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Pedagogical scaffolding strategies for supporting students with mathematical learning difficulties in special education

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Abstract

Students with special needs, including those with speech impairments, often face challenges in learning mathematics and therefore require specialised strategies, such as scaffolding, to enhance their mathematical understanding. This study aimed to examine how scaffolding strategies support students with speech impairments in overcoming difficulties in learning mathematics in a special school setting. This qualitative case study involved one teacher and five students with speech impairments, selected through purposive sampling. Data were collected through observations, tests, interviews, and audio and video recordings. Data analysis was conducted in three stages: data reduction, data display, and conclusion drawing and verification. The findings show that the teacher's scaffolding aligned with six aspects of the Mäkinen and Mäkinen framework: activation, presence, sensitivity, assistance, trust, and autonomy. Activation and assistance were the most strongly associated with improved conceptual understanding. The students demonstrated the ability to define, represent, and calculate the perimeter of squares and rectangles. Visual aids, concrete objects, and multimodal communication (oral, gestural, and sign language) enhanced understanding. Integrating visual, kinesthetic, and nonverbal strategies provides meaningful support for students with speech impairments, and the six-dimensional scaffolding framework serves as a practical guide for inclusive instructional design.

Keywords: mathematics learning difficulties; scaffolding strategies; special school

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Introduction

Mathematics is a core subject taught universally across all levels of education, playing a pivotal role in nurturing the logical, critical, and systematic thinking skills necessary for solving real-world problems (Ukobizaba et al., 2021). In Indonesia, the obligation to teach mathematics extends to special schools for students with special needs, known as *Sekolah Luar Biasa* (SLB), where educational delivery must be adapted to diverse learner profiles (Phutane et al., 2022).

Mathematics is deeply integrated into everyday life and requires both conceptual and procedural understanding (Khan & Krell, 2019). However, students with special needs, particularly those with speech impairments, often encounter challenges in learning mathematics due to limited verbal communication, difficulty in interpreting symbols, and barriers to classroom interaction (Fuchs & Fuchs, 2002; Yantoro et al., 2021; Young et al., 2002). These barriers can hinder the comprehension of abstract concepts and reduce opportunities for collaborative learning activities (Wainscott & Spurgin, 2024).

Given these challenges, there is a critical need for adaptive instructional strategies that can accommodate communication limitations while also supporting conceptual learning. Students with speech impairments tend to rely more on visual aids, concrete experiences, and alternative communication methods to understand mathematical ideas (Ashqar & Atawnih, 2025; Byrne et al., 2023). Visual scaffolds, gesture-based cues, and step-by-step demonstrations can enhance access to mathematical content, especially when combined with supportive technologies (Cagıltay et al., 2019; Herawati & Anjany, 2025; Lin & Riccomini, 2025).

To ensure inclusive education, the Indonesian government issued Regulation No. 48 of 2023 concerning Reasonable Accommodation (Akomodasi yang Layak) for students with disabilities. This regulation mandates equitable and quality education through tailored instructional strategies that accommodate the learning needs of students with impairments, including those with limited speech (Kemdikbudristek, 2023). In practice, schools like *Sekolah Luar Biasa Tunarungu Yayasan Pembinaan Anak Cacat* (SLB-B YPAC) Banda Aceh, a special school for students with speech impairments, encounter persistent challenges in mathematics instruction due to limited access to assistive tools, difficulties in conceptualising abstract mathematical ideas, and reduced student participation due to communication barriers.

Scaffolding has emerged as a promising pedagogical strategy to address these challenges. Unlike general instructional methods, scaffolding offers temporary individualised support that is gradually withdrawn as learners gain competence (Slavin, 2008). When applied to students with speech impairments, scaffolding may include the use of manipulatives, diagrams, written instructions, and nonverbal cues, which are strategies that align with students' preferred learning modalities and communication styles (Jannah et al., 2019; Siller et al., 2023). By reducing the reliance on verbal instruction, scaffolding helps bridge cognitive gaps and fosters learner autonomy (Anghileri, 2006).

Several recent studies (e.g., Susilo & Prihatnani, 2022; Prabaswara & Pratama, 2023; Faber et al., 2024; Lim et al., 2024; Ashqar & Atawnih, 2025) suggest that the effectiveness of scaffolding lies in its ability to provide structured and adaptive support that aligns with students' individual learning needs. The indicators of effectiveness in these studies included increased conceptual understanding, improved task completion, and better retention of material. For instance, Susilo and Prihatnani (2022) found that students demonstrated greater accuracy in solving integer problems after receiving step-by-step guidance. Similarly, Prabaswara and Pratama (2023) reported that students demonstrated a practical understanding of monetary values through repeated visual and contextual scaffolding. In a broader context, Faber et al. (2024) showed that adaptive scaffolding in game-based learning environments enhances student performance and reduces cognitive load. Similarly, Lim et al. (2024) demonstrated that real-time personalised scaffolds support the development of self-regulated learning behaviours in diverse classroom settings. Most recently, Ashqar and Atawnih (2025) found that real-time sign language recognition as a scaffolding tool significantly enhanced mathematical understanding among students with speech and hearing impairment. Collectively, these findings reinforce the role of scaffolding in improving academic outcomes and promoting active engagement and learning independence among students with special needs.

Although previous research has demonstrated the general effectiveness of scaffolding in supporting students with learning difficulties, very few studies have specifically focused on its application to students with speech impairments in mathematics learning. Most existing studies either concentrate on students with general learning disabilities or emphasize language-based subjects rather than mathematics. This creates a gap in understanding how scaffolding can be tailored to support students with speech impairments, who face unique communication barriers, in grasping abstract mathematical concepts (Siller et al., 2023; Wainscott & Spurgin, 2024). This study aims to address this gap.

The novelty of this study lies in its application of the six-dimensional scaffolding framework by Mäkinen and Mäkinen (2011) in the context of a special school in Indonesia. By documenting the mathematics teacher's practical strategies for scaffolding students with speech impairments at SLB-B YPAC Banda Aceh, this study contributes unique empirical insights into inclusive mathematics instruction in Indonesia. Therefore, this study aimed to explore how pedagogical scaffolding strategies are implemented to help students with speech impairments overcome mathematical learning difficulties. It also examines which aspects of scaffolding most effectively enhance students' engagement and conceptual understanding.

Methods

This study employed a qualitative approach with a case study design, focusing on the description of events occurring during the mathematics teaching and learning process for students with speech impairments at a special school (*Sekolah Luar Biasa* [SLB]). This case study aimed to explore the experiences and scaffolding strategies used in teaching mathematics to students with speech impairments in an inclusive classroom setting.

A total of six participants were involved in this study, consisting of one mathematics teacher (MR) and five students with speech impairments (AG, AZ, DH, MA, and YA) from SLB-B YPAC Banda Aceh. Participant selection was conducted using purposive sampling guided by specific inclusion criteria. For the teachers, the criteria included having at least several years of experience teaching at an SLB and using scaffolding strategies in mathematics instruction for students with speech impairments. Teachers were not required to have a degree in special education but were expected to demonstrate a strong understanding of the needs of students with communication difficulties. For student participants, the criteria included being diagnosed with a speech impairment and receiving instruction using differentiated methods aligned with their level of mathematical understanding.

The sampling process began with school visits to three SLBs in Banda Aceh City, Indonesia: *SLB Negeri Pembina Provinsi Aceh, SLB Negeri Banda Aceh*, and *SLB-B YPAC Banda Aceh*. The first school had no students with speech impairments, and the second had only one. In contrast, SLB-B YPAC Banda Aceh had five students with speech impairments, making it the most suitable site for this research.

The selected teacher had nine years of teaching experience in special education and held a degree in Biology Education. Although the teacher did not have formal training in special education, they had independently developed expertise in using sign language (both SIBI and BISINDO) and frequently served as a resource person for inclusive education events and disaster simulation interpretation roles. The teacher also conducted sign language workshops in various institutional settings, including universities and correctional facilities.

At SLB-B YPAC Banda Aceh, classrooms are not grouped strictly by grade level but are instead organised based on the individual needs of students using a differentiated-instruction model. The class involved in this study comprised five students with varying degrees of speech impairments. AG had mild speech impairment, could understand oral explanations without sign language, and communicated verbally despite unclear articulation. MA, who also had mild impairment, required supplementary sign language support to comprehend, and sometimes responded with signs. YA had moderate speech impairment, relied on sign language for understanding and expressing ideas, and was nonverbal due to her condition. DH and AZ had severe speech impairments, were fully reliant on sign language, and were unable to vocalize at all. This diverse student profile allowed for an in-depth exploration of how scaffolding strategies could be adapted to various levels of communication ability in mathematics learning.

The researchers then collected data using several qualitative techniques, including observation, testing, interviews, and documentation. These techniques were applied systematically to ensure that the data collected were valid, credible, and aligned with the study's focus. In this study, data collection instruments were categorised into two types: the main instrument and supporting instruments. The researchers served as the main instrument, consistent with the qualitative nature of the enquiry. In this role, the researcher was responsible for designing the study, collecting and analysing data, and presenting the findings.

Supporting instruments included observation sheets, interview protocols for both teachers and students, mathematics comprehension test items, and audio-visual recording devices. The observation sheet was developed based on the scaffolding framework by Mäkinen and Mäkinen (2011), focusing on six key aspects: activation, presence, sensitivity, assistance, trust, and autonomy. Each aspect was represented by specific indicators, totalling 26 items that were operationalised into observable behaviours. These were assessed using a qualitative rating scale comprising five descriptive categories (very good, good, adequate, poor, and not evident). Interview protocols for both teachers and students were designed to gather in-depth insights related to the implementation of scaffolding strategies and students' mathematical understanding.

The teacher interview guide contained 22 questions centred on the six scaffolding aspects, with two to three questions for each aspect and additional prompts to explore challenges, impacts, and reflections. Flexibility in phrasing was allowed to adapt to the respondents' experiences and responses.

The student interview protocol aimed to explore how students with speech impairments understood geometric concepts—specifically, the perimeter of squares and rectangles—and to evaluate how scaffolding supported their comprehension. The student interviews consisted of 25 questions grouped into several themes: concrete learning experiences, conceptual understanding of perimeter, teacher support, use of visual aids and symbols, ability to re-explain concepts, and overall learning experience.

To assess students' mathematical understanding, a written test was administered consisting of four open-ended questions focused on the concept of perimeter. The test items were based on indicators from NCTM (2000), which emphasise defining mathematical concepts verbally and in writing and using diagrams, models, and symbols for representation. The test assessed students' ability to explain and calculate the perimeter of squares and rectangles and represent these figures accurately. Audio and video recording devices were used as essential instruments to capture classroom instruction and interviews. Audio recordings supported the accurate transcription and analysis of teacher responses, while video recordings documented teacher-student interactions and students' reactions to scaffolding during mathematics instruction. These tools provided a rich visual and auditory dataset for deeper analysis and enabled data triangulation alongside observations, interviews, and tests, thereby contributing to the validity and credibility of the findings.

The validity and reliability of the instruments were addressed through expert validation and inter-rater reliability. The supporting instruments were validated by six validators, including three university lecturers specialising in mathematics education and three mathematics teachers with experience teaching in inclusive classrooms. Based on the validation results, the instruments were deemed suitable for use with minor revisions focused on improving the clarity and effectiveness of the language. To ensure reliability, two trained raters independently assessed all observation data and students' mathematical test responses using the established rubrics. The raters compared their results and achieved a high level of agreement (90%) between them. In cases of disagreement, discussions were conducted to reach a consensus.

The data analysis technique used was qualitative data analysis, as outlined by Miles et al. (2014), which involves three stages: data reduction, data display, and conclusion drawing and verification. In this study, all data were analysed manually, without the use of any qualitative data analysis software. Data reduction involved filtering and simplifying the relevant information obtained from observations, interviews, tests, and documentation. Observation data were reduced by identifying teacher–student interactions during the implementation of the scaffolding strategies. The interview data were transcribed and coded to highlight statements related to scaffolding strategies, students' mathematical understanding, and learning difficulties. Test data were used in their original form, as they already represented students' learning achievements. Documentation data were selectively used, focusing on recordings that captured the implementation of scaffolding, while off-topic conversations were excluded from the analysis.

Interview coding was conducted to facilitate data classification and thematic analyses. Table 1 presents the transcript codes used in this study.

Table 1. Teacher and student interview transcript codes

Descriptions	Codes
Teacher interview on Activation aspect	PWA/GWA
Teacher interview on Presence aspect	PWB/GWB
Teacher interview on Sensitivity aspect	PWC/GWC
Teacher interview on Assistance aspect	PWD/GWD
Teacher interview on Trust aspect	PWE/GWE
Teacher interview on Autonomy aspect	PWF/GWF
Student interview (AG)	PWAG/SWAG
Student interview (YA)	PWYA/SWYA
Student interview (MA)	PWMA/SWMA

The data display was organised systematically. The observation data are presented in tables detailing the scaffolding strategies and corresponding student responses. Interview data are presented as narrative excerpts to illustrate students' levels of understanding and learning challenges. The test results were displayed using images of student work to demonstrate progress in mathematical understanding. Documentation data were integrated into the presentation of observations, interviews, and test results to provide a comprehensive depiction of the learning process of the participants.

Conclusions were drawn based on the interpretation of the data obtained using multiple methods. Triangulation techniques were employed to ensure the validity and consistency of the findings. This included comparing data from classroom observations, teacher and student interviews, mathematics tests, and audio and video documentation. Cross-checking these sources helped verify the consistency of teacher scaffolding practices and student responses. When inconsistencies appeared, further verification was conducted through follow-up interviews and peer discussions, ensuring that the conclusions accurately reflected classroom realities.

Results

This study aimed to explore the scaffolding strategies used by a mathematics teacher to support students with speech impairments in overcoming learning difficulties in mathematics. The results and discussion below describe the observed scaffolding practices and interview findings related to these strategies as applied in a special-education setting.

The mathematics teacher, referred to as "MR", was observed across four learning sessions with students with speech impairments at SLB-B YPAC Banda Aceh. The mathematical topics covered during these sessions were circles (Session I), triangles (Session II), squares (Session III), and rectangles (Session IV). The observations were followed by debriefing and feedback sessions with the MR. At the end of the data collection process, a comprehensive interview was conducted to confirm the scaffolding strategies employed. Both the observation and interview components were analysed using Mäkinen and Mäkinen's (2011) scaffolding framework, which includes six aspects: activation, presence, sensitivity, assistance, trust, and autonomy. The findings for each aspect are presented below:

Activation

Scaffolding observations in the activation domain revealed that the MR employed collaborative strategies using nonverbal communication and visual media (e.g. number cards, diagrams, concrete objects), with increased frequency from Sessions I to IV. By the final session, MR was actively connecting new materials to concepts that were already familiar to the students.

The interview results confirmed that MR implemented scaffolding by initially identifying students' needs through formative assessments, selecting engaging media, tailoring instruction to student characteristics, and collaborating with parents. MR emphasised the diversity of abilities among students with speech impairments and adjusted her instruction accordingly (GWA.1, GWA.3, GWA.4). The approach included adaptations for different communication modes, such as spoken and sign languages, as needed (GWA.2).

To introduce mathematical concepts, the MR used a variety of tools, including pictures, videos, props (e.g. rope to form a circle), and hand gestures (e.g. mimicking the shape of a triangle) (GWA.1, GWA.2). These tools were designed to capture attention and stimulate curiosity (GWA.2). Connections were drawn between new learning materials and real-life objects (e.g. comparing circles to balls or rectangles to windows) to support their comprehension (GWA.2). MR also incorporated songs, games, and guiding questions to sustain engagement (GWA.2 and GWA.4).

Communication strategies were adapted to students' needs—MR spoke slowly, used sign language, and provided constructive feedback, including small rewards to encourage accurate responses and gentle guidance for incorrect responses (GWA.1, GWA.2). Repetition was used to enhance memory retention. Collaboration with parents was essential, as the MR provided guidance on how to reinforce learning at home (GWA.1). The focus remained on concept mastery rather than meeting specific curriculum targets (GWA.2), with a commitment to treating each student equitably, based on their individual needs (GWA.4).

Presence

In terms of presence, observations showed that the MR consistently responded to students' needs by interpreting nonverbal cues, such as facial expressions and gestures. MR demonstrated strong awareness of social dynamics and regularly offered positive reinforcement to encourage participation and conceptual understanding. Although adaptive strategies were initially lacking when confusion arose during Session I, notable improvements were observed in Sessions II through IV. MR increasingly uses body language and visual tools to clarify mathematical procedures and foster a participatory learning environment.

The interview data reinforced that the MR demonstrated a strong commitment to providing emotional and instructional support. MR's physical and emotional presence fostered student motivation and confidence. For instance, lessons began with simple check-ins about how students were feeling—an effort to build emotional connection and encourage engagement (GWB.1).

Differentiated instruction was consistently applied based on individual student needs (GWB.3). MR simplified mathematical content and contextualised it within students' everyday experiences (GWB.3; GWB.4). Students who faced difficulties received individualised attention without neglecting others (GWB.2). When one approach proved ineffective, MR explored alternative strategies or interactive games to ensure inclusivity (GWB.2). Repetition of the material was also employed to ensure comprehension (GWB.4).

For students with speech impairments, learning focused more on communication skills, pronunciation, reading, and basic arithmetic rather than complex content (GWB.3). MR acknowledged that these students often required more time to grasp concepts and did not push rigid curriculum benchmarks (GWB.3; GWB.4). Emphasis was placed on the quality of understanding rather than the quantity of the material covered. MR was mindful to avoid practices that could make students feel excluded or inadequate, recognising that such experiences could seriously affect their motivation and self-confidence (GWB.2).

Sensitivity

Scaffolding observations on the sensitivity aspect showed that the MR consistently created an environment that valued alternative forms of communication, such as sign language and written tools. While MR initially showed limited responsiveness to students' emotional cues, such as changes in mood or focus, this improved by sessions III and IV. Similarly, the use of instructional aids, such as whiteboards, images, and communication applications, was minimal in the earlier sessions but became more frequent and effective in the final session. By Session IV, MR had demonstrated strong efforts to avoid any behaviours that might cause students to feel pressured or marginalised.

In interviews, MR expressed deep concern for the needs of students with speech impairments and emphasised the importance of bridging their understanding of learning materials. MR highlighted the need to conduct initial assessments to identify each student's cognitive abilities (GWC.1) and understand their emotional states through direct interaction (GWC.1). When students appeared unfocused or confused, the MR sought to determine the underlying causes, whether academic or personal (GWC.1, GWC.3). The MR utilised consistent facial expressions, gestures, and body language to enhance communication (GWC.3).

While sign language was used, MR placed greater emphasis on slow and clear oral communication (GWC.3, GWC.5), complemented by visual media and real-life examples, such as using a rope to measure the circumference of a rectangle (GWC.4). Explanations were repeated to support memory retention, especially in terms of explaining formulas and basic concepts (GWC.2, GWC.4, GWC.5). Instruction focused on applicable foundational skills, such as shape recognition and basic counting, rather than abstract theory (GWC.4).

MR stressed that instruction should be tailored to student needs rather than to rigid lesson plans. All students received equal attention to prevent feelings of exclusion (GWC.2). Creative methods, including games and visual activities, were used to maintain students' attention and enhance their comprehension. The MR emphasised the need for patience and rejected any form of discrimination that could harm students' confidence (GWC.3, GWC.4, GWC.5).

Assistance

Initially, the MR did not provide scaffolded assistance, such as simple examples or step-by-step cues, when teaching mathematical problem-solving. Likewise, MR does not consistently encourage active student participation or help students relate mathematical symbols to concrete objects. However, these strategies became increasingly evident in the fourth session.

Consistently, MR provided visual aids and technology to enhance understanding, offered assistance without pressure, encouraged student independence, and allowed additional time for mastering concepts. During the interviews, MR expressed a preference for direct, tangible approaches, such as using balls or clocks to explain circular shapes (GWD.1, GWD.2). Visual media, including pictures of geometric shapes, were frequently incorporated into games and worksheets (GWD.1 and GWD.2). These tools helped students connect abstract mathematical ideas to real-world applications (GWD.1, GWD.2).

MR combined various media—print (images), digital (projectors), and manipulatives (real objects)—to enhance engagement (GWD.2). Although not heavily reliant on digital applications, MR favoured interactive, hands-on methods to maintain student focus (GWD.2). Assistance was tailored to each student's condition; for instance, MR approached students individually when they continued to struggle despite repeated explanations (GWD.3 and GWD.4). MR recognised that students might be hesitant to seek help due to embarrassment and proactively offered support without making them feel inadequate (GWD.3).

During independent work, the MR monitored the classroom, provided encouragement to those showing signs of confusion, and promoted student independence (GWD.3). While the MR offered help when necessary, the students were encouraged to attempt tasks independently before receiving assistance. MR acknowledged that students might claim to understand the material without truly grasping it (GWD.4) and therefore relied on behavioural cues in addition to verbal responses. Creating a supportive atmosphere where students could request help without fear or shame was a key priority for us.

Trust

Scaffolding observations in the trust domain showed that MR consistently fostered a safe and inclusive learning environment, encouraging positive peer interactions and preventing negative behaviours, such as teasing or discrimination. Initially, MR was hesitant to prompt students with speech impairments to attempt problems independently, but in later sessions, this encouragement became routine. The MR also regularly reinforced student efforts.

In the interviews, MR emphasised the importance of cultivating a comfortable learning atmosphere (GWE.1) and building student confidence (GWE.2). The MR responded to frustration or resistance by seeking to understand the underlying causes, whether internal (e.g. shame or confusion) or external (e.g. family issues) (GWE.2, GWE.3). Individual conversations were held during class and in informal settings to explore these concerns. If necessary, the MR contacted the parents for additional support (GWE.3).

MR did not force students to complete assignments when they were in poor emotional states. Instead, lighter tasks and extra time were provided. MR showed patience and flexibility, understanding that students with speech impairments may require additional time to process and express information. MR acknowledged that their approach significantly influenced student learning outcomes and therefore prioritised sensitivity, emotional awareness, and friendly support.

Autonomy

In the domain of autonomy, MR consistently recognised and rewarded student initiative and effort in completing assignments. MR increasingly used clear, accessible media to communicate expectations and instructions and provided students with opportunities to take responsibility for their learning by using appropriate aids.

MR's autonomy-supportive strategies included integrating creative media, involving students in peer evaluation, and emphasising personal responsibility through clear instructions and structured classroom routines. MR used applications such as Canva and Kahoot to make assignments more engaging (GWF.1) and rewarded effort with praise or points to foster healthy competition.

Students were also given opportunities to assess their peers' work, helping them to internalise assessment criteria and build collaborative skills (GWF.2). They were entrusted with managing their own time for assignment submissions, fostering responsibility and accountability. MR ensured that all instructions and evaluation procedures were easy to understand to support student independence (GWF.2). Respect for peer work was emphasised, and negative behaviours, such as teasing, were discouraged.

By allowing students to complete tasks without constant oversight, the MR instilled a sense of trust and confidence. These strategies helped students develop autonomy through repeated opportunities for self-assessment, decision making, and independent learning.

From sessions I to IV, MR's scaffolding practices encompassed all six dimensions of the Mäkinen and Mäkinen (2011) framework, namely activation, presence, sensitivity, assistance, trust, and autonomy. Constructive feedback and reflection after each session contributed to the continuous development of the MR's scaffolding strategies. These strategies include early identification of student needs, engaging learning media, visual and kinesthetic communication, positive reinforcement, repetition of material, collaboration with parents, structured tasks, personalised guidance, interactive activities, and the cultivation of self-confidence. Collectively, these practices significantly supported the mathematical learning of students with speech impairment.

The impact of the scaffolding provided by MR on the mathematical abilities of students with speech impairments was assessed through a mathematical understanding test administered to five students—AG, AZ, DH, MA, and YA—who participated in four mathematics lessons with MR. After completing the test, the students were interviewed by the researchers to confirm and elaborate on their written responses. The test consisted of four open-ended essay questions aimed at measuring students' conceptual understanding of mathematics.

1. **Question I**

   The first question asked students to: *"Explain in simple terms the definition of the circumference of a square and the circumference of a rectangle."* This question assessed the indicator of mathematical understanding related to students' ability to define geometric concepts both verbally and in writing. Of the five students, three (AG, AZ, and DH) answered the question correctly, while two students (MA and YA) provided partially correct responses. Specifically, MA and YA were able to explain the definitions of the circumference of a square and a rectangle but incorrectly wrote the formulas. Figure 1 presents the responses from students who answered this question incorrectly.

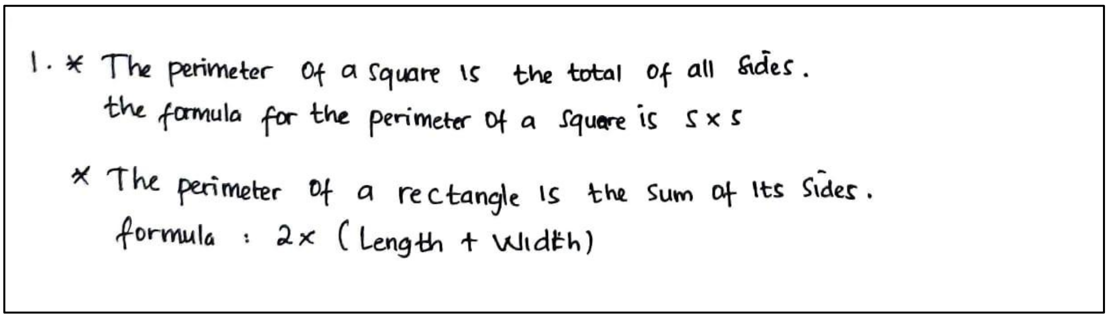


Figure I. MA's answer to Question I

2. **Question II**

   The second question of the mathematical understanding test presented to students with speech impairments was: "Give one example of a square and a rectangle, and show the circumference of both shapes using colored pens." This question also aimed to assess students' understanding of the concept of circumference, both verbally and in writing. All five students—AG, AZ, DH, MA, and YA—answered the question correctly, demonstrating their ability to identify and represent the circumference of squares and rectangles in a written format.

   The performance of students with speech impairments on Questions I and II was further supported by their interview responses, which provided confirmation of their understanding. The following are excerpts from the students' interview answers related to both questions.

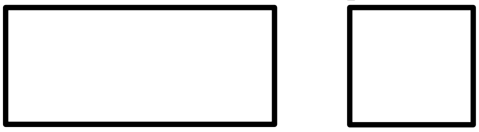
PWAG.2: Okay, how is your understanding when the teacher explains the circumference using a rope. Do you understand?

SWAG.2: I understand ma'am

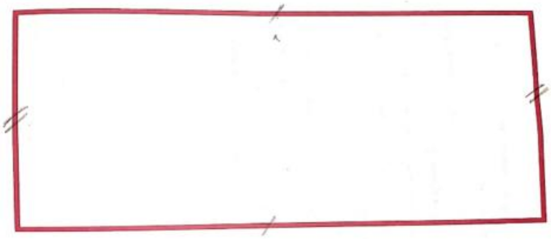
PWAG.3: Does the way the teacher explains make it easier for you to understand the circumference of a rectangle?

SWAG.3: Yes ma'am, I understand the circumference of a rectangle now

PWAG.4: Do you know the names of the two shapes below?



SWAG.4: eh this is a rectangle, this is a square
PWAG.5: Why did you say the first shape is a rectangle?
SWAG.5: because this shape has 2 opposite sides of equal length (showing a picture, while drawing lines that are opposite each other of equal length)



PWAG.6: … Next, can you show which one is called the perimeter of a rectangle?
SWAG.6: this (shows the image of the perimeter of a rectangle)
PWAG.7: From the figures, which one is said to be the length and width?
SWAG.7: this is the length and this is the width (shows the length and width in the image)

Based on the interview transcript, AG demonstrated a solid understanding of the concept of the perimeter of both squares and rectangles (SWAG.4, SWAG.6). AG reported that the use of a rope to explain perimeter was particularly helpful in understanding the perimeter of a rectangle (SWAG.2, SWAG.3), indicating that MR's use of concrete materials was effective in visualizing abstract mathematical concepts. AG was also able to correctly identify squares and rectangles based on the properties of their sides (SWAG.5, SWAG.7) and explained that opposite sides of a rectangle are equal in length (SWAG.5). Furthermore, when asked to indicate the parts that constitute the perimeter, AG correctly highlighted them in the diagram (SWAG.6), confirming a sound understanding of perimeter as the total distance around a shape. AG also correctly identified the length and width of a rectangle (SWAG.7), demonstrating comprehension of the two main dimensions of rectangular shapes.

3. **Question III**

The third question of the mathematical understanding test asked students to: *"Draw a square with a side length of 4 cm, then calculate its perimeter."* This item aimed to assess the students' ability to use diagrams, models, and mathematical symbols to represent the concept of perimeter. Of the five students, three (AG, AZ, and DH) answered correctly, while two students (MA and YA) made errors in either the formula or the calculation. Incorrect student responses for Question III are presented in Figure 2.

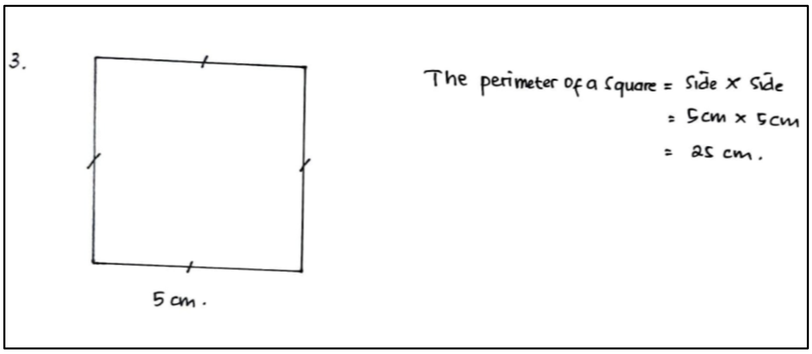


Figure 2. YA's answers to Question III

4. **Question IV**

The fourth question required students to: *"Draw a rectangle with a length of 6 cm and a width of 3 cm, then calculate its perimeter."* Similar to Question III, this item measured students' abilities to use diagrams and symbolic representation to demonstrate conceptual understanding. Four students—AG, AZ, DH, and YA—answered correctly, while one student (MA) made a mistake in applying the formula and performing the calculation. Incorrect responses to Question IV are presented in Figure 3.

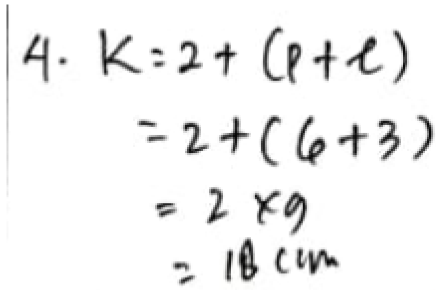
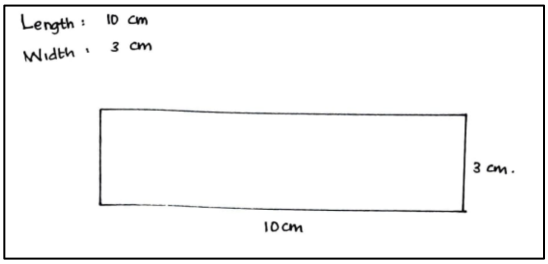


Figure 3. MA's Answer to Question IV

The mathematical abilities of students with speech impairments in responding to Questions III and IV were further corroborated by their interview responses, as described below.

PWYA.10: If the length is 10 cm and the width is 3 cm, what is the shape of the rectangle?

SWYA.10: (students draw the rectangle)



PWYA.11: From the picture, can you show which one is the perimeter of the rectangle?

SWYA.11: this one ma'am (showing the picture)

PWYA.12: Okay, now for example if the perimeter of the shape is 100 cm, how many rectangles can be made?
SWYA.12: um I don't know ma'am (confused)
PWYA.13: Is there any part of the concept of the perimeter of a rectangle that is still confusing to you? Which part?
SWYA.13: yes
PWYA.14: Which part are you confused about?
SWYA.14: still having trouble remembering the formula

Interview results indicate that YA has a partial understanding of the concept of the perimeter of a rectangle but still encounters difficulties in applying it abstractly and in recalling the correct formula. YA was able to draw a rectangle with the correct dimensions (10 cm × 3 cm) when given specific measurements (SWYA.10, SWYA.11), demonstrating visual-spatial understanding and basic representational skills. However, when asked to create a rectangle based on a known perimeter (100 cm), YA became confused (SWYA.12), suggesting difficulty in connecting perimeter with side lengths and generating corresponding value pairs. Furthermore, YA struggled to recall the perimeter formula accurately (SWYA.14), indicating that procedural fluency is not yet firmly established.

In contrast, MA expressed appreciation for the teacher's use of concrete and visual learning strategies.

PWMA.26: How does your teacher help you?
SWMA.26: Explaining using pictures of squares, explaining using rulers, and ropes
PWMA.27: Is this help very meaningful to you?
SWMA.27: Yes ma'am
PWMA.28: How meaningful is this help to you?
SWMA.28: Yes, because I understand
PWMA.29: Is there anything you don't understand about the teacher's explanation or help?
SWMA.29: Yes ma'am
PWMA.30: After the teacher explained, could you understand all of the teacher's explanations well?
SWMA.30: I understand ma'am, but sometimes I forget
PWMA.31: Which part do you find difficult to understand?
SWMA.31: Using rope when calculating circumference
PWMA.32: Okay, … Furthermore, when explaining, does the teacher use pictures or objects that are similar to flat shapes, for example showing the shape of a square or rectangle?
SWMA.32: yes, you use pictures to explain flat shapes
PWMA.33: When explaining, teachers use pictures and concrete objects. Is it easier for you to understand?

SWMA.33: yes, I understand
PWMA.34: What makes you understand better the way your teacher explains?
SWMA.34: because mother explains slowly and uses pictures of flat shapes
PWMA.35: OK, now if your friend asked you how to calculate the perimeter of a square, would you explain it?
SWMA.35: Yes, yes
PWMA.36: how would you explain it?
SWMA.36: Perimeter is this one (shows the side that is included in the circumference), the formula for finding the circumference is K= 4× side
PWMA.37: OK, after getting help from the teacher, do you now understand the concept of circumference better?
SWMA.37: Yes, ma'am, I understand better

According to MA, MR supported learning through visual aids, such as geometric shape images, and concrete tools like rulers and ropes to explain the concept of perimeter (SWMA.26). MA found this assistance meaningful, as it facilitated understanding even though some content was occasionally forgotten (SWMA.30). The teacher's slow-paced explanation and supporting visuals made the material more accessible (SWMA.34). Although MA experienced initial confusion when learning to calculate perimeter using a rope (SWMA.31), understanding improved through the use of visual representations and systematic instruction (SWMA.33, SWMA.34). Following these scaffolding efforts, MA reported a clearer understanding of square perimeter concepts and even demonstrated the ability to explain the formula $K = 4 \times side$ to peers (SWMA.35, SWMA.36).

The results described above show that the scaffolding provided by the mathematics teacher (MR) had a meaningful impact on how students with speech impairments developed their understanding of perimeter concepts. Following four instructional sessions involving structured scaffolding, the majority of students demonstrated improved conceptual comprehension. Specifically: three out of five students were able to correctly define the perimeter of a square and a rectangle, both verbally and in writing; all five students successfully demonstrated that they understood the concept of perimeter as the total distance around a shape; three out of five students accurately drew a square and calculated its perimeter; four out of five students accurately drew a rectangle and calculated its perimeter. These findings indicate that scaffolded instruction that includes concrete representations, visual media, and patient, individualized support can enhance mathematical understanding among students with speech impairments.

Discussion

This study explored how pedagogical scaffolding strategies are implemented to support students with speech impairments in overcoming difficulties in mathematics learning and identified which scaffolding aspects most effectively enhance their engagement and conceptual understanding. The findings of this research provide strong evidence that the teacher, MR, implemented scaffolding strategies in alignment with the six-dimensional framework by Mäkinen and Mäkinen (2011), namely, activation, presence, sensitivity, assistance, trust, and autonomy. These dimensions manifest through adaptive teaching practices, emotional support, the use of concrete learning media, and encouragement of independent thinking. These results confirm prior studies indicating that scaffolding is not only a supportive instructional technique but also a critical mediator in inclusive classrooms that serve learners with communicative and cognitive challenges (Ashqar & Atawnih, 2025; Lim et al., 2024).

The activation strategies employed by MR involved the use of non-verbal communication, visual representations, and formative assessments to identify learning gaps. The teacher utilised diagrams, hand gestures, and concrete tools, such as ropes and number cards, to make abstract concepts, such as perimeter, more accessible. These techniques align with constructivist principles, emphasising the importance of linking new content to students' prior knowledge and real-life experiences (Cagıltay et al., 2019; Herawati & Anjany, 2025). The teacher's presence was instrumental in fostering student motivation. MR maintained attentiveness to students' emotional cues and differentiated instruction to sustain their engagement. This is consistent with the findings of Byrne et al. (2023); Ariza and Hernández Hernández (2025), who found that teacher presence and relational pedagogy are crucial for building trust with learners with special needs.

Sensitivity, as the third scaffolding aspect, was evident in the MR's continuous adaptation of communication methods and the emotional consideration extended to students. MR demonstrated increasing responsiveness in recognising students' confusion or disengagement through their facial expressions and body languages. The use of repeated explanations and slow-paced oral instructions was complemented by integrating sign language and pictorial representations, facilitating both comprehension and retention. Such multimodal communication techniques are known to be particularly effective for learners with speech and language difficulties (Faber et al., 2024; Nardacchione & Peconio, 2021; Prystiananta & Noviyanti, 2025). MR also ensured equal participation and emotional safety for all students, a key requirement for trauma-informed and inclusive pedagogy (Wainscott & Spurgin, 2024).

The assistance provided by the MR evolved over time, beginning with general explanations and progressing toward tailored support for each student's needs. The integration of physical manipulatives, contextual games, and kinesthetic tasks supports a deeper understanding and symbol manipulation. According to Khan and Krell (2019), this type of differentiated assistance enhances representational fluency, particularly in the context of geometry. Although MR initially overlooked opportunities for scaffolded problem solving, the instructional approach improved significantly through feedback and reflection. This is consistent with Ukobizaba et al. 's (2021) findings, who stressed the importance of iterative teacher development in refining scaffolding techniques.

Trust was cultivated by creating an emotionally safe and inclusive environment whichere students felt seen and valued. MR promoted confidence by validating students' responses, respecting their communication pace, and accommodating their emotional states during the instruction. These practices resonate with the findings of Ashqar and Atawnih (2025), who highlighted that students with speech impairments require supportive teacher-student relationships to thrive academically. MR also maintained open communication with parents, reinforcing the trust triangle among teachers, students, and families. As trust increased, students exhibited more initiative in their tasks and began to engage in peer collaboration without hesitation.

Autonomy, the final aspect of the framework, was developed through structured opportunities for independent work, peer feedback, and classroom routines that emphasised personal responsibility, as follows: the use of digital tools such as Canva and Kahoot not only enhances student engagement but also promotes learner agency by allowing students to contribute creatively (Lin & Riccomini, 2025; Smith & Juergensen, 2023). Students were empowered to manage assignment timelines, evaluate peer work respectfully and apply conceptual knowledge without constant prompting. These findings align with those of Lim et al. (2024), who noted that autonomy-supportive scaffolding cultivates students' self-regulation skills and academic perseverance, particularly in inclusive classrooms with diverse learner needs. These practices were reflected in students' performance, where most were able to correctly identify, draw, and calculate the perimeter of geometric shapes following scaffolded instruction. Specifically, three of the five students could define the perimeter of both squares and rectangles, and four were able to accurately solve related problems using diagrams and formulas.

Furthermore, this study affirms the need for personalised scaffolding strategies tailored to individual student profiles. For example, AG, who demonstrated more advanced mathematical abilities, benefited from open-ended scaffolding that challenged his reasoning skills. This aligns with Munshi et al. 's(2023) finding that cognitively demanding scaffolds support higher-order thinking in students with strong academic potential. In contrast, AZ and DH, despite having severe speech impairments, responded positively to scaffolding through visual symbols, modelling, and repeated kinesthetic cues, strategies also highlighted by Kooloos et al. (2023); Hart and Heathfield (2017) as effective for students with limited verbal outputs. YA's learning was supported by a combination of visual models and partial verbal scaffolds, reflecting the dual-modality approach emphasized by Wainscott and Spurgin (2024). MA, who had the lowest baseline performance, showed substantial improvement through visual-concrete scaffolding using diagrams and real-life objects, consistent with the findings of Siller et al. (2023).

These variations across learners reinforce the importance of adopting a multimodal and flexible approach to scaffolding, particularly for students with communication delays. As emphasised by Jannah et al. (2019); Ariza and Hernández Hernández (2025), such strategies not only enhance conceptual understanding but also foster greater participation and engagement in classroom activities. The differential outcomes observed in this study further validate the significance of real-time teacher sensitivity and adaptation, contributing to more equitable and effective mathematics instruction in special education settings.

This study has two practical implications. First, the findings emphasise the importance of comprehensive scaffolding that extends beyond cognitive support to include emotional, social, and communicative dimensions. Teachers should be equipped with flexible strategies based on real-time classroom observations and student feedback. Second, school administrators and policymakers should consider integrating scaffolding models into professional development programs for teachers working in special education and inclusive settings. The study's findings echo the recommendations of Faber et al. (2024), Lim et al. (2024); Prystiananta and Noviyanti (2025), who advocate scaffolding training that incorporates adaptive, multimodal, and culturally responsive practices. However, this study was limited to one teacher and a small group of students in a single special school, which may limit the generalisability of the results to other contexts. Future research should replicate this study in different school contexts, with more diverse student populations, and over longer instructional periods to further validate and expand these findings.

Conclusion

The scaffolding strategies implemented by MR, a mathematics teacher at a special school (SLB-B) in Banda Aceh, toward five students with speech impairments were reflected across six aspects of the Mäkinen and Mäkinen (2011) framework, namely activation, presence, sensitivity, assistance, trust, and autonomy. Each aspect played a distinct role in enhancing students' engagement and conceptual understanding, particularly in learning the concept of the perimeter. Among these, activation and assistance were most strongly associated with improved conceptual comprehension, as evidenced by the students' ability to define, represent, and calculate the perimeter of squares and rectangles. Visual aids, concrete materials, and multimodal communication (oral, gestural, and sign language) emerged as effective scaffolding tools for facilitating understanding among students with varying degrees of speech impairment. Most students demonstrated an improved grasp of perimeter concepts after receiving scaffolded instruction. Specifically, three out of five students accurately explained the definition of perimeter, and all five correctly identified it as the total boundary of a shape. Additionally, most students were able to represent and calculate the perimeters of basic geometric figures with increasing independence.

This study was limited to a small sample of five students in a single special school setting, which may restrict the generalisability of the findings to broader contexts. Moreover, the study focused only on the topic of perimeter; further research could examine other mathematical topics and include more diverse school settings. Despite these limitations, this study offers practical implications for mathematics teachers in inclusive and special education classrooms. Scaffolding that integrates visual, kinesthetic, and nonverbal communication strategies can be particularly beneficial for students with speech impairments. The six-dimensional scaffolding framework provides a comprehensive guide for planning, executing, and evaluating instructional practices tailored to individual learner profiles. Future research could build on these findings by exploring how digital tools and collaborative learning models further support scaffolding in special needs education.

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Conflicts of Interest

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Author Contributions

Melda Anggreni: Conceptualization, writing - original draft, editing, and visualization; **Anwar:** Writing - review & editing, formal analysis, and methodology; **Said Munzir:** Validation and supervision.

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