Purwantoyo, 2022).

Numerous studies demonstrate that junior high school pupils in Indonesia still need to enhance their numeracy skills (Andriatna et al., 2024). Indonesian students' math scores decreased from 379 in 2018 to 366 in 2022, according to the Program for International Student Assessment (PISA) 2022 results (OECD, 2023). Additionally, junior high school pupils' numeracy achievement is still in the middle range, according to the 2024 Indonesian Education Report. In particular, 65% of junior high school pupils in public schools achieved the necessary basic competency criteria in numeracy. From just 43.03% the year before, the percentage has risen by almost 21.97%.

Students' low numeracy levels have been noted in previous reports (Rahmawati, Usodo, & Fitriana, 2021; Rakhmawati & Mustadi, 2022; Sari, Zulkardi, & Darmawijoyo, 2021). These studies' findings show that pupils continue to struggle with math problems. They often fail to understand the problem's context, struggle to translate verbal problems into mathematical models, and apply symbols and algebraic operations imprecisely. These difficulties are evident in the example of Two-Variable Linear Equation Systems (SPLDV), which necessitated the use of abstract reasoning abilities to comprehend the ideas of variables, coefficients, and the connections between equations (Juliani, Sudiarta, & Nuadi, 2023).

In addition to cognitive factors, pupils' lack of self-regulated learning abilities also contributes to low numeracy scores. According to Zimmerman (2002), self-regulated learning is essentially the capacity of students to oversee their own learning process, which involves organizing, observing, assessing, and regulating motivation and learning behavior. According to Inayah, Wardono, & Mariani (2024), students who struggle with autonomous learning are typically passive, reliant on their teachers, and struggle to take charge of their education. The inadequate usage of digital media in schools aggravates this issue. Previous research has demonstrated that inadequate teaching practices, such as an excessive dependence on traditional teaching methods and a lack of use of interactive learning resources, are frequently the cause of low numeracy abilities among Indonesian students (Purniawan, Hidayah, & Sukestiyarno, 2022). Despite several attempts to create and utilize interactive learning materials, their application is still subpar. For instance, there is still need for improvement in the use of ICT-based learning materials for mathematics instruction (Budiarti & Triyono, 2020; Possumah & Qohar, 2024)

The STEM (Science, Technology, Engineering, and Mathematics) method is one possible strategy to deal with these problems because it incorporates interdisciplinary ideas in practical settings (Eshaq, 2023; Evans et al., 2021). The goal of STEM education is to apply knowledge to address real-world problems by integrating four disciplines into a single learning unit (Sanders, 2009; Stohlmann et al., 2012). STEM education provides a dynamic approach to studying mathematics by incorporating practical experiments, problem-solving exercises, and real-world applications. This multidisciplinary approach enhances numeracy abilities and fosters a deeper comprehension of mathematical ideas (Eshaq, 2023).

Ibrahim et al. (2024) demonstrates how STEM education significantly improves pupils' quantitative numeracy abilities. The analysis reveals a significant increase in numeracy abilities, proving the value of STEM education in this domain. Furthermore, Kong & Mohd Matore (2021) study demonstrates that kids who engage in STEM-based learning significantly outperform their peers in

mathematics. This demonstrates how STEM education that emphasizes problem-solving can enhance numeracy abilities. According to Lin, Wu, Hsu, & Williams (2021), the Engineering Design Process (EDP) paradigm in STEM enables students to actively experiment and systematically find solutions, which has positive implications for improving numeracy. It has also been demonstrated that integrating STEM with self-regulated learning techniques promotes student autonomy and motivation to learn, both of which are critical for enhancing numeracy (Evans et al., 2021; Harahap, Andayani, & Ekwan, 2025).

Numerous research have demonstrated how well digital learning resources can enhance numeracy (Marthani & Ratu, 2022). Nevertheless, the majority of these innovations do not incorporate the STEM approach, are not interactive, are restricted to specific platforms, and do not support students' self-regulated learning characteristics (Aprilia, Pujiastuti, & Rafianti, 2021; Nofriyandi, Abdurrahman, & Andrian, 2023; Sukmawati, Pramita, Santanapurba, Wiranda, & Utami, 2021; Tuong et al., 2023). In order to increase numeracy in SPLDV material for eighth-grade junior high school students, this study offers a novel solution by integrating the STEM approach with the EDP model and self-regulated learning strategies in a single interactive digital learning medium. With features including subject summaries, instructional videos, numeracy-based tasks, and assessments with immediate feedback, this content is made to be readily accessed via desktop or smartphone devices. In keeping with the demands of the twenty-first century, it is intended that this media will help students become more independent learners in addition to improving their numeracy (Permendikbudristek, 2022).

Based on this background, this study aims to produce valid, practical, and effective STEM-based digital mathematics learning media to improve students' numeracy and self-regulated learning in SPLDV material. This study is expected to contribute to enriching educational literature and practice by showing how the integration of STEM and self-regulated learning through interactive media can improve numeracy skills in a meaningful and sustainable way.

METHOD

This study used the Research and Development (R&D) method with the ADDIE development model, which includes the stages of Analyze, Design, Development, Implementation, and Evaluation (Hidayat, Rohaeti, Hamidah, & Putri 2023). The research subjects were 22 eighth-grade students at one of the MTsN in Sleman Regency in the odd semester of the 2024/2025 academic year, selected using purposive sampling, based on certain criteria considered most relevant and representative to answer the research objectives. Data were collected through questionnaires and tests. The validity, usefulness, and efficacy of self-regulated learning were evaluated using questionnaires. Ten questions made up the numeracy test: two multiple-choice questions, four complicated multiple-choice questions, two essay questions, one short-answer question, and one matching question. The purpose of this range of question types is to acquaint students with the format of the Minimum Competency Assessment (AKM) (Pusat Asesmen dan Pembelajaran, 2021). The self-regulated learning questionnaire instrument was developed based on the model Pintrich (1991). Quantitative data was then converted into qualitative data according to the criteria in Table 1.

Table 1. Reference Scale for Assessment Criteria

Interval	Kategori
$X > \bar{X}_i + 1,8 \cdot sb_i$	Very Good
$\bar{X}_i + 0,6 \cdot sb_i < X \leq \bar{X}_i + 1,8 \cdot sb_i$	Good
$\bar{X}_i - 0,6 \cdot sb_i < X \leq \bar{X}_i + 0,6 \cdot sb_i$	Fair
$\bar{X}_i - 1,8 \cdot sb_i < X \leq \bar{X}_i - 0,6 \cdot sb_i$	Poor
$X \leq \bar{X}_i - 1,8 \cdot sb_i$	Very Poor

Where, X = Empirical score, $\bar{X}_i = \frac{1}{2}(\text{ideal maximum score} + \text{ideal minimum score})$ and $sb_i = \frac{1}{6}(\text{ideal maximum score} - \text{ideal minimum score})$.

The quality of learning media is evaluated based on three aspects, namely validity, practicality, and effectiveness (Nieveen, 1999). Media is considered valid if it meets content suitability and construct consistency; practical if it is easy to use by teachers and students in accordance with the development objectives (Plomp & Nieveen, 2013); and effective if it can improve students' numeracy and self-

regulated learning through pretest and posttest results. The categories of learning media validity based on the scores of subject matter experts and media experts are shown in Table 2.

Table 2. Media Learning Validity Assessment Category

Expert Assessment of Material		Expert Assessment of Media	
Validation Interval	Category	Interval Validasi	Category
$X > 138,6$	Highly Valid	$X > 105$	Highly Valid
$112,2 < X \leq 138,6$	Valid	$85 < X \leq 105$	Valid
$85,8 < X \leq 112,2$	Fairly Valid	$65 < X \leq 85$	Fairly Valid
$59,4 < X \leq 85,8$	Less Valid	$45 < X \leq 65$	Less Valid
$X \leq 59,4$	Not Valid	$X \leq 45$	Not Valid

Validity was assessed using a questionnaire with a scale of 1 (poor) to 5 (excellent). The validity of learning media was assessed by subject matter experts (33 items) and media experts (25 items). The aspects of validity assessed by subject matter experts were relevance of material, organization of material, evaluation and practice questions, language, influence of learning strategies, and visual appearance. The aspects assessed by media experts were language, learning media coherence, learning media consistency, software engineering, visual appearance, and feedback. Meanwhile, the practicality level of learning media based on teacher and student responses is shown in Table 3.

Tabel 3. Category Practicality

Teacher Response		Student Response	
Interval	Category	Interval	Category
$X > 79,8$	Very Practical	$X > 63$	Very Practical
$64,6 < X \leq 79,8$	Practical	$51 < X \leq 63$	Practical
$49,4 < X \leq 64,6$	Quite Practical	$39 < X \leq 51$	Quite Practical
$34,2 < X \leq 49,4$	Less Practical	$27 < X \leq 39$	Less Practical
$X \leq 34,2$	Not Practical	$X \leq 27$	Not Practical

The practicality of learning media is assessed through teacher and student assessment sheets and observation of learning implementation. Teacher and student assessments use a 1–5 Likert scale, while observations are conducted at each meeting to assess teacher and student activities during the learning process.



The effectiveness of the media was tested using a quasi-experimental One-Group pretest-posttest design. Pretest and posttest data were analyzed using the paired sample t-test technique to identify differences before and after using the media, as well as N-Gain to measure improvements in numeracy and self-regulated learning. Data analysis was performed using R Studio. The test instruments were validated by two Mathematics Education lecturers at Yogyakarta State University. The validation results showed that the instruments were suitable for use, with a Cronbach's Alpha value of 0.83 for the numeracy test (good category) and 0.90 for the self-regulated learning questionnaire (very good category) (George & Mallery, 2016, p. 240). The KMO Measure of Sampling Adequacy value of 0.55 indicates adequate construct validity.

Table 4. Interpretation of N-Gain Scores

Gain Score (g)	Category
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g < 0.3$	Low

Table 4 shows the N-gain score categories for determining the level of improvement in student learning outcomes (Hake, 1998).

Use the information about the purchase of stationery below to answer questions 8-9!
Icha, Putri, and Lina bought clipboards and pencils of the same type at the same store as shown in the table.

Buyer	Lots of Stuff	Price
Icha		Rp 50.000,00
Putri		Rp 75.000,00

8. Mark the correct or incorrect answer box in the table with a check mark (✓)!

Statement	Correct	Incorrect
The price of one clipboard is Rp 10.000		
The total price of two clipboards and five pencils is Rp 45.000		
The price of two pencils is Rp 5.000		

9. How much does Lina have to pay if she buys one clipboard and four pencils?

Figure 1. Sample numeracy test questions

Figure 1 shows an example of a personal context numeracy question that measures students' ability to use mathematical concepts and procedures to solve real-world problems. This question requires mathematical reasoning in understanding and interpreting quantitative information, thus falling under the cognitive level of reasoning.

Table 5. Numeracy Test Guidelines for Students

Numeracy Indicators	Context of Questions	Cognitive Level
Be able to use mathematical concepts, procedures, and tools to solve real-life problems.	Personal	<i>Reasoning</i>
	Social Culture	<i>Reasoning</i>
	Personal	<i>Applying</i>
	Personal	<i>Knowing</i>
Be able to understand and interpret quantitative information in various forms (data, graphs, tables, or mathematical text)	Scientific	<i>Reasoning</i>
Be able to state reasons, explain solution steps, and draw logical conclusions based on relevant mathematical principles.	Social Culture	<i>Applying</i>
	Social Culture	<i>Reasoning</i>
	Personal	<i>Reasoning</i>

Table 5 presents a numeracy test grid that includes numeracy indicators, question contexts, and cognitive levels measured to assess the application of mathematical concepts in various situations.

Table 6. Questionnaire grid for student self-regulated learning

Indicators of self-regulated learning	Category
Metacognitive <i>Self-regulation</i>	Planning activities
	Business management
Evaluation	Evaluating learning outcomes
Peer learning	Collaborating with peers

Table 6 shows the self-regulated learning questionnaire grid, which covers metacognitive, evaluation, and peer learning aspects as indicators of student learning independence.

Table 7. Implementation of STEM Aspects in Learning Media

STEM Aspects	Description
<p>Science</p> 	<p>Relate SPLDV to real-world situations such as measuring mass, energy, and nutrition. In this material, science is evident in biological research on the mass of peacocks, which shows the scientific relationship between measurements and mass variables.</p>
<p>Technology</p> 	<p>Using digital tools such as GeoGebra to visualize graphs and Google Forms for interactive exercises and collaboration.</p>
<p>Engineering</p> 	<p>Encouraging students to design and develop solutions, such as creating healthy menus according to nutritional needs using SPLDV concepts.</p>
<p>Mathematics</p> 	<p>Becoming the basis for modeling and solving SPLDV through graphical, substitution, and elimination methods as shown in the graphical method example.</p>

Table 7 explains the application of STEM aspects in learning media. Each aspect plays a role in connecting concepts with real contexts, utilizing digital technology, training contextual solution design, and applying mathematical modeling and problem solving.

RESULTS

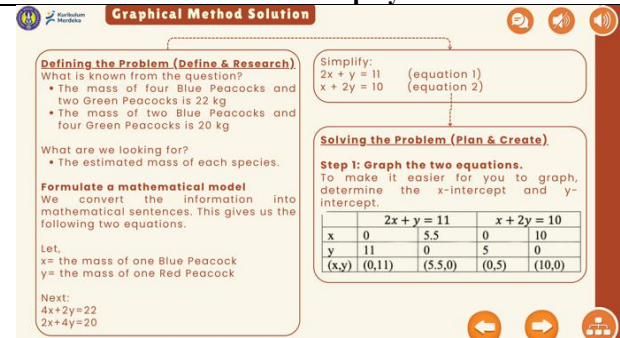
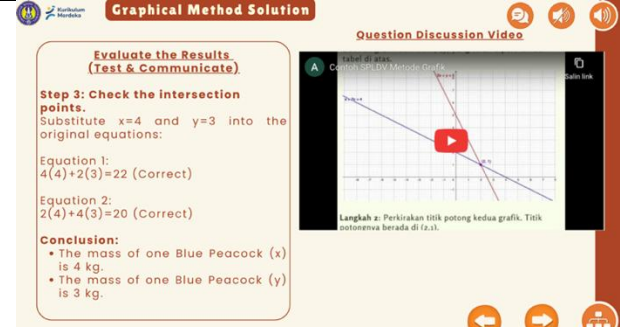
Analysis Stage

Analysis was conducted to gain an understanding of the needs, characteristics of students, and curriculum context as a basis for developing technology-based mathematics learning media. Interviews with one of the teachers at the research school showed that mathematics learning is currently still centered on teachers and textbooks, so that students tend to imitate and memorize procedures without understanding the concepts in depth, especially in solving contextual problems. Analysis of the characteristics of eighth-grade students identified low response to questions, difficulty in applying mathematical concepts in new situations, and the presence of external factors that affect concentration, even though students showed a high interest in the use of interactive technologies such as smartphones. The Merdeka Curriculum provides flexibility in the selection of learning tools with a focus on SPLDV material, which requires conceptual understanding, the ability to solve problems through various methods, and contextual problem modeling. Based on these findings, the development of interactive, contextual, and technology-based learning media is needed to support the improvement of students' numeracy and self-regulated learning abilities, in line with the demands of 21st-century learning.

Design Stage

STEM-based digital learning media developed using Smart App Creator software, which allows the creation of applications for Android and iOS without the need for coding (Mudinillah, 2021). This application produces HTML5 and .exe formats, which can be accessed by students via smartphones (iOS or Android) or desktops. The application of EDP steps in learning media is described in Table 8.

Table 7. Application of EDP stages in STEM-based learning media

Media Display	Description												
 <p>Graphical Method Solution</p> <p>Defining the Problem (Define & Research) What is known from the question? <ul style="list-style-type: none"> The mass of four Blue Peacocks and two Green Peacocks is 22 kg The mass of two Blue Peacocks and four Green Peacocks is 20 kg What are we looking for? <ul style="list-style-type: none"> The estimated mass of each species. Formulate a mathematical model We convert the information into mathematical sentences. This gives us the following two equations. Let, x = the mass of one Blue Peacock y = the mass of one Red Peacock Next: $4x + 2y = 22$ $2x + 4y = 20$</p> <p>Simplify: $2x + y = 11$ (equation 1) $x + 2y = 10$ (equation 2)</p> <p>Solving the Problem (Plan & Create) Step 1: Graph the two equations. To make it easier for you to graph, determine the x-intercept and y-intercept.</p> <table border="1"> <thead> <tr> <th></th> <th>$2x + y = 11$</th> <th>$x + 2y = 10$</th> </tr> </thead> <tbody> <tr> <td>x</td> <td>0</td> <td>5.5</td> </tr> <tr> <td>y</td> <td>11</td> <td>0</td> </tr> <tr> <td>(x,y)</td> <td>(0,11)</td> <td>(5,0)</td> </tr> </tbody> </table>		$2x + y = 11$	$x + 2y = 10$	x	0	5.5	y	11	0	(x,y)	(0,11)	(5,0)	<p>This digital learning media was developed using a STEM approach that integrates the following EDP stages:</p> <ol style="list-style-type: none"> 1. Define the Problem & Research: Students identify relevant problems in everyday life related to SPLDV. 2. Plan & Create: Students plan and select appropriate methods for solving SPLDV.
	$2x + y = 11$	$x + 2y = 10$											
x	0	5.5											
y	11	0											
(x,y)	(0,11)	(5,0)											
 <p>Graphical Method Solution</p> <p>Evaluate the Results (Test & Communicate)</p> <p>Step 3: Check the intersection points. Substitute $x=4$ and $y=3$ into the original equations: Equation 1: $4(4) + 2(3) = 22$ (Correct) Equation 2: $2(4) + 4(3) = 20$ (Correct)</p> <p>Conclusion:</p> <ul style="list-style-type: none"> The mass of one Blue Peacock (x) is 4 kg. The mass of one Blue Peacock (y) is 3 kg. <p>Question Discussion Video</p> <p>Langkah 3: Perkirakan titik potong kedua grafik. Titik potongnya berada di (4,3).</p>	<ol style="list-style-type: none"> 3. Test & Evaluate: Students test and evaluate the solutions they have found by verifying whether the results match the initial conditions of the problem. 												

The implementation of self-regulated learning indicators in learning media can be seen in Table 9, which illustrates the relationship between the EDP stages and the development of students' independent learning skills.

Table 8. Implementation of self-regulated learning indicators in learning media

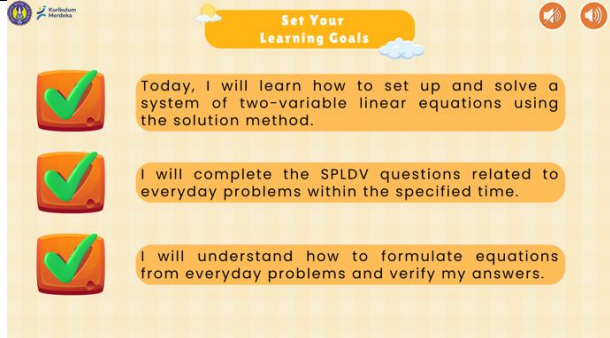
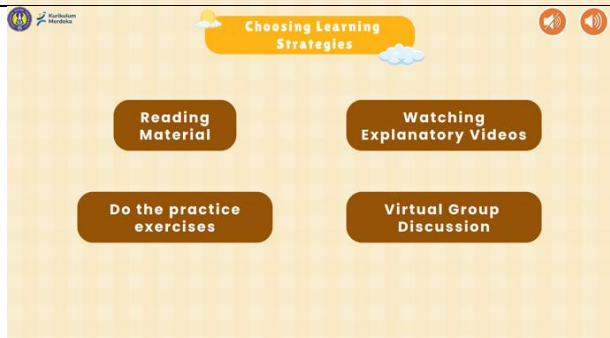
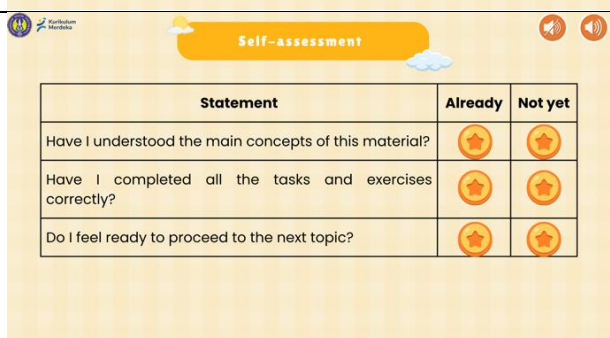
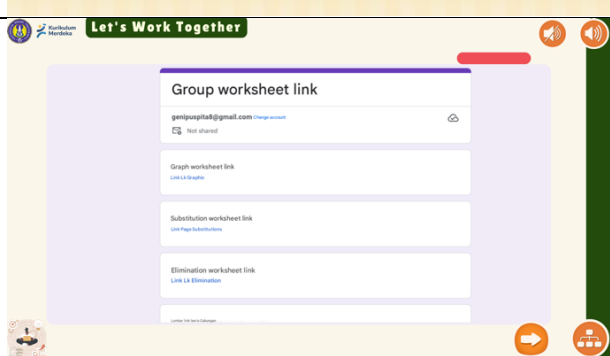
Media Display	Description												
	<p>The implementation of <i>self-regulated learning</i> indicators in digital learning media includes:</p> <ol style="list-style-type: none"> 1. Setting goals: Students set learning goals according to their individual needs and abilities. 												
	<ol style="list-style-type: none"> 2. Learning strategies: Demonstrating students' ability to select and apply appropriate learning strategies to achieve learning goals. 												
 <table border="1" data-bbox="277 1048 820 1223"> <thead> <tr> <th>Statement</th> <th>Already</th> <th>Not yet</th> </tr> </thead> <tbody> <tr> <td>Have I understood the main concepts of this material?</td> <td>★</td> <td>★</td> </tr> <tr> <td>Have I completed all the tasks and exercises correctly?</td> <td>★</td> <td>★</td> </tr> <tr> <td>Do I feel ready to proceed to the next topic?</td> <td>★</td> <td>★</td> </tr> </tbody> </table>	Statement	Already	Not yet	Have I understood the main concepts of this material?	★	★	Have I completed all the tasks and exercises correctly?	★	★	Do I feel ready to proceed to the next topic?	★	★	<ol style="list-style-type: none"> 3. Self-evaluation: Showing a process of self-reflection, in which students assess their learning achievements and evaluate the results obtained.
Statement	Already	Not yet											
Have I understood the main concepts of this material?	★	★											
Have I completed all the tasks and exercises correctly?	★	★											
Do I feel ready to proceed to the next topic?	★	★											
	<ol style="list-style-type: none"> 4. Peer learning: Describing collaborative activities between students that encourage the exchange of understanding and reinforcement of concepts. 												

Table 9 shows that self-regulated learning strategies have been explicitly integrated into STEM-based digital learning media. This aims to encourage students to become active, reflective, and collaborative independent learners during the learning process.

Development Stage

The results of the digital learning media assessment by validators show that this media is valid. The validity score by subject matter experts is 135, which falls within the valid category ($112,2 < X \leq 138,6$), while the validity score by media experts is 104, which also falls within the valid category ($85 < X \leq 105$). Based on these results, it can be concluded that the developed learning media meets the

validity criteria. However, there are several improvements that need to be made based on input from validators, both in terms of material and media. Revisions made by subject matter experts and media experts aim to improve the quality of the appearance, content, and ease of use of digital learning media.

Table 9. Appearance of media before and after revision by subject matter experts

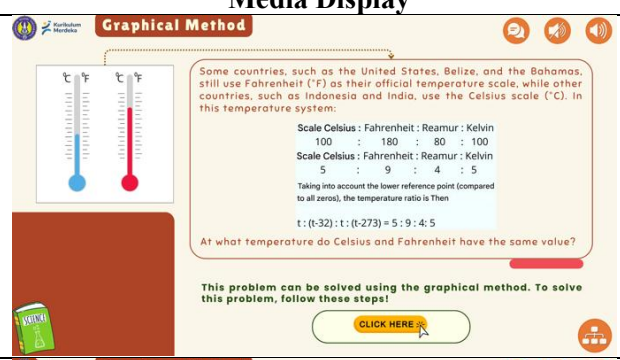
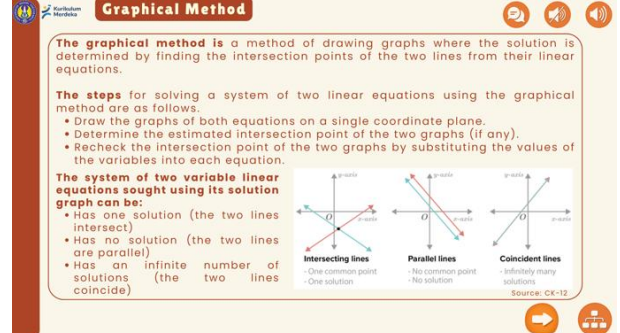
Media Display	Description
	<p>Before the revision, the presentation still focused on reinforcing concepts.</p>
	<p>After the revision, students were first introduced to the basic material of SPLDV, rather than directly solving problems, so that they could better understand the concepts.</p>

Table 10 shows the changes in the media display before and after revision. These changes aim to strengthen students' conceptual understanding so that the learning process becomes more meaningful and effective.

Implementation Stage

Based on Table 8, the total practicality score of the media by teachers was 80, which falls into the *very practical* category. Meanwhile, the average score of 22 students was 63.41, also in the *very practical* category.

Table 10. Results of the Practicality Assessment Questionnaire by Teachers and Students

Assessment Aspects	Assessment Score (Teacher)	Assessment Aspects	Assessment Score (Student)
Ease of use of media	16	Ease of use of media	12,3
Time efficiency	5	Time efficiency	4,2
Ease of interpretation	12	Relevance to subject matter	17,6
Relevance to subject matter	16	Appeal	17,5
Appeal	19	Suitability for self-directed learning	11,7
Suitability for self-directed learning	12		
Total	80	Total	63,41

Based on these results, both teachers and students assessed that digital learning media is very practical, easy to use, and effective in supporting learning activities. Furthermore, Table 12 shows the results of observations of the implementation of learning during three meetings. Teacher and student activities each received an average score of 96.67%, which is classified as very good.

Tabel 11. Percentage of observation results on learning implementation

Meeting No.	Percentage of Implementation (%)		Average (%)
	Teacher Activities	Student Activities	
2	90	90	90
3	100	100	100
4	100	100	100
Average	96,67	96,67	96,67

Teacher and student activities were classified as very good because the percentage of learning implementation exceeded the minimum limit of 75% (Sulistiyowati & Sugiman, 2014). Thus, it can be concluded that the developed digital learning media is practical for use in learning.

Evaluation Stage

After passing the feasibility test stage, the next step is to evaluate the effectiveness of STEM digital learning media. The evaluation is carried out by analyzing the differences in student learning outcomes before and after using the developed learning media, both in terms of numeracy and self-regulated learning.

Table 12. Sample numeracy questions and student answers

Question	Answer
<p>Use the information about the following types of fabric to answer question 1!</p> <p>As a basic material for making clothes, fabric is a primary necessity for humans. The various styles of clothing that are currently available are inseparable from the role of the fabric used. There are many different types of fabric, each with its own characteristics. These different characteristics ultimately create a unique impression on each piece of clothing. Some types of fabric for clothing include linen, polyester, cotton, satin, rayon, knit, spandex, nylon, denim/jeans, viscose, and so on. Sekar wants to make clothes from cotton and satin. She bought 3 meters of cotton fabric and 2 meters of satin fabric for Rp 107,000. At the same store, Eci bought 5 meters of cotton fabric and 3 meters of satin fabric for Rp 173,000.</p> <p>How much does one meter of cotton fabric and one meter of satin fabric cost at that store? Show your calculations!</p>	

This test assesses how well students can apply mathematical ideas, methods, and resources to address real-world issues. Students' responses demonstrate their ability to convert practical issues into methodical mathematical models. This skill demonstrates functional numeracy, which is the capacity to logically and successfully use mathematical knowledge in daily life.

Tabel 13. Description of students' numeracy test results and self-regulated learning questionnaires

Data	Numeracy Test Results		Self-regulated Learning Questionnaire Results	
	Pretest	Posttest	Pretest	Posttest
Mean	36,91	79,27	44,95	74,09
Minimum Score	20	60	30	68
Maximum Score	64	96	66	88
Ideal Minimum Score	0	0	20	20
Ideal Maximum Score	100	100	100	100
Number of students who passed	0	18	0	20
Number of students	22	22	22	22
Percentage of Mastery >KKM	0%	81,81%	0%	90,90%

According to the findings, the completion percentage went from 0% to 81.81%, and the average numeracy score rose by 42.36 points. In the meantime, completion rates went from 0% to 90.90%, and the average self-regulated learning score rose by 29.14 points. This indicates that STEM-based digital learning resources enhance students' learning results and independence.

Table 14. Achievement Results for Each Numeracy and Self-regulated Learning Indicator

Indicator	Percentage of Numeracy Test Results		Percentage of Self-regulated Learning Questionnaire Results	
	<i>Pretest</i>	<i>Pretest</i>	<i>Posttest</i>	<i>Posttest</i>
1	30,3%	49,5%	72,4%	80,3%
2	43,9%	38,4%	71,8%	87,9%
3	42,7%	40,68%	81,5%	75,5%

Table 15 demonstrates how STEM-based learning materials can enhance students' logical reasoning, numeric information processing, and real-world problem-solving abilities. Nonetheless, more work needs to be done on the capacity to describe problem-solving procedures. All measures showed gains in self-regulated learning. The collaborative learning indicator, which demonstrates that STEM-based media effectively promoted student engagement and cooperation, showed the most improvement.

Table 15. Results of Paired Sample T-test and N-Gain Test

Numeracy Test Results				Self-regulated Learning Questionnaire Test Results			
t	$t_{\frac{\alpha}{2}(n-1)}$	<i>p-value</i>	N-Gain	t	$t_{\frac{\alpha}{2}(n-1)}$	<i>p-value</i>	N-Gain
33,816	2,0796	2,2e-16	0,683	15,267	2,0796	7,648e-13	0.5180231

Table 16's inferential statistical analysis employing a paired sample t-test reveals that the pretest and posttest results for self-regulated learning and numeracy differ significantly ($p < 0.05$). With scores of 0.68 for numeracy and 0.52 for self-regulated learning, the N-Gain score likewise demonstrates progress in the moderate group.

DISCUSSION

The goal of this project is to create STEM-based digital mathematics learning resources that are reliable, useful, and efficient in order to enhance students' self-regulated learning and numeracy in SPLDV content. With a material expert score of 135 and a media expert score of 104, the validation results demonstrate that the created medium satisfies the validity requirements. These ratings fall into the legitimate category, demonstrating how well the material aligns with learning objectives and scientific theory. Additionally, the self-regulated learning questionnaire and the numeracy test instrument were deemed valid and reliable. These results corroborate Plomp & Nieveen (2013) assertion that instruments built with a solid theoretical basis and internal consistency can ensure the validity of measurement outcomes. Additionally, these findings are consistent with studies by Aditya & Maryani (2022) and Andriatna et al. (2024), which highlight the significance of expert participation in the process of learning media validation.

Positive reactions from teachers and students, with teacher assessment ratings of 80 and student scores of 63.41, as well as a learning implementation rate of 96.67%, showed how useful the medium was. This demonstrates that STEM-based digital learning resources are user-friendly, effective, and suitable for classroom instruction. These findings are consistent with research by Boyd & Hamlin (2023) and Eliza et al. (2023), which demonstrates that practical learning materials are distinguished by their accessibility, adaptability, and capacity to boost students' enthusiasm to learn.

The notable gain in numeracy skills, with an average score rising from 36.91 to 79.27 and an N-Gain of 0.68 (moderate category), demonstrates the media's effectiveness. Similarly, with an N-Gain of 0.518 (moderate category), pupils' self-regulated learning scores rose from 44.95 to 74.09. These findings are in line with studies by Ibrahim et al. (2024), Purniawan et al. (2022), and Setiawan et al. (2024), that demonstrate how STEM-based education can enhance numeracy literacy while promoting student learning autonomy. Additionally, by demonstrating that STEM integration affects affective

elements, this study builds on earlier research and supports the views of Panadero (2017), and Zimmerman (2002) regarding the significance of self-regulated learning in continuous learning.

The findings of this study are in line with various studies showing that technology-based media and STEM approaches contribute positively to improving students' numeracy and learning independence. Kamal, Subali, Astuti, Rusilowati, & Widiyatmoko (2024); Susanta, Susanto, Stiadi, & Rusnilawati (2023) and Husnah, Nur, Sriyanti, Sulasteri, & Mattoliang (2025) prove that STEM-based digital learning and context-based videos are effective in interactively improving numeracy literacy. Similar results were reported by Fajriana et al. (2025) and Maryam & Sampoerno (2021), through the use of multimedia and digital handouts. In addition, research by Hidayati, Roesdiana, & Sari (2024); Sukmawati et al. (2021); and Pixyoriza, Nurhanurawati, & Rosidin (2022) confirms that STEM-based interactive learning media is valid, practical, and effective in developing problem solving and student learning independence.

The STEM-based digital mathematics learning media developed has several advantages. First, this media focuses on developing two main aspects, namely numeracy skills and self-regulated learning, which have rarely been studied together in similar research. Second, the use of interactive technology that can be accessed via smartphones or desktop devices increases flexibility and student engagement in the learning process. Third, the presentation of contextual learning videos helps students understand SPLDV concepts more deeply and practically.

However, this media has limitations, including dependence on a stable internet connection and a scope of material that is still limited to SPLDV. Overall, the findings demonstrate the validity, usefulness, and efficacy of STEM-based media created using the ADDIE approach. These results confirm empirical evidence that integrating the STEM method into digital media can enhance students' learning independence and numeracy while promoting meaningful learning and the development of 21st-century skills.

CONCLUSION

According to the study's findings, STEM-based digital learning resources for math in SPLDV content satisfy the requirements of efficacy, validity, and practicality. Validity is proven through expert assessment results and instrument feasibility, practicality is evident from the positive responses of teachers and students, and effectiveness is demonstrated through a significant increase in numeracy and self-regulated learning abilities with a moderate N-Gain category. The integration of STEM in interactive digital media has been proven to strengthen mathematical understanding while encouraging student independence in learning. However, this media is still limited to SPLDV material and depends on a stable internet connection. In the future, further development is recommended by adding a variety of questions, adaptive features, and expanding the scope of material so that the media is more comprehensive and interesting.

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