

# Enhancing Numeracy Literacy of Deaf Students: Developing Problem-Based Learning with Realistic Mathematics Education Assisted By E-Comic

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## ABSTRACT

Numeracy literacy is a crucial 21st-century competency, yet deaf students often face significant challenges in understanding abstract mathematical concepts due to communication limitations. This study aims to develop and produce an E-Comic based on Realistic Mathematics Education (RME) integrated with a Problem-Based Learning (PBL) model to enhance the numeracy literacy of deaf students. This Research and Development (R&D) study adapted the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation. The research was conducted with a sample of 5 deaf students at the junior high school level at SLB BC YMS Wonogiri. Data were collected using numeracy literacy tests, validity questionnaires, and teacher and student response questionnaires to measure practicality. The results demonstrate that the developed e-comic is highly valid, achieving an average validity score of 89.02%. In terms of practicality, the media received an average score of 82.19% from teachers and students. Furthermore, the e-comic proved to be effective in improving numeracy literacy, as evidenced by an N-Gain score of 0.77, which falls into the high improvement category. Therefore, realistic mathematics education based e-comics with a problem based learning model is a valid, practical, and effective learning medium that significantly improves the numeracy literacy skills of deaf students.

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## 1. INTRODUCTION

Education plays an important role in the learning process of an individual or group to acquire knowledge, develop skills, and shape attitudes through good and educational teaching (Bariyah, 2019). Therefore, amid the challenges of the 21st-century, quality education is the key to creating superior human resources who are adaptive, creative, and innovative. In line with the views of Rohmah et al. (2024), it is these quality human resources that will be the driving force behind the nation's progress in various fields. Thus, education plays an important role in shaping an inclusive society.

Education is a right for all individuals, including students with special needs, in accordance with Indonesian Law Number 20 of 2003 concerning the National Education System, which emphasizes the

importance of inclusive education. However, major challenges arise for students with special needs (ABK), especially deaf students. The main difficulty faced by deaf children is barriers in language access (Nugroho & Lintangari, 2022). The performance of children with language difficulties is lower than that of children who develop normally (Barilaro et al., 2025). In addition, limitations in communication often have an impact on their academic integration (Chacon & Hayes, 2023). All of these obstacles cause deaf children to experience difficulties in the learning process, especially in mathematics (Bakti et al., 2021).

Mathematics is closely related to the 2030 Sustainable Development Goals (SDGs). One of the SDGs is Quality Education, which ensures that all children receive inclusive and equitable education and improves literacy and numeracy skills. Numeracy literacy is also important in 21st-century development (World Economic Forum, 2016). Numeracy literacy skills can help students compete in social, economic, and welfare growth for individuals and communities (Elina & Maimunah, 2024). Therefore, numeracy literacy plays an important role in the development of basic skills for students, especially deaf students.

Numeracy literacy is one of the OECD's assessments through PISA. According to PISA (Programme for International Student Assessment), Indonesia's scores are consistently below the global average (Liestari et al., 2024). In 2022, Indonesia scored 366 in mathematics and 359 in literacy (OECD, 2023). In addition, we can see that the average set by the OECD in mathematics is 472 and in literacy is 476. The cognitive difficulties of students with special needs also affect numeracy literacy. Several studies show that students with special needs face challenges in understanding basic mathematical concepts, which are at the core of numeracy literacy (Butterworth & Neuroscience, n.d.; Susetyawati & Danuri, 2023). Therefore, innovation in inclusive learning is needed to improve the numeracy literacy of deaf students.

Interviews with mathematics teachers at SLB BC YMS Wonogiri showed that students' numeracy literacy still needs to be improved. Literacy activities carried out at school still focus on reading books in general in the morning, and are not specifically aimed at strengthening numeracy literacy. The learning resources used are textbooks that are in line with the independent curriculum. In addition, there are no teaching materials available to help students understand the material. To overcome this problem, learning innovations in the form of teaching materials oriented towards numeracy literacy are needed.

One learning model that can be used to improve numeracy literacy is Problem-Based Learning (PBL). This model was chosen because it incorporates learning based on contextual problems. In addition, PBL includes activities where students present the results of discussions that are in line with numeracy literacy indicators, namely representation, reasoning, and decision making (Purwati et al., 2021). Research by Pale & Meke (2025) shows that the application of the PBL model has been proven effective in improving students' numeracy literacy and contributing to more meaningful and contextual mathematics learning. Thus, the PBL model can improve the numeracy literacy of deaf students.

Realistic Mathematics Education (RME) supports the role of improving numeracy literacy among deaf students. This method of mathematical instruction initiates with real-life contexts to foster the development of mathematical concepts. The goal is to embed mathematics into everyday experiences, thereby making the learning process more relevant, better comprehended, and effectively memorized by students (Sari & Yuniati, 2018). Research by Fauzan et al. (2024) also confirms that the implementation of RME can significantly improve students' numeracy literacy. This approach has been proven effective in improving students' understanding of mathematical concepts, including for those with learning difficulties (Hiba et al., 2024). Therefore, the RME learning approach can improve numeracy literacy for deaf students.

Findings by Layachi & Pitchford (2025) identify the need for improvements in visual presentation and language in educational technology for children with special needs, including those with hearing impairments. E-comics can be a tool that helps explain learning concepts by emphasizing the use of visuals. This medium effectively combines attractive visual elements with contextual storylines, making it possible to present mathematical material that is easier for students to understand. Thus, e-comics not only make learning mathematics more enjoyable, but also effective in improving students' numeracy literacy skills.

In the study by Pramesti & Wahyudi (2025), RME-based e-comics have not been specifically integrated to improve the numeracy literacy of deaf students. In addition, there are differences with the research conducted by Fitriani et al. (2025) in terms of numeracy literacy in deaf students. Although previous research has discussed the use of RME or PBL separately, no study has systematically developed an e-comic that integrates the PBL model and the RME approach together specifically for deaf students. This study will fill the gap related to the development of RME-based e-comics that suit the learning needs of deaf students so that they can improve their numeracy literacy. Therefore this research aims to develop an E-Comic based on Realistic Mathematics Education (RME) integrated with a Problem-Based Learning (PBL) model to enhance the numeracy literacy of deaf students.

Based on the presentation on e-comic learning innovations for deaf students, an e-comic will be developed using an RME-based PBL model that can improve the numeracy literacy skills of deaf students in mathematics learning. This development research is expected to overcome the problems experienced by deaf students in numeracy and literacy. In addition, it can help teachers and students so that the learning process runs effectively and efficiently so that, learning objectives are achieved.

## 2. METHODS

The type of research used is Research and Development (R&D). this research was conducted at SLB BC YMS Wonogiri. However, due to the limited number of participants specifically, the availability of only one class of deaf students the experimental design employed in this study is one group pretest posttest design. The development method for this e-comic uses the ADDIE model. The purpose of this research is to develop a product in the form of an E-Comic PBL with RME that can improve the numeracy literacy skills of deaf students. The stages of the ADDIE model can be seen systematically in Figure 1.

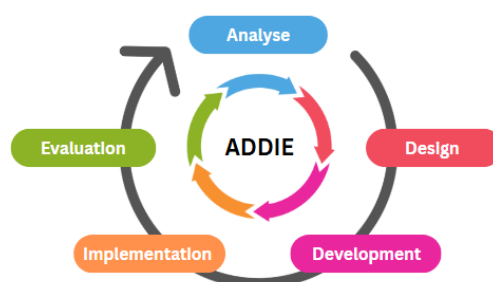


Figure 1. Stages of ADDIE

The data collection techniques were interviews, questionnaires, and tests. The research instruments were interview guidelines, e-comic validity questionnaires, numeracy literacy tests, and teacher and student response questionnaires. The quality of the research instruments was tested through validity and reliability procedures. Content validity was analyzed using the Content Validity Index (CVI) based on assessments from two experts and one practitioner. Given that there were three experts, the item eligibility criterion (I-CVI) was set at 1.00, while the minimum value for the entire instrument (S-CVI/Ave) was 0.90, referring to the criteria of Polit & Beck (2006). Furthermore, the internal consistency of the questionnaire instrument was tested using Cronbach's Alpha coefficient. The instrument is considered reliable if it has an  $\alpha$  value  $\geq 0.70$  according to the criteria of George & Mallery (2016), as shown in Table 1.

**Table 1.** Classification of Reliability Coefficients

Score	Description
$\alpha \geq 0.9$	Very Good
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$\alpha < 0.5$	Unacceptable

The data analysis techniques used were descriptive, qualitative, and quantitative. The e-comic validity test was assessed by three experts using a validation questionnaire. Then, the practicality test will be assessed by 5 students and 1 teacher at SLB BC YMS Wonogiri, which will be given after the learning process is carried out. The results of the validity and practicality tests are represented in the form of percentages and then compared with the criteria described in Table 2 below.

**Table 2.** Validity/Practical Criteria of E-Comic

No.	Score	Criteria
1.	81% - 100%	Very Valid/Very Practical
2.	61% - 80%	Valid/Practical
3.	41% - 60%	Quite Valid/Quite Practical
4.	21% - 40%	Invalid/Impractical
5.	0% - 20%	Very Invalid/Very Impractical

The effectiveness of e-comics will be measured based on the results of numeracy literacy tests. The experimental research design used to collect quantitative data is a one-group pretest-posttest design. This design was chosen to conduct an in-depth analysis of the development of numeracy literacy for each subject intensively within the specific context of deaf students. The effectiveness analysis is based on an increase in pre-test and post-test scores of more than or equal to 75. The difference between the pre-test and post-test averages is determined based on their significance using the Wilcoxon signed-rank test. The collected post-test learning data is analyzed for improvement from the pre-test scores using the following N-Gain formula.

$$N - Gain = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}}$$

The N-Gain categories can be seen in Table 3.

**Table 3.** N-Gain Score

No.	N-Gain Score	Category
1.	$G \geq 0,70$	High
2.	$0,30 \leq G < 0,70$	Medium
3.	$G < 0,30$	Low

### 3. FINDINGS AND DISCUSSION

The development of realistic mathematics education-based e-comics to improve the numeracy literacy skills of deaf students was carried out following the ADDIE stages. The analysis stage consisted of three stages, namely needs analysis, student analysis, and curriculum and material analysis. In the design stage, there were two designs, namely material design and e-comic design. The development stage involves the creation of the e-comic, followed by validation by experts and revisions. In the

implementation stage, the e-comic is tested on students to see improvements in numeracy literacy and to test the practicality of the e-comic. Finally, the evaluation stage is carried out at all stages to identify weaknesses and improvements that need to be made to enhance the development of the e-comic.

### **3.1 Analysis Stage**

#### **3.1.1 Need Analysis**

Based on the results of observations and interviews related to student issues, several findings were obtained. The main findings in the needs analysis indicate an urgent need to develop learning media. This is driven by the finding that the numeracy literacy skills of deaf students are still low. This low level of skill is related to communication barriers and conventional learning methods. In addition, learning resources in the classroom rely solely on textbooks provided by the school without the support of media that can facilitate student understanding. Therefore, a solution in the form of a problem-based learning model can be used to train numeracy literacy indicators such as analyzing, interpreting, and solving numerical problems. In addition, the variety of teaching materials used can be presented in line with technological developments such as e-comics. Furthermore, conventional learning that does not provide a contextual approach can be overcome using the RME approach. Therefore, the development of e-comic media with an RME-based PBL model is needed to overcome these problems.

#### **3.1.2 Students Analysis**

The analysis of students was conducted through classroom observation, interviews with teachers, and theoretical studies based on cognitive learning theory. This analysis aimed to identify the cognitive characteristics and learning needs of deaf students as a basis for determining the appropriate learning approaches and media. This analysis refers to Jean Piaget's theory of cognitive development, particularly the processes of assimilation, accommodation, and equilibration, which explain how students construct and reorganize knowledge through interaction with their environment.

Assimilation occurs when learners integrate new information into their existing cognitive schemas, while accommodation occurs when existing schemas must be modified because new information does not fit with previous understanding (Park, 2026). Equilibration is the natural drive of learners to achieve a balance between the processes of assimilation and accommodation, which motivates learners to achieve a deeper understanding of concepts (Kusmaryono et al., 2022). In deaf students, these processes are greatly influenced by the dominance of visual-spatial cognition and limited access to verbal-auditory information.

Based on the results of observations, deaf students experience communication barriers that have a significant impact on learning abstract mathematical concepts. Conventional learning, which relies heavily on verbal explanations and symbolic representations, is often unable to optimally support the accommodation process. The lack of visual support and learning context makes it difficult for students to meaningfully integrate new mathematical concepts, resulting in low numeracy literacy skills.

The Realistic Mathematics Education (RME) approach addresses these cognitive challenges by viewing mathematics as a human activity rooted in real-life contexts (Laurens et al., 2018). RME is particularly suitable for deaf students because it emphasizes the presentation of contextual problems, the use of visual representations, and a gradual process of mathematization, which are in line with the visual learning characteristics of deaf students. Through real contexts, students can relate abstract number concepts to familiar everyday experiences, thereby facilitating the assimilation process and encouraging accommodation when initial schemas are no longer adequate.

In this study, the use of RME-based e-comics was chosen as a strategic solution to meet the cognitive needs of deaf students. The e-comic format presents mathematical concepts through visual narratives, concrete illustrations, and simplified language, thereby reducing the linguistic burden while reinforcing the clarity of the concepts. The contextual storyline presented in the e-comics presents meaningful problem situations and guides students to explore, analyze, and solve numerical problems in stages. This visual and contextual support helps students reorganize their cognitive structures and achieve equilibrium.

In addition, the integration of the RME approach with the Problem-Based Learning (PBL) model in e-comics supports the development of higher-order cognitive processes. The PBL stages of problem orientation, investigation, solution development, and reflection are explicitly visualized through systematically arranged comic panels. This structure helps deaf students actively engage in the mathematical reasoning process, rather than simply receiving information passively. Through interaction with contextual problems that are visualized, students are encouraged to build knowledge independently, develop reasoning skills, and improve numeracy literacy in a meaningful and sustainable way.

### 3.1.3 Material and Curriculum

Curriculum and material analysis were conducted through observation and interviews with teachers. Whole numbers are one of the subject areas that play a fundamental role in shaping students' numeracy literacy. The goal of numeracy literacy is to develop a sense of number, which means providing contextual problems related to calculating temperature, determining sea depth, and the height of an object. This material was chosen because of its conceptual complexity and because it is a prerequisite for more advanced mathematics. The Merdeka Curriculum Review emphasizes that learning must be student-centered and contextual in order to improve numeracy literacy. Thus, the development of e-comics must be oriented towards presenting material based on real-life problems or everyday life.

The problems and solutions presented in the analysis stage are in line with previous research. Low numeracy literacy among students may be caused by the continuous administration of routine questions. In line with this, according to Kemdikbud (2017), students' numeracy literacy must be trained through the use of real numerical elements so as to bring out their sense of number. Providing context in the development of numeracy literacy as a fundamental skill must take into account the principles of meaningfulness, relevance, and full awareness of the lesson (Oktaviani et al., 2025; Srinivas et al., 2025). One of the reasons for the gap in ability between people with hearing impairments is verbal ability. Terry's research shows that people with hearing impairments find it easier to understand information and communicate with the help of visual aids, in the context of this research, with the help of virtual reality. Mathematics is considered a subject with a high level of complexity, so visual representations in mathematics, such as diagrams, also help students with hearing impairments (Almalhy, 2022; Amril et al., 2020; Gin et al., 2021). In line with the development of e-comics for deaf students, learning resources for mathematics that use visual symbols rather than verbal symbols are more helpful for their cognitive processes. Problem-based learning and technology can have a positive influence on learning experiences, motivation, and enthusiasm (Boom-Carcamo et al. 2024). In addition, the realistic learning approach is seen as a mathematical activity that forms the basis for the development of human quality of life. Mathematics learning aims to develop a person's ability to apply mathematics in real-world problems (Sumirattana et al., 2017). The results of a study by Fajri et al. (2025) show that there is a correlation between RME and problem-based learning that teachers can use to develop more contextual and meaningful learning.

### 3.2 Design Stage

At the design stage, researchers compiled e-comics based on the fundamentals obtained from the analysis stage. At this stage, researchers determined the storyline that would carry the concept of integers presented in stages with reference to PBL syntax and realistic mathematics education characteristics. The researchers sought reference materials from the 2022 Ministry of Education, Culture, Research, and Technology textbook for seventh grade. The researchers also used an adventure theme because it was relevant to the students' daily lives. In addition, the researchers created interactive pages in several panels within the e-comic to enable students to actively engage in learning. Then, the researchers created the e-comic using Canva software.

The researcher determined the title of the e-comic to be *Mathture Comic*, which contains adventures. The pages in the e-comic contain: (1) the opening page (cover) consisting of the title of the

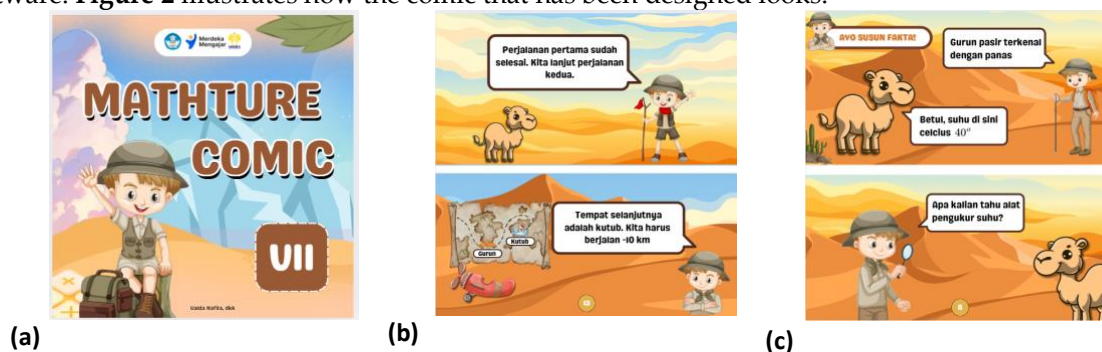
e-comic, the author's name, and the class; (2) the learning outcomes page; (3) the learning objectives page; (4) an introduction to the main characters in the e-comic; (5) the opening story page, which begins with the discovery of a treasure map for the adventure; (6) an adventure page to the desert to introduce positive integers; (7) an adventure page to the poles to introduce negative integers; (8) an adventure page to sort integers; (9) an interactive page containing questions that must be answered by students, as well as correct or incorrect responses to the answers; and (10) a conclusion page.

The design of a suitable and practical e-comic must consider each design element separately because they each contribute to the learning process. The font chosen is Genty Sans because it prioritizes the right font selection, optimal text size, and appropriate contrast. A highly legible font with clear contrast against the background can help students understand the instructions well (Betries et al., 2024). This also increases user engagement and can reduce eye strain due to prolonged screen use. The theme used in the development of this e-comic is adventure. The animation theme must be interesting and relevant to the context of the material so that it can increase motivation, enthusiasm, and contextualization of problems in the real world. The colors chosen in Mathture Comic are striking colors. Bright colors are chosen to create visuals that are bold and inspiring. According to Lestari et al. (2024), the use of bright colors and images is an important factor in attracting students' interest and encouraging them to actively engage in the storyline. Image resolution and visual quality must be high and attractive, where concrete visuals can facilitate the understanding of abstract mathematical concepts (Fitriana & Aziz, 2024; Jusniani & Monariska, 2025; Shalihati, 2024). Furthermore, the layout of the e-comic panels must be systematic, sequential, and intuitive to guide students to focus on the learning steps and solve numeracy problems in sequence. The layout also makes the display more communicative and can support the arrangement of text and images so that it is easier for readers to capture information.

In development research, a medium is considered suitable for use in learning if it meets the criteria of validity, practicality, and effectiveness. Therefore, after the e-comic was completed, the researchers created questionnaires such as e-comic validation questionnaires for subject matter experts and media experts, numeracy literacy test question validation questionnaires, practicality questionnaires for students and teachers, and teaching module validation questionnaires. Before use, all instruments will first be validated by experts.

### 3.3 Development Stage

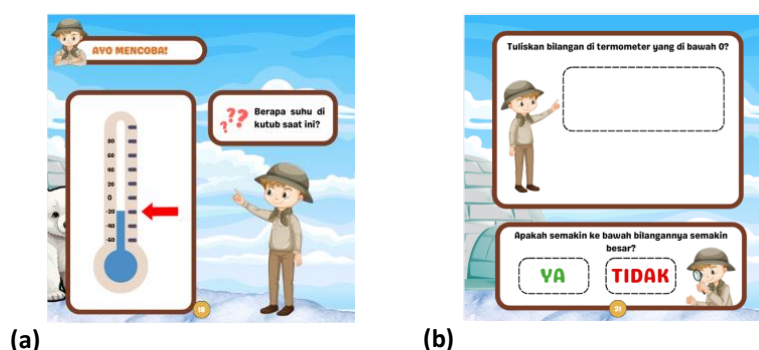
In the Development stage, researchers begin to create overall and detailed designs, starting from characters, speech bubbles, text, backgrounds, and so on. The third stage, Development, involves creating E-Comic media based on the designs that have been prepared, followed by validation and further revisions. At this stage, the e-comic will be created visually and interactively, integrating the contextual RME storyline with the PBL steps. The e-comic creation process is carried out using Canva software. **Figure 2** illustrates how the comic that has been designed looks.





**Figure 2.** E-Comic PBL with RME: (a) Cover of e-comic; (b) Problem orientation; (c) Organizing students for learning; (d) Guiding individual and group investigations; (e) Developing and presenting work; (f) Analyzing and evaluating

In addition to the overall comic layout presented in Figure 2, several panels are displayed in Figure 3 to illustrate how mathematical concepts are integrated into interactive learning activities. These panels depict problem situations using visual representations of thermometers accompanied by guiding questions that encourage students to identify numbers above and below zero, as well as to reason about the relative magnitude of integers. These visual elements demonstrate how abstract integer concepts are translated into concrete and accessible representations through sequential illustrations, simple text, and contextual prompts, which are particularly well-suited to the visual learning characteristics of deaf students.



**Figure 3.** Sampel Panel of RME Based E-Comic Illustrating Contextual Integer Problems

### 3.3.1 Content Validity Index (CVI)

Based on the assessment of two experts and one practitioner on 59 statements, the majority of items showed very high validity. A total of 58 items obtained an I-CVI of 1.00. However, for item 20, 2 experts gave a score of 2, resulting in an I-CVI value of 0.33 for that item. Overall, the average content validity index (S-CVI/Ave) was 0.988.

An S-CVI value of 0.988 indicates that, in general, this instrument is highly valid in terms of content. Regarding the item with a low value of 0.33, the researcher revised or replaced the wording of the sentence to match the expert's input. After the improvements were made, the instrument was declared suitable for use.

**Table 4.** Summary of Content Validity Index (CVI) Calculation Results

Item	Expert 1	Expert 2	Practitioner	Agreement	I-CVI	Description
S1-S19	3-4	3-4	3-4	3	1.00	Highly Relevant
S20	4	2	2	1	0.33	Revision
S21-S59	3-4	3-4	3-4	3	1.00	Highly Relevant
<b>S-CVI/Ave</b>					0.99	Highly Valid

### 3.3.2 Reliability Analysis Using Cronbach's Alpha

Based on the results of data processing using SPSS, it is known that the instrument consisting of 59 statements has a very high level of consistency. The Cronbach's Alpha value obtained is 0.948. Considering that this value is greater than the threshold of 0.70, it can be concluded that this instrument is reliable and suitable for use in research.

This indicates that the questionnaire is capable of producing stable data even when repeated measurements are taken. In detail, a summary of the reliability statistics from the SPSS output can be seen in Table 5 below:

**Table 5.** SPSS Reliability Test Result of Questionnaire

Reliability Statistics	
Cronbach's Alpha	N of Items
.948	59

*Source: SPSS Results (2026)*

### 3.3.3 Feasibility Test

After the e-comic has been developed, the next step is expert validation testing, where the e-comic product is validated by subject matter and media experts to assess its feasibility. The results of this feasibility assessment form the basis for product revisions, ensuring that the e-comic to be tested meets the feasibility standards. The validation assessment results are detailed in Table 6 below.

**Table 6.** Validation Results on E-Comic Feasibility

No.	Validator	Percentage	Classification
1	Validator 1	95%	Very Valid (used with revision)
2	Validator 2	85.83%	Very Valid (used with revision)
3	Validator 3	86.25%	Very Valid (used with revision)
Average		89.02%	Very Valid (used with revision)

Based on Table 3, it was found that the developed e-comic is suitable for use as a mathematics learning medium because it meets the feasibility criteria with an average of 89.02%. The feasibility classification of the developed e-comic is very valid. E-comics that meet the feasibility aspects are very crucial because they are an important prerequisite to ensure that e-comics improve students' numeracy literacy skills. The developed e-comic with the PBL model is feasible to implement because it is able to present material through contextual problems that are relevant to real life (Suh et al., 2024). E-comics are able to facilitate PBL syntax explicitly. RME as an approach in learning media can improve students' ability to implement mathematics in everyday life (Andrian et al., 2025; Laurens et al., 2018; Risdiyanti et al., 2024). E-comics that have undergone a validation process and are declared feasible are a prerequisite before the media is tested to measure improvements in student abilities. In line with the principles of media development, feasibility tests must be carried out and declared valid by experts before the learning media is implemented or tested on actual research subjects.

Although the e-comic met the eligibility criteria, the validators provided comments and suggestions for improvement to make the final product even better. The comments and suggestions from the validators can be seen in Table 7 below.

**Table 7.** Feedback from Validators for Product Improvement

No.	Aspects	Feedback for improvement
1	Contents	PBL can be made more visible
2	Presentation	No revision
3	Language	The language/sentences need to be simplified further for deaf children to understand easily (avoid terms without explanation)
4	Innovation	No revision

Suggestions from validators were used to improve the developed e-comic. **Table 8** below shows the results of improvements to the e-comic.

**Table 8.** Repair of E-Comic

Feedback for improvement	Before repair	Result
PBL can be made more visible		
The language/sentences need to be simplified further for deaf children to understand easily (avoid terms without explanation)		

### 3.4 Implementation Stage

#### 3.4.1 Practicality Test

After the e-comic was developed and refined, it was deemed suitable for use as a learning medium for deaf students. Realistic mathematics education-based e-comic learning was provided to five deaf seventh-grade students at SLB BC YMS Wonogiri. After the students received the integer material presented through the e-comic, they were given a questionnaire to see their responses to the practicality of the e-comic used.

The results of the practicality test of e-comics based on realistic mathematics education can be seen in Table 9 below.

**Table 9.** Practicality Result of E-Comic by Teacher and Students

No.	Practicality questionnaire	Percentage	Classification
1	Teacher	78.84%	Practical
2	Students	85.55%	Very practical
	Average	82.19%	Very Practical

The table above shows that RME-based e-comics are very practical, as indicated by the 82.19% response rate from teachers and students. This shows that students' numeracy literacy skills can be improved using e-comics as a learning medium. This practicality is assessed from two aspects. First, the ease of use aspect, where e-comics are considered easy to use because they can be accessed flexibly anywhere and anytime. In addition, the visual design supports the implementation of PBL syntax because the storyboard in e-comics is arranged according to the problem-based learning flow. This is in line with the findings that the integration of PBL syntax into the comic story flow provides a collaborative, exploratory, and reflective learning experience (Nurchurifiani & Zulianti, 2021). This ease of use facilitates students' independent search for information and problem-solving. Where students who independently search for information and solve problems provide a concrete educational experience, thereby increasing motivation and engagement in the learning process (Guerra, 2025; Mahmud et al. , 2018). Second, e-comics are easy to understand because they implement RME, which makes it easier for students to relate abstract mathematical concepts to everyday situations (Rahmasantika & Prahmana, 2022; Yuniawati et al., 2024).

### 3.4.2 Feasibility Test

The results of the study on students obtained pre-test and post-test scores from the completion of numeracy literacy questions. The results of the students' pretest and posttest can be seen in Table 10 below. The data on the increase in pretest and posttest scores obtained by students can be seen in Figure 4.

**Table 10.** Results of Deaf Students in Numeracy and Literacy Test

No. Subject	Pretest score	Posttest score	Improvement
1	37.5	75	37.5
2	56.25	100	43.75
3	43.75	87.5	43.75
4	43.75	81.25	37.5
5	62.5	93.75	31.25

Based on Table 10, all subjects experienced an increase in scores. Subject 1 experienced an increase of 37.5. Subject 2 scored 56.25 on the pretest and 100 on the posttest. Subject 3 scored 43.75 on the pretest and 87.5 on the posttest. Subjects 2 and 3 showed the highest increase, which was 43.75. Subject 4 scored 43.75 on the pretest and 81.25 on the posttest, with an increase of 37.5. Meanwhile, subject 5 scored 62.5 on the pretest and 93.75 on the posttest, with an increase of 31.25.

The data on the increase in the pretest and posttest scores of the five subjects is visualized in Figure 4, which shows an increase in numeracy literacy skills in all students after using the learning media. These results indicate that the developed media is suitable for use in improving the numeracy literacy skills of deaf students.

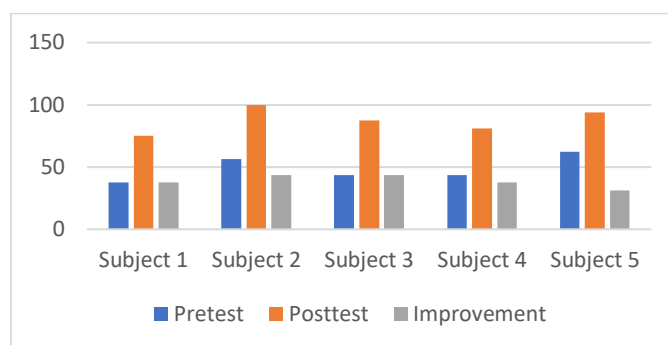


Figure 4. Data of Increase in Pretest and Posttest

The data was then analyzed using nonparametric statistics with the Wilcoxon Signed Rank Test. The test results can be seen in Table 11 below.

Table 11. Wilcoxon Signed Rank Test

Test Statistics <sup>a</sup>	
Z	POST_TEST - PRE_TEST -2.041 <sup>b</sup>
Asymp. Sig. (2-tailed)	.041

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Source: SPSS Results (2026)

Based on the results of the analysis above, we can see that the significance value obtained is 0.041, which means that this value is  $< 0.05$ . So, it can be concluded that there is a difference between before and after using RME-based e-comic media.

The - Gain test was conducted to determine the extent of the e-comic media's influence on student learning outcomes. The N-Gain calculation was performed using SPSS, and the results can be seen in Table 12 below.

Table 12. N-Gain Descriptive Statistics of Students' Numeracy Literacy Scores

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
NGain_Score	5	.60	1.00	.7756	.15524
NGain_Percent	5	60.00	100.00	77.5556	15.52378
Valid N (listwise)	5				

Based on the above analysis, it can be seen that the average N-Gain score is 0.7756 and the N-Gain percentage is 77.55%. The distribution of N-Gain scores shows an average of 0.7756 in the high category and N-Gain effectiveness with a value of 77.55% in the effective category. These results show similarities and even an increase in effectiveness compared to previous findings using similar media. Research by Saragih & Siregar (2025) on the development of RME-based electronic comics shows that the N-Gain value obtained is 0.73. Yuniawati et al. (2024) in their development of RME-based e-comics obtained an N-Gain score of 0.7. Asria et al. (2024) in their research on RME-based e-comics, they obtained an N-Gain score of 0.5485, which is in the moderate category. Then, research by Irmaya et al. (2024) on PBL-based e-comics obtained an N-Gain value of 0.68, which is in the medium category. Umam & Iriani (2024) in their research on PBL-based math comics obtained an N-Gain score of 0.72. In addition, research developed by Sastrawati & Budiono (2025) on PBL-based mathematics comics showed an N-Gain score of 0.68 in the experimental class and 0.42 in the control class, which is in the moderate category, meaning that the improvement in the experimental class was greater after the treatment. The average N-Gain score of 0.7756 obtained in this study is in the high category and is comparatively superior to the results of similar studies. This difference indicates that PBL e-comics with

the RME approach consistently improve students' abilities. Therefore, it can be concluded that the developed e-comics are effective and suitable for use.

From the teachers' perspective on the learning process, the significant improvement in students' post-test scores and high N-Gain values indicate that the learning model and approach used were able to support the learning process. These results indicate that RME-based e-comics with the PBL model can help deaf students understand abstract integer concepts. This improvement is reflected in the students' ability to interpret numerical information, analyze contextual problems, and apply mathematical reasoning.

After the implementation stage, there were several aspects of the developed e-comic that distinguished it from similar learning media that had been reported previously. In terms of comic design, the main advantage lies in the visual presentation that greatly supports the learning characteristics of deaf students. The use of clear illustrations, sequentially arranged panels, and simple text helps reduce linguistic barriers for students, allowing them to focus more on understanding mathematical concepts. In addition, the visual narrative linked to everyday contexts makes the abstract concept of integers more concrete and easier to understand.

Another advantage of this e-comic is its ease of use, which allows students to learn independently and repeat the material as needed without relying on the teacher's explanation. This accessibility supports student understanding both during and after the learning process. The effectiveness of these visual features and designs is reflected in measurable improvements in learning outcomes. The improvement in students' numeracy literacy skills is evidenced by pre-tests and post-tests that show high N-Gain scores. These findings confirm that the improvement is a direct result of the learning intervention using RME-based e-comics with the PBL model.

Furthermore, RME-based e-comics with the PBL model show potential for application to other mathematics topics and different levels of education. Further development can focus on refining visual and interactive features to increase student engagement, as well as on implementation support through educator assistance so that this media can be used optimally in various learning contexts. Further research is also needed to test the sustainability of the impact of this intervention in the long term.

### 3.5. Evaluation Stage

The evaluation stage is carried out at every stage of the research. Evaluation in this development research is carried out formatively at each stage of the ADDIE model to ensure the quality and effectiveness of the product. Evaluation at the analysis stage is carried out by the supervisor to help find solutions to problems. This evaluation is carried out when selecting the type of media, learning approach and model, and material selection. Evaluation at the design stage is also carried out by the supervisor, where the supervisor evaluates the e-comic and the instruments that have been created. At the development stage, evaluation is obtained from three experts as validators, who will provide comments and suggestions for improvements to the media.

Previous research by Rahmasantika & Prahmana (2022), which developed an RME-based e-comic to foster critical thinking skills in deaf students, was validated by validators and found to be practical based on student responses with an average percentage of 66.67%. Additionally, research by Fitriani et al. (2025), which developed an e-comic supported by the RME approach on three-dimensional space material, was declared 80% valid and 87% practical. Harisman et al. (2023), in their research on e-comics, obtained a validity score with an average of 91.2%, a practicality score from students of 89.98%, and from teachers of 84.02%. These studies support the results of the research conducted that the development of RME-based e-comics with the PBL model is effective in improving the numeracy literacy skills of deaf students.

## 4. CONCLUSION

Based on the results of the research and discussion described above, it can be concluded that RME-based e-comic media with the PBL model can improve the numeracy literacy of deaf students in grade

VII at SLB BC YMS Wonogiri. The development of this media achieved a high validity level with an average score of 89.02% and a practical level of 82.19%, categorized as highly practical. Furthermore, the media proved effective in enhancing student performance, as evidenced by a high average N-Gain of 0.77. Despite these positive results, the study is limited by its small sample size and the lack of a control group, which may affect the generalizability of the findings to broader populations.

Practical implications of the study suggest that educators should adopt these RME-based e-comics as a viable alternative teaching medium to create more inclusive and engaging mathematics lessons. Additionally, curriculum developers are encouraged to integrate similar interactive digital resources into the special education curriculum to better support diverse learning needs. For future research, it is recommended that studies involve larger, more diverse samples and compare multiple media types to further establish the effectiveness of digital tools in special education. Future researchers can also explore the integration of more advanced interactive features to ensure even higher levels of student participation and independent study.

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