AXIOM : Jurnal Pendidikan dan Matematika
(2025) Volume 14, No. 1, Page 126-140
https://doi.org/10.30821/axiom.v14i1.22007

Development of a PBL-Based e-module to improve the critical thinking skills of deaf and speech-impaired students

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Received: 07 November 2024 / Accepted: 05 June 2025 / Published Online: 30 June 2025

Abstract

In mathematics education, the integration of innovative approaches is essential to support deaf students' mastery of mathematical concepts. Students with special needs exhibit learning characteristics distinct from their typically developing peers, requiring educators to possess specialized pedagogical skills that facilitate the development of critical thinking.. Observations conducted at a Special School (SLB) in Sorong City revealed that mathematics instruction remained conventional and lacked teaching materials capable of effectively stimulating critical thinking among students with special needs. This study, therefore, aims to develop an interactive e-module grounded in Problem Based Learning (PBL) that is valid, practical, and effective in enhancing critical thinking skills. The research employed the ADDIE model and involved 10 SDLB students as participants. The resulting e-module received a material expert validity score of 4.46 and an average media expert validity of 3.36. Furthermore, the average student score of 54.09 indicated that this e-module was effective in fostering students' critical thinking skills. In terms of learning outcomes, the average pretest score of 30,100 increased to 84,500 post-intervention, with an average N-gain of 54.00, classified within the "highly effective" category. These findings suggest that the development of PBL-based-e-modules significantly enhnaces the critical thinking skills of deaf and speech-impaired studentsspeech-impaired.

Keywords: Development, E-module, PBL, Critical Thinking Skills, Deaf and Speech-Impaired

How to Cite: Musaad, F., Hidayani, H., Rusnia, W.O., Bafadal, S., & Sulkipli, S. (2025). Development of a PBL-Based e-module to improve the critical thinking skills of deaf and speech-impaired students. *AXIOM : Jurnal Pendidikan dan Matematika, 14*(1), 126-140. https://doi.org/10.30821/axiom.v14i1.22007

Introduction

In the context of 21st century education, Information and Communication Technology (ICT) plays a critical role, especially in mathematics instruction, in fostering critical thinking skills and enabling students to solve complex problems (Rahayu et al., 2022; Siregar et al., 2025). Critical thinking in mathematics is fundamental, as it enables students to comprehend, analyze, and communicate concepts and solutions that are relevant to real-world challenges.

However, cultivating thinking skills among deafspeech-impaired students presents distinctive challenges on a global scale. International research (Bonk & Smith, 1998; Chikeleze et al., 2018) highlights that communication barriers hinder students with hearing loss from processing abstract information and constructing logical arguments. Limited access to visual-based learning resources and assistive technologies further impedes their ability to engage effectively in conventional classroom settings.

To mitigate these barriers, mathematics instruction aimed at developing critical thinking must adopt inclusive, ICT-enabled strategies. Tools such as interactive visual-based software, sign language-integrated applications, and image-driven mathematical simulations can support deaf students in building conceptual understanding and linking abstract ideas to practical experiences speech-impaired (Sadewo et al., 2022). Additionally, collaborative learning techniques utilizing visual media can strengthen their analytical skills, enabling them to synthesize information, identify alternative solutions, and make data-informed decisions.

Global initiatives, such as the educational inclusion agenda (Global Education Monitoring Report Team, 2024) underscore the imperative of equitable access for all learners, including those with communication challenges. By promoting the development of critical thinking through technological innovation, mathematics education can become more inclusive-ensuring that deaf students have the opportunity to contribute meaningfully within an increasingly interconnected societyspeech-impaired.

Nevertheless, observational findings in Special Schools (SLB) in Sorong City indicate low levels of critical thinking among students. To substantiate this, researchers administered questions aligned with critical thinking indicators, revealing that only 10% of students demonstrated critical thinking proficiency. One contributing factor is the lack of open-access materials designed to foster these skills. Critical thinking encompasses the abilities to analyze, solve, and evaluate problems (Parameswari & Kurniyati, 2020; Reilly et al., 2019) According to (Rosmalinda et al., 2021), enhancing these abilities requires a pedagogical model capable of stimulating student engagement in higher-order thinking processes. Problem-Based Learning (PBL) is one such model (Musaad & Suparman, 2023; Wahyu Ariyani & Prasetyo, 2021).

It introduces students to real-world problems from the outset, thereby cultivating critical thinking in deaf learners (Kolo et al., 2021; Kusuma, 2021). PBL transforms the learning process into an active, inquiry-based experience that promotes deeper intellectual engagement (Baker et al., 2004; Hidayani et al., 2021; Rosmalinda et al., 2021; Zeng et al., 2016). Despite its potential, observations in SLB classrooms show that teachers continue to rely on traditional printed materials not integrated with sign language or designed to enhance critical thinking. Lectures remain the primary mode of instruction, with minimal opportunities for students to analyze, evaluate, and apply problem-solving strategies (Musaad & Suparman, 2023).

Moreover, students frequently use mobile phones during lessons, diverting attention from instructional activities. In response, this study aims to develop an interactive, creativity-oriented e-module based on Problem-Based Learning to improve the critical thinking skills of deaf students.

Methods

This Research and Development (R&D) study employed the ADDIE model, Analyze, Design, Development, Implementation, Evaluation, as its framework (Marianto et al., 2024). The research was conducted on August 18, 2024, at a Special Elementary School in Sorong City, involving a sample of 10 deaf students. Instruments utilized included pretest and posttest assessments, expert validation forms for media and content, and practicality questionnaires for the e-module. The following outlines the research procedures based on the ADDIE phases:

1. Analysis
   In this initial phase, the researcher conducted three types of need analysis:
   a. Material Analysis: Identified, explored, and organized instructional content relevant to the curriculum.
   b. Student Character Analysis: Assessed students' abilities, prior knowledge, developmental levels, skills, and learning attitudes.
   c. Condition and Situational Analysis: Investigated classroom dynamics and the instructional techniques currently used during mathematics lessons.
2. Design
   The proposed product was an interactive video-based e-module integrating Problem-Based Learning (PBL) to enhance the critical thinking skills of students who are deaf. Key design elements included: speech-impaired
   a. Problem Orientation: Students were introduced to video stimuli featuring visual cues and scenarios on addition and subtraction word problems tailored for learners with special needs (ABK)
   b. Group Organization: Students were divided into collaborative groups to solve contextual problems.
   c. Work Presentation: Groups presented the results of their discussions to their peers.
   d. Outcome Evaluation: Teachers and students collaboratively assessed the learning outcomes and process.
3. Development
   The initial design was constructed and subsequently validated by a team of subject-matter experts. Revisions were made based on expert feedback to strengthen content quality and instructional design.
4. Implementation
   Pilot testing was first conducted in small groups. Following a revision based on initial results, the e-module was then implemented in a broader classroom setting to examine scalability and effectiveness.
5. Evaluation
   The final phase involved a comprehensive evaluation encompassing the validity, practicality, and effectiveness of the developed e-module, as evidenced by the collected data.

A visual representation of the e-module development stages is provided in Figure 1.

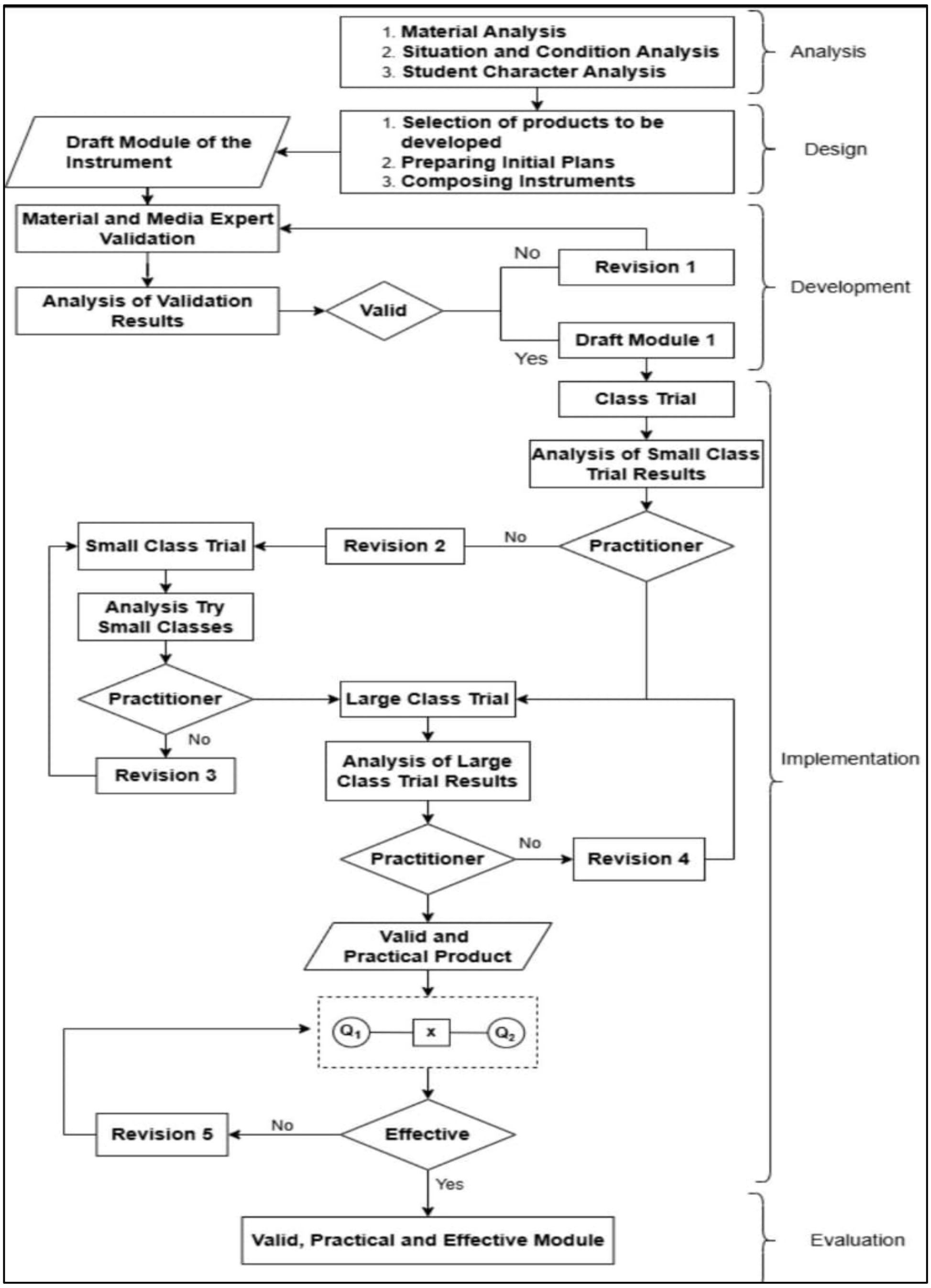

Figure 1. Research Flow Diagram

Data Analysis Techniques

1. Electronic module validation
   The validity of the multimedia module was assessed using an expert validation instrument, which consists of five response categories rated from 1 to 5. The scores provided by validators were analyzed by calculating the mean score, using Formula 1.

$$V = \frac{\sum xi}{n} \quad (1)$$

Description :
V = average score
$\sum xi$ = total score from all validators
n = number of items evaluated

The resulting average score was then interpreted using predefined validity categories, as shown in Table 1.

Table 1. Multimedia Validity Level Category

Number	Mean	Criteria
1	$V = 5$	Very Valid
2	$4 \leq V < 5$	Valid
3	$3 \leq V < 4$	Quite Valid
4	$2 \leq V < 3$	Less Valid
5	$1 \leq V < 2$	Not Valid

Source: (Kurniawan, 2021)

2. Practicality of the E-Modul
The practicality of the e-module was evaluated through student response questionnaires administered during its use. These questionnaires captured students' experiences and perceptions regarding the e-module's functionality and usability. The results of this analysis are summarized in Table 2.

Table 2. Practicality Criteria

No	Mean	Criteria
1	$80\% \leq \bar{x} \leq 100\%$	Very Practical
2	$60\% \leq \bar{x} < 80\%$	Practical
3	$40\% \leq \bar{x} < 60\%$	Quite Practical
4	$20\% \leq \bar{x} < 40\%$	Not Practical
5	$0\% \leq \bar{x} < 20\%$	Very Impractical

Source: (Riduan et al., 2021)

3. Effectiveness of the electronic modules
The effectiveness of the electronic module was evaluated by comparing the mean scores and by administering a critical thinking ability test. The test items were developed based on the indicators of critical thinking skills, as presented in Table 2, to provide a more comprehensive measurement of learning outcomes. The statistical analysis was conducted using a Paired Sample T-Test. Prior to conducting the t-test, a normality test was performed to ensure the data met parametric assumptions.
   a. Normality Test
   The normality of the data was assessed for two groups: pre-test and post-test scores. Both the Kolmogorov–Smirnov and Shapiro–Wilk tests were applied. The hypotheses for normality testing are defined as follows:
   - H_0: Pre-test and post-test data are normally distributed
   - H_1: Pre-test and post-test data are not normally distributed
   Decision criteria:
   - If sig > 0.05, then H_0 is accepted and H_1 is rejected
   - If sig < 0.05, then H_0 is rejected and H_1 is accepted
   b. *Paired Sample t Test*
   The paired sample t-test (Formula 2) was used to identify differences in critical

thinking performance before and after the use of the e-module. This statistical test compares the means of two related samples—in this case, the pre-test and post-test scores of the same group.

$$t_{hit} = \frac{D}{\frac{SD}{\sqrt{n}}} \tag{2}$$

Where:

SD = $\sqrt{Var}$

Var (s^2) = $\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$

T = t-value

D = mean difference between pre-test and post-test

SD = Standard deviation of the difference

n = number of samples

c. *N-Gain Score*

The N-Gain (Formula 3) Score was calculated to assess the effectiveness of the PBL-based interactive module.

$$Gain = \frac{\mu_{post} - \mu_{pre}}{Maximum\ Score - \mu_{pre}} \tag{3}$$

Description:

$\mu_{post} = Post - test$ score

$\mu_{pre} = Pre - test$ score

Table 3. Critical Thinking Ability Indicators

	Indicator
Critical Thinking Skills	Formulating problems
	Analyzing
	Answering questions
	Assessing the credibility of information sources

(Source: Arifin, 2017)

Effectiveness categories based on the N-Gain Score are presented in Table 4.

Table 4. Categorization of N-Gain Effectiveness

N-Gain Score	Interpretation
0,7< $Gain$	Tall
0,3≤ $Gain$ ≤ 0,7	Currently
$Gain$ < 0,3	Low

Source: (Musa et al., 2023)

Results

Needs Analysis

The results of the student characteristics analysis indicate that deaf and speech-impaired students exhibit relatively low levels of critical thinking skills. To support this observation, the researcher administered assessment questions aligned with critical thinking indicators. The results revealed that only 30% of students successfully completed the tasks.

This outcome may be attributed to students' limited exposure to learning activities that stimulate critical thinking. Instructional approaches have largely remained conventional, where students passively listen to lectures, observe examples provided by the teacher, and replicate those examples without engaging in active inquiry or group-based learning. Notably, collaborative learning models have not yet been integrated into the classroom environmentspeech-impaired.

Design

An interactive e-module grounded in Problem-Based Learning (PBL) principles was designed to enhance the critical thinking skills of deaf and speech-impaired students. The module was developed for use in SDLB (Sekolah Dasar Luar Biasa) schools in Sorong City and serves as an open teaching resource. It is intended to provide opportunities for students to engage with content that stimulates reasoning, analysis, and problem-solving through structured PBL activities.

An illustration of the designed e-module is presented in Figure 2.

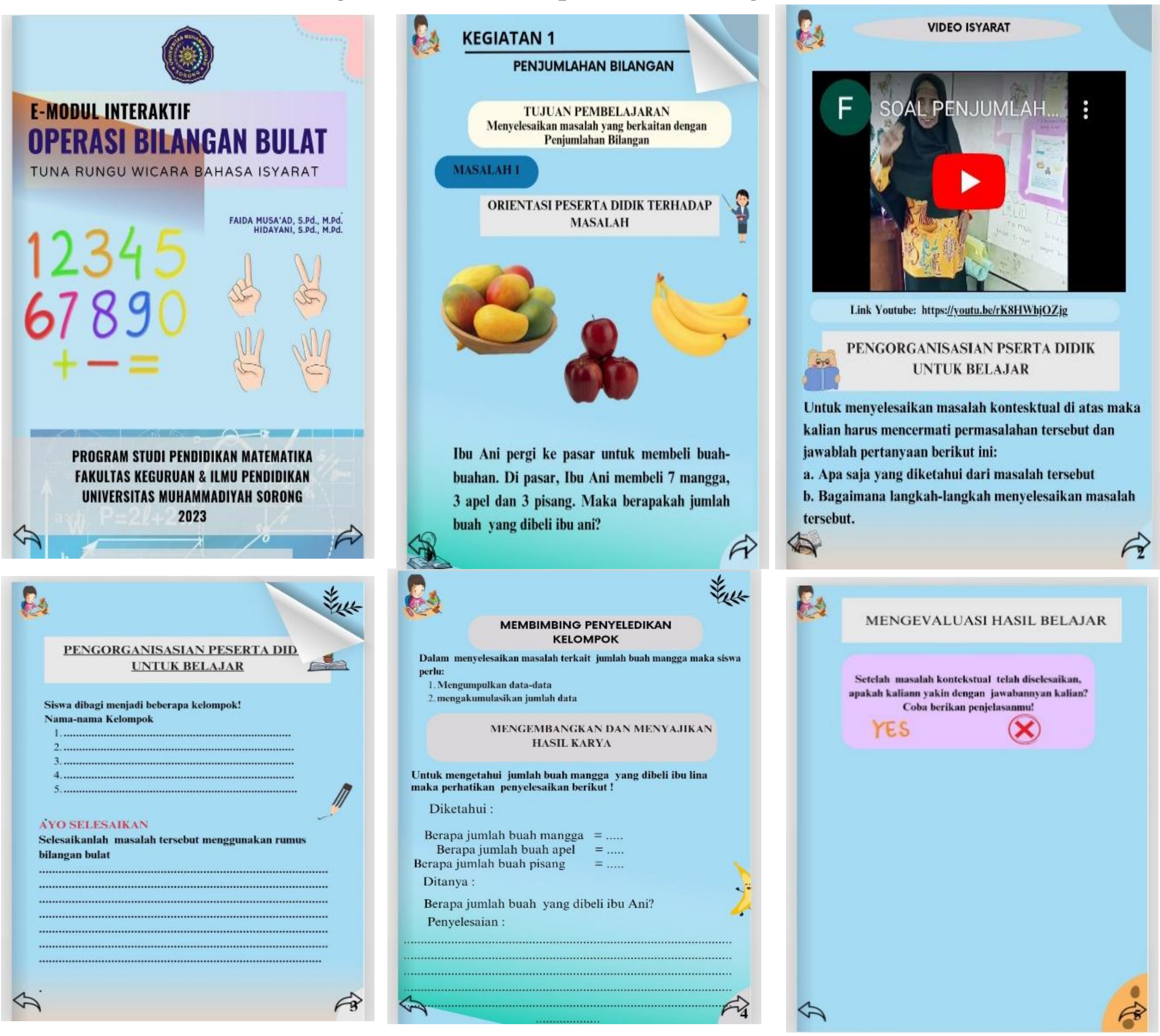

Figure 2. E-Module PBL To Improve Critical Thinking

Development

During the development phase, the researchers conducted validation assessments with several media and subject-matter experts. These evaluations aimed to refine the e-module to enhance its appeal and effectiveness, particularly for deaf students with special learning needs.

The resulting e-module was designed to reflect real-life contexts, guide students in structured learning activities, facilitate problem identification and resolution, support the presentation of findings, and encourage the dissemination of work.

Validation results from subject-matter experts are summarized in Table 5.

Table 5. Subject Matter Expert

Validator	Average
Validator 1	4,7
Validator 2	4,2
Validator 3	4,5
Average	**4,46**

The average score presented in Table 4 indicates that the developed module falls within the “valid” category. Subsequently, the researcher sought further evaluation from media experts, who provided several constructive revisions to enhance the module's visual appeal and usability. Notable feedback included improvements to color selection, emoji layout consistency, and overall design adjustments to make the module more engaging for deaf students with special needs.

Feedback from material experts regarding the validity of the content is summarized in Table 6. The media expert assessment results are outlined in Table 7.

Table 6. Material Expert Revisions

Validator	Feedback and Suggestions
Validator 1	The questions lack contextual relevance and should incorporate images to stimulate analysis.
Validator 2	Indicators of critical thinking skills must be framed in a way that is accessible to young learners
Validator 3	The questions should be adjusted to match students’ cognitive abilities.

Table 7. Media Expert Assessment

Validators	Average
Validators 1	4,3
Validators 2	4,5
Validators 3	4,3
Average	4,36

Table 6 confirms that the module achieved a mean score of 4.36, placing it within the valid category. However, improvements were relatively minor, indicating the module's baseline quality. Nevertheless, researchers are advised to refine various elements of the e-module, such as: Ensuring transparent color contrast, maintaining consistent font and image sizing, Harmonizing layout features to enhance accessibility and engagement for learners with special needs. Detailed comments from media experts are presented in Table 8.

Table 8. Media Expert Revision

Validators	Comment
Validators 1	Font size is not optimized for open materials on Android platforms. Background design should be updated for better visual appeal Student answer layout requires improved alignment
Validators 2	Address typographical errors, especially in investigative sections Revise numbering in Question 4 to ensure clarity; avoid misplaced punctuation.
Validators 3	-

Implementation

During the implementation phase, the researcher conducted both small- and large-group trials. The small-group trial involved 5 deaf-speech-impaired students, while the large-group trial included 10 third-grade deaf-speech-impaired students. The learning process followed the Problem-Based Learning (PBL) model with a total duration of 90 minutes. The PBL syntax was applied as follows:

1. Problem Orientation (10 minutes)
   Students were introduced to contextual problems involving addition and subtraction of integers. To ensure comprehension, the researcher provided a video in which the teacher explained the problem using finger gestures tailored to the students' needs.
2. Problem Organization (5 minutes)
   Students worked in groups to identify known information, determine what needed to be solved, and decide on appropriate steps. The problems embedded indicators of critical thinking and were integrated with the e-module.
3. Group Investigation (50 minutes)
   Within their groups, students discussed problem elements, formulated hypotheses, and refined their understanding. The teacher guided the process and provided support throughout.
4. Presentation of Work (15 minutes)
   Students presented their solutions using finger gestures in front of the class. This stage supported peer learning and expression.
5. Evaluation (10 minutes)
   The teacher reviewed the students' work, provided feedback on errors, and reinforced learning objectives.

One notable challenge during implementation was the need for repeated instruction to support deaf students' understanding of problems aligned with critical thinking indicators. As a result, additional time was often required to ensure full engagement and comprehension.

A practicality questionnaire was distributed to assess student perception of the e-module. Results indicated that 9 students rated it as “very good,” and 1 student rated it as “good.” The overall student response rate of 79% placed the module in the “practical” category.

Evaluation

In the evaluation phase, the researcher identified areas for improvement in the implementation of the e-module to ensure its suitability for classroom use. A pre-test was administered to measure students’ critical thinking skills prior to the intervention, followed by a post-test after the PBL-based e-module had been implemented.

The results of the pre-test and post-test were analyzed using descriptive statistics, as presented in Table 9.

Table 9. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Pre-test	10	.0	65.0	30.100	20.8191
Post-test	10	75.0	100.0	84.500	7.9757
Valid N (listwise)	10				

a. Paired Sample T-test Analysis

Prior to conducting the paired sample t-test, a normality test was performed as a prerequisite using SPSS version 22.

1. Normality Test

The normality assessment was conducted on the pre-test and post-test data using the Kolmogorov–Smirnov and Shapiro–Wilk tests. The results are presented in Table 10.

Table 10. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Pretest	.133	10	.200*	.964	10	.826
Posttest	.214	10	.200*	.917	10	.329

* This is a lower bound of the true significance.

Note: Lilliefors Significance Correction applied

The purpose of this test is to determine whether the dataset follows a normal distribution. Based on the Shapiro–Wilk test results shown in Table 10, both the pre-test and post-test data yielded significance values greater than 0.05. Therefore, the data can be considered normally distributed and suitable for further analysis using parametric methods. The subsequent section presents the results of the paired sample t-test analysis.

2. Paired sample t-test analysis

Table 11. Paired Sample T-test

		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	-54.4000	18.0813	5.7178	-67.3346	-41.4654	-9.514	9	.000

In table 11 it can be seen that the sig value (2-tailed) < 0.05, this shows that there is a difference after and before the implementation of PBL-based e-modules in improving students' critical thinking skills. The next stage is the N-gain test.

3. N-gain Test

Table 12. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NGain	10	33.44	79.90	54.0990	18.27414
Valid N (listwise)	10				

Table 12 shows that the average N-gain of 54.09 is included in the very effective category. Thus, it can be said that the e-module based on PBL and critical thinking mathematics is effective to use.

Discussion

The learning process was conducted over four sessions, each integrating the stages of the Problem-Based Learning (PBL) model with indicators of critical thinking skills. During the first session, deaf students required time to adjust to the PBL approach, which began by presenting real-world problems. Despite initial unfamiliarity, the lesson proceeded smoothly in a conducive learning environment. By the second session, students began to adapt to the PBL-based group learning format, showing increased engagement and enthusiasm. This observation aligns with (Dahlan, 2019), who noted that group-based learning can prevent boredom among deaf students by fostering interactive participation. In the third session, student enthusiasm continued to rise, supported by the presence of a specialized teacher for deaf students. The interactive e-module, which was accessible via mobile phone, contributed positively to student motivation. As Rahmadhani (Rahmadhani, 2022) observed, mobile devices are effective tools for enhancing student focus during the learning process. Similarly, Mukaromah (Mukaromah, 2020) emphasized that the integration of technology acts as a stimulus for learner engagement. Throughout these sessions, the e-module—designed with embedded indicators of critical thinking—encouraged students to practice and develop higher-order thinking skills. Ririn et al. (Ririn et al., 2021) asserted that critical thinking must be nurtured consistently through student routines embedded in classroom instruction.

The practicality of the developed e-module was demonstrated through student questionnaire responses, with 80% of deaf students indicating a positive experience—placing the module in the “good” category. Its effectiveness during classroom implementation is further supported by student performance data. Specifically, the post-test results for critical thinking skills surpassed the Minimum Mastery Criteria (KKM), signifying meaningful learning gains. As shown in Table 9, the average N-Gain score reached 54.0, categorizing the module’s effectiveness as "high." This improvement reflects the importance of selecting an appropriate instructional model that promotes critical thinking—consistent with the view of (S.Sirate & Ramadhana, 2017), who emphasized that well-designed e-modules enhance student learning outcomes.

This improvement is also consistent with the e-module’s intended purpose: to strengthen students’ critical thinking skills through structured engagement. Evidence from student responses highlights notable progress. In the pre-test, students demonstrated the ability to analyze contextual problems, but they struggled to formulate solution steps, resolve problems, and draw written conclusions. The average score at this stage was 30, indicating a low proficiency level. Following the implementation of the PBL-based e-module—designed around critical thinking indicators—students exhibited significant growth. The post-test yielded an average score of 84, placing their performance in a substantially higher category. Students were able to analyze problems, determine solution strategies, solve the problems effectively, and articulate conclusions in writing.

Conclusion

Based on the study's findings and discussion, it can be concluded that the interactive e-module based on Problem-Based Learning (PBL) effectively enhances students' critical thinking skills. This is evidenced by the increase in average scores—from 30.10 on the pre-test to 84.50 on the post-test. Furthermore, the N-Gain score reached 54.00, placing it in the "very effective" category.

Future research could explore the development of alternative learning media beyond e-modules, such as Android-based interactive applications, educational videos, or instructional games that further support PBL-based instruction. Additionally, subsequent studies may adapt e-module development to better accommodate the unique needs and characteristics of students with diverse disabilities in SDLB settings, including visual impairments, hearing loss, and autism spectrum conditions.

Acknowledgement

The author gratefully acknowledges the support and contributions that made this research possible. Special thanks are extended to the Principal of SDLB Inpres 73 Sorong City and the dedicated teachers who facilitated the e-module implementation in the classroom. Appreciation is also conveyed to the Ministry of Education, Culture, Research, and Technology for providing research grants through the PkM Batch 2 program.

It is hoped that the outcomes of this research can serve as practical teaching material for SDLB schools—particularly in mathematics—and inspire similar instructional innovations across other subject areas.

Declarations

Author Contribution	:	FM : Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing, Project Administration. H : Methodology, Formal Analysis, Data Curation, Writing – Review & Editing. WOR: Data Curation, Formal Analysis. SB : Investigation, Resources. S : Formal analysis.
Funding Statement	:	This research was funded by a novice lecturer research grant provided by the Ministry of Education and Culture (Kemdikbud) through the Directorate General of Higher Education
Conflict of Interest	:	The authors declare no conflict of interest
Additional Information	:	Additional information is available for this paper.

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