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Accessible Mathematics for Deaf Students in Metro City, Indonesia

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Abstract
Background: Deaf students need access to the language and representations through which mathematical ideas are taught and assessed.
Objectives: This study identified barriers and learning needs among Grade 7 deaf students and translated them into preliminary specifications for adaptive hybrid mathematics instruction.
Methods: The define phase of a development study at SLB Negeri Kota Metro, Indonesia, combined eight classroom observations with teacher questionnaires, learner profiles and diagnostic tasks, document analysis, and interviews with two teachers, four parents or guardians, and one health professional. The lead researcher coded interviews and observation notes and compared categories across sources.
Results: Four needs emerged: visual and communication access, explicit links between concrete, pictorial, and symbolic representations, scaffolding adjusted to learner responses, and opportunities to revisit materials after class. A health professional provided contextual advice on lighting and classroom sightlines. The findings informed a design that pairs guided in-person concept work with replayable signed explanations and tiered asynchronous practice.
Conclusion: The study specifies accessibility and instructional features for a future model in this setting. Their feasibility and effects on conceptual understanding require testing.

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Keywords: Adaptive instruction, deaf education, hybrid learning, mathematics education, needs analysis

1. Introduction

A student can understand the mathematical relation represented in a task and still struggle to access the language in which the task is posed. A recent synthesis found that mathematics performance among deaf and hard-of-hearing children varies across domains and task demands [1]. Research on early numeracy among children acquiring spoken language distinguishes performance across specific numerical skills [2]. Among signing students, American Sign Language proficiency has been associated with mathematics achievement, with variation across learners and contexts [3]. These findings make it important to distinguish language access, the ability to interpret conventional notation, and conceptual understanding when designing instruction and assessment.

Signed discourse can communicate mathematical relations through movement, orientation, and spatial placement. Classroom analyses show that teachers and students coordinate signing with written notation and diagrams to establish meaning [4, 5]. Work on geometry illustrates how gesture and manipulation can make spatial reasoning visible [6]. Studies of language and executive function or vocabulary among deaf children also underscore the importance of accessible language experience [7, 8]. Research on deaf learners with and without cochlear implants also cautions against inferring uniform language profiles from a hearing technology category [9]. These studies concern different languages and settings. In Metro City, instructional decisions must reflect the sign systems, written language, and representational practices already used in the classroom.

Universal Design for Learning (UDL) provides a framework for planning multiple routes to information, participation, and response. Reviews of UDL in school settings report heterogeneous designs and findings and support attention to how accessibility features are implemented [10, 11, 12]. Standards-based UDL lesson design keeps the learning goal explicit while allowing flexibility in how students access and demonstrate it [13]. Work on distance learning for deaf students emphasizes planning access across communication and instructional activities [14]. School-level evidence on online and blended learning likewise suggests that the design and support surrounding delivery matter [15]. In mathematics, the function of digital tools varies with the tasks and interactions in which they are used [16]. These strands support a needs assessment that specifies which activities benefit from face-to-face guidance and which can be revisited independently.

This study reports the define phase of a development project at a public special school in Metro City, Lampung. It asks how Grade 7 mathematics is taught and accessed at the site, what learning needs emerge from the available evidence, and how those needs can inform an adaptive hybrid model. Here, hybrid refers to a planned combination of in-person and asynchronous instruction. Adaptive refers to teacher adjustment of representations, prompts, and task levels based on learner responses.

Mathematics requires coordination across several forms of language. In a word problem, the student must identify which quantities are known, infer the relationship among them, and translate that relationship into an operation. Evidence across age groups links language and mathematics, while research on word-problem instruction shows that making problem structure visible can support reasoning [17, 18]. The instructional question for a deaf learner is therefore which language and representation make a relationship available and which mathematical decisions the learner still has to make. A task can provide an accessible description of a change in temperature while leaving the direction, magnitude, and result of the change to be inferred.

The gap addressed here is the translation of classroom evidence into a sequence that can be implemented and evaluated. A signed video can make an explanation available after class, but it does not specify how that explanation connects to prior work with objects, how the teacher will choose a follow-up task, or what evidence will justify reducing support. The study brings these decisions together by linking the needs categories to proposed activities and observable indicators for a pilot. This contribution is grounded in one school and intended to guide the next design cycle. It follows an educational design research principle of linking proposed solutions to the evidence and context from which they were developed [19].

2. Materials and Methods

2.1. Design and Setting

The study was conducted at SLB Negeri Kota Metro, a public special school in Lampung, Indonesia. It addressed the define phase of a four-phase development process (define, design, develop, and disseminate). The study used qualitative description with descriptive summaries planned for structured measures. The unit of analysis was mathematics instruction and the needs observed or reported for Grade 7 deaf students at the site.

2.2. Participants

Students and teachers were selected purposively from the Grade 7 special junior secondary program and its mathematics teaching staff. Two teachers with undergraduate qualifications in special education and 8 and 12 years of teaching experience contributed. Four parents or guardians and one health professional participated in interviews. Student records described ages of 13–16 years, severe to profound hearing loss, and use of Sistem Isyarat Bahasa Indonesia (SIBI), Bahasa Isyarat Indonesia (BISINDO), and total communication. Transparent reporting of the composition and scope of a qualitative sample supports interpretation of its evidence [20].

2.3. Data Sources and Instruments

Table 1 summarizes the five instruments and supplementary documentation. The research team organized the instruments around instructional conditions, learner characteristics, curriculum, mathematics content and tasks, teacher capability, infrastructure and materials, family support, and requirements for hybrid learning. The curriculum was examined through document analysis. Other aspects could draw on multiple sources.

Table 1: Instruments and evidence sources in the define phase

Source	Purpose	Coverage
Teacher questionnaire	Describe perceptions of needs and readiness for the proposed model.	Two mathematics teachers. 80 items on a five-point scale.
Classroom observation	Document instruction, communication access, and media use.	Eight meetings (60 minutes each). 28 indicators on a four-point scale, with field notes.
Learner profile and diagnostic tasks	Describe communication and learning access and probe prerequisite and target mathematics concepts.	17 profile domains and 14 diagnostic items, with a 42-point maximum. Student counts require reconciliation.
Semistructured interviews	Explore instructional barriers, family context, and recommendations for communication access.	Two teachers, four parents or guardians, and one health professional. 45–60 minutes per interview.
Curriculum and materials review	Review the relation between Grade 7 learning objectives, tasks, representations, and assessments.	Six Grade 7 mathematics modules and worksheets.
Supplementary documentation	Contextualize classroom activities and tasks.	Activity photographs, practice materials, and field notes.

The teacher questionnaire comprised 80 five-point items, 51 on perceived needs and 29 on readiness. The observation form comprised 28 items scored on a four-point scale: 11 on mathematics instruction, 12 on communication access, and five on media and technology. The learner profile addressed 17 characteristics. The 14-item diagnostic mathematics assessment covered 11 prerequisite items and three target items on integers. Items were scored from 0 to 3, for a

maximum of 42. Students could respond through signing, writing, speech, or demonstration. Pictures, concrete materials, and instructions adapted to students' communication modes supported access.

Interviews were semistructured and addressed classroom barriers and hybrid readiness, family accounts of development and service access, and health-related context and classroom accessibility. The respective interview guides included 15 teacher prompts, 19 parent or guardian prompts, and 13 health professional prompts. Sessions lasted 45–60 minutes and were recorded and documented in notes. Six Grade 7 teaching modules and worksheets were reviewed. Expert review of the five instruments addressed content, construct, wording, and presentation across 11 criteria. Instrument-specific validation scores were unavailable for reporting.

2.4. Analysis and Trustworthiness

The lead researcher coded interview transcripts and field notes inductively, condensed 24 initial codes into four categories, and discussed differing interpretations with the research team. The analysis proceeded through reduction, categorization, evidence display, and interpretation. Structured measures were to be summarized using instrument-specific scoring rules. Because the available materials did not include questionnaire totals, observation ratings, or individual diagnostic scores, this report presents qualitative patterns, source counts, and instrument characteristics. Table 2 retains the source labels for illustrative excerpts. Quotations were translated from Indonesian for this article.

Table 2: Learning needs and illustrative evidence

Category	Identified need	Illustrative excerpt
Visual and communication access	Concise written directions, diagrams, and signing suited to pupils' communication practices.	"The children quickly get confused when the problem is written as a long sentence. They need pictures and clear signs." (W2)
Concept construction	Explicit mapping from objects and pictorial models to conventional notation.	"Students had difficulty adding integers without help from real objects or a pictorial number line." (O3)
Pedagogical adaptation	Flexible prompts, repetition, tiered tasks, and feedback based on responses.	"Student A understands quickly with SIBI, but Student B needs a slower explanation with interactive pictures." (W1)
Learning flexibility	Guided classroom work complemented by materials that can be replayed and reviewed.	"If there are videos at home that can be replayed, children can learn with their parents." (W2)

Note. W1 and W2 are teacher interview codes. O3 is an observation record. Excerpts were translated from Indonesian.

The study compared evidence across observations, interviews, diagnostic activities, and documents where available. Teachers and the health professional checked interview summaries. The research team used peer debriefing to discuss interpretations. The distinction between the source of each claim and the inferences drawn from it follows guidance on making qualitative analysis and trustworthiness procedures transparent [21, 22].

The evidence sources support different inferences. An observation can document what happened on a particular task, a teacher interview can explain a recurring concern or describe a proposed response, and a document can show which tasks or formats were available. The interviews with families and the health professional provide context for communication access and prior experiences. The analysis therefore distinguishes directly described classroom events from participants' interpretations and the researchers' design proposals. The examples in the Results and Discussion preserve these distinctions so that readers can trace a design decision to the type of evidence that supports it.

2.5. Permissions and Consent

The study materials record education authority permission and school authorization from the principal of SLB Negeri Kota Metro (Letter No. 421.1/108/SLBN/2026). The teachers, parents or guardians, and health professional provided written consent. Students provided assent in an accessible visual and signed format. Participant identities were anonymized in the reporting.

3. Results

3.1. Classroom Characteristics and Learning Needs

Across eight lessons, observations and teacher accounts indicated that explanations communicated verbally could be missed or only partly understood. Teachers used combinations of speech and signing. Long sentences in word problems were a recurring barrier in the teachers' accounts. Short written directions, illustrations, and signs were identified as ways to make both the instructions and the mathematical relations more accessible. The reports also described variation in pupils' responses to signs and pictures, giving teachers reasons to check comprehension individually. The notes on arithmetic, integers, and fractions described the need to connect objects and visual representations to written symbols. One observation documented difficulty with integer addition when concrete objects or a pictorial number line were absent. The evidence indicates a need for instructional bridges across representations. It does not establish the prevalence of particular misconceptions or comparative performance across students.

Four categories organized the findings (Table 2). Accessibility concerned the language and channels through which information was made available. Concept construction concerned links between representations. Pedagogical adaptation concerned the timing and intensity of guidance, repetition, and feedback. Flexibility concerned the opportunity to review explanations after class. One teacher proposed replayable videos that pupils could use at home with family members. This was a suggested provision rather than evidence of home access or platform use.

3.2. Family and Health Professional Perspectives

Parent and guardian interviews covered developmental history, initial concerns about hearing, experiences with assessment, and access to support. The available summary describes the interview domains but does not give participant-level histories or frequencies. Its contribution to

this article is contextual. Classroom planning should accommodate variation in communication histories without inferring individual causes or diagnoses from the interview topics.

The health professional discussed several possible routes to childhood hearing loss and described variation in detection and access to support. These comments represent one professional perspective. The study materials do not contain individual audiograms or diagnostic records to verify clinical classifications, causal histories, or possible associated conditions. The actionable educational input was to preserve unobstructed sightlines to faces and hands and use lighting that allows students to see signing and other visual communication clearly.

3.3. Preliminary Design Specifications

The proposed design combines an accessible in-person introduction with guided comparison of concrete, pictorial, and symbolic representations. A brief response at the end of the lesson would inform the teacher's selection of asynchronous practice. Students could replay signed explanations, use visual hints, and respond through an accessible mode. The teacher would review responses to decide whether to revisit a representation, change the prompt, or progress to a less supported task. Table 3 connects the reported needs to proposed activities and evidence to collect during a pilot. Figure 1 depicts the instructional sequence and the teacher's feedback loop. Both are design outputs of the needs assessment.

Table 3: Preliminary design features and evidence for a pilot

Design priority	Proposed activity or provision	Evidence to collect in a pilot
Communication access	Align signs, concise text, and visuals. Plan unobstructed sightlines and glare-free lighting.	Check whether students can access directions and explain what the task asks.
Concept construction	Use concrete materials and number lines and explicitly map them to signed and written expressions.	Ask students to translate between representations and explain a new example.
Pedagogical adaptation	Use exit responses to select visual hints, change the degree of guidance, or offer a more demanding task.	Record what assistance was used, which errors persisted, and what students could do independently.
Learning flexibility	Use in-person time for guided work and provide signed clips and short asynchronous practice for review.	Document access to the materials, successful navigation, and barriers to home practice.

Note. Features and pilot measures are proposed. They were not evaluated in the define phase.

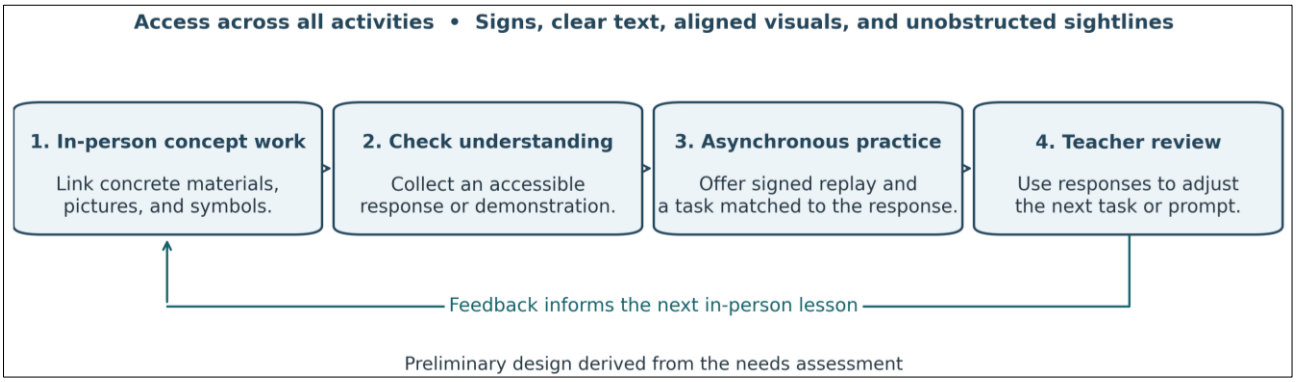


Fig 1: Proposed adaptive hybrid sequence for accessible Grade 7 mathematics

4. Discussion

4.1. Separate Access to the Task from the Mathematical Demand

The teachers' accounts of long word problems suggest that the language used to present a task can obscure the concept it is intended to assess. Accessible signing, concise written instructions, and an aligned diagram can make the same problem available through multiple routes while retaining the mathematical demand. Research on signed language access supports attending to the language environment [23, 24]. Research on language and literacy across modalities and on sign-to-print instruction shows why links between signed and written forms deserve explicit attention [25, 26]. Those studies examined literacy outcomes, so their implications for mathematics word problems remain to be tested. For this setting, teachers can check whether a student has understood the question before interpreting an incorrect calculation as a conceptual error.

The health professional's advice about sightlines has a clear classroom implication because signs, diagrams, and written expressions all compete for visual attention. Teachers can show a representation, pause to sign its meaning, and then direct attention to the relevant part. Clinical research supports taking developmental histories and timing of support seriously, given the diversity of childhood hearing loss and associations between intervention timing and language outcomes [27, 28, 29]. Those associations cannot identify the causes of individual students' mathematics difficulties in this study.

A bilingual or multimodal explanation can retain specialized mathematical language while giving learners multiple ways to inspect it. Deaf education research describes how signed and spoken or written resources may be combined in classroom interaction, and how language and reading profiles differ across communication groups [30, 31]. At the site, teachers reported using combinations of speech and signs. A design team can start by identifying signs and written terms pupils already use for direction, opposite, and change. When a term varies across the classroom, a short demonstration can establish its intended meaning for the current task. The teacher can then use the same mathematical relation in a new context to check whether the learner recognizes it beyond the original wording.

The visual arrangement of a lesson matters because an explanation may ask students to shift attention between the teacher, a diagram, and their own work. In a proposed classroom routine, the teacher would establish a shared visual reference, sign or demonstrate one step, pause for students to examine it, and ask them to point to or reconstruct the relevant change. The same principle applies to video. A replayable clip can place a sign beside the representation it explains and keep the step visible long enough for inspection. Research on instructional video supports decisions about segmenting explanations and directing attention to relevant content [32, 33]. These studies do not test the particular placement and pacing needed by the students in Metro City. The placement and pace are features for students to evaluate in the pilot. Research on viewers' experiences of captions also supports asking students which combinations of captions, signs, and graphics they can use with ease [34].

4.2. Make the Connection Between Representations Explicit

The integer-addition observation points to a specific design problem: students must understand how a move on a number line or the combination of counters corresponds to an operation in notation. Research on concreteness fading emphasizes aligning the structural features of successive representations [35]. Studies of concrete–representational–abstract instruction and manipulative-based integer tasks provide examples of how representations and prompts can be sequenced for learners with disabilities [36, 37]. Those populations differ from the participants at this site. The relevant design hypothesis is that comparing equivalent representations side by side will help students explain why a symbolic operation works. A later pilot can test that hypothesis using accessible transfer tasks rather than repeating the worked example.

A representation sequence should make invariants visible across formats. For signed integer addition, the initial position, direction of change, and magnitude of change can be identified in a story, enacted on a line, and represented in an expression. If only one feature changes across examples, the student can compare its effect. For example, keeping the starting point and the magnitude fixed while changing the direction allows the teacher to ask what stays the same and why the endpoint differs. Research on embodied design offers a rationale for connecting actions and spatial arrangements to mathematical meaning [38]. Studies of virtual–representational–abstract instruction in fractions illustrate that links among representations can be studied across topics, though the instructional decisions for signed integer addition still require local verification [39].

Objects and pictures also have limits. Signed counters make opposite pairs visible, while a number line makes direction and order visible. Each representation can clarify a relationship and obscure another. In an initial design, the teacher can ask students to explain where the same quantity or operation appears in both formats. This check is especially important when a correct answer could be produced by copying a movement demonstrated moments earlier. A different starting value, a different context, or an explanation in the learner's preferred mode would provide additional evidence that the relation was understood.

4.3. Adjust Assistance in Response to Evidence

The contrast between two students described by a teacher indicates the need for more than one route to an explanation. Research on scaffolding shows that uptake depends on how support is offered and used, while syntheses of computer-based scaffolding document its potential across STEM and in problem-based learning [40, 41, 42]. Research on adaptive teaching and feedback also emphasizes the role of instructional decisions and the information carried by feedback [43, 44]. In the proposed design, a student who misreads the direction of movement on a number line could revisit a pictorial example, whereas a student who explains the movement accurately could proceed to a symbolic problem. The relevant cue is the student's reasoning on the task. A hearing threshold alone cannot specify how much mathematics support a learner needs.

The same incorrect answer can call for different responses. A pupil who cannot identify the starting temperature may need a clearer signed explanation of the situation. A pupil who identifies the starting point and direction but counts the starting position as a step may need to compare two marked movements. A pupil who can enact the movement and explain it but selects the wrong symbol may need support linking the action to notation. The proposed assessment therefore records the form of the response and the prompt that was needed, alongside answer accuracy. Work on classroom assessment locates this kind of evidence within pedagogical decisions, and a review of formative assessment in school settings highlights the importance of how the evidence informs subsequent action [45, 46].

Support could follow a simple sequence: clarify the task, restore a relevant representation, and invite the learner to try a related problem with less assistance. An accessible demonstration or signed explanation can carry the same mathematical evidence as a written explanation. The response mode and the level of prompting should be recorded separately. This distinction helps the teacher determine whether the next task should change how information is presented, which representation is used, or how much of the mathematical procedure remains to be worked out.

4.4. Give In-Person and Asynchronous Work Distinct Purposes

In-person time would support dialogue, demonstration, comparison of strategies, and responsive feedback. The asynchronous component would provide replayable explanations and short practice connected to the same goal. Reviews of online instruction and research on blended teaching readiness underline the need to specify interaction and support across modes [47, 48]. Platform development for deaf learners and a recent Indonesian signed mathematics application illustrate ways to make digital material accessible [49, 50]. These designs inform the choice of features, while the usability of local signs, videos, and navigation still needs to be assessed at this school.

The home-review proposal came from a teacher. Family availability, connectivity, device access, and independent use were not established by the reported evidence. Deaf secondary students' accounts from the Philippines illustrate why learner perspectives are important when examining communication and material access in remote schooling [51].

A pilot could therefore compare the accessibility of signed online clips with downloadable or offline materials and examine whether learners can complete the same mathematical task across formats. Families could support access as needed without being expected to take over classroom instruction.

Continuity across modes depends on a shared mathematical goal. The asynchronous resource can use the number-line convention introduced in class and ask the learner to use it with a different example. A downloadable clip and a printed sequence can provide parallel ways to revisit the relation, with the same follow-up question in each. The pilot can document which route students choose, whether a family member assisted with access, and whether they could complete the mathematics independently. A missing submission alone cannot distinguish a connection problem, difficulty using the interface, or difficulty with the task.

4.5. Worked Example for the Design Phase

Table 4 illustrates one possible sequence for adding integers. It begins with a temperature at −2 °C that rises by 5 °C. The teacher would make the language of the situation available through concise text and locally understood signing, then ask students to choose the starting position and show the change. The teacher can connect the learner's movement from −2 to +3 to the expression −2 + (+5) = +3. In a matched follow-up, a learner would explain how a decrease of the same magnitude changes the direction while preserving the starting value and the number of units moved. A second follow-up can change the context entirely while preserving the mathematical structure.

The sequence distinguishes the availability of information, the accuracy of a calculation, and the ability to explain the relation across representations. An exit response could ask the pupil to locate the starting point, show the direction and magnitude of change, and match the result to notation. A teacher can judge the same three features in a signed explanation, a drawing, or a demonstration. The worked example and response criteria are proposed specifications derived from the needs analysis. They require review with the school to establish that the language, task difficulty, and feedback fit the intended Grade 7 curriculum.

Table 4: Illustrative hybrid lesson sequence for adding integers

Lesson step	Accessible mathematics task	Evidence or proposed teacher response
In-person entry	Show an initial temperature of −2 °C and a rise of 5 °C in concise text and locally understood signs.	Ask the student to point to or sign the starting value and show what changes.
Link representations	Use five unit moves to the right on a number line and connect the endpoint +3 to −2 + (+5).	Ask the student to match the direction, number of steps, and endpoint to the symbols.
Check understanding	Use the same starting temperature with a decrease of 5 °C and invite a signed, drawn, written, or demonstrated response.	Record direction, magnitude, and notation separately. Restore the relevant representation if the student needs a prompt.
Asynchronous practice	Provide a short signed replay or offline equivalent, followed by a similar problem in a different context.	Record access and mathematical response separately. Allow review without changing the mathematical goal.
Teacher review	Compare the exit response with the asynchronous response and select a related task for the next meeting.	If the learner explains the relation independently, change the representation or context. If support is needed, target the specific difficulty.

Note. This lesson is a design example for a future pilot.

4.6. What a Feasibility Pilot Should Establish

The first question is whether the instructional sequence can be delivered and used as intended. A small pilot can distinguish practical feasibility from educational effectiveness by specifying what will be learned from each stage [52, 53]. Before classroom delivery, the design team could work with deaf pupils and teachers to inspect the signs, visual cues, and response formats. During delivery, it could record whether the in-person explanation, comprehension check, asynchronous task, and teacher follow-up took place. When a step changes, the record can distinguish an adaptation made for a learner from a step omitted because a resource or connection was unavailable.

Feasibility and acceptability also require different evidence. Feasibility concerns whether teachers can prepare or reuse the materials, students can open them or obtain a usable equivalent, and teachers can review responses before the next lesson. Acceptability concerns how learners and teachers experience the language, pace, workload, and feedback. Implementation research separates these constructs and describes measures that can inform locally appropriate questions [54, 55]. For this school, a brief, accessible student interview and teacher log could help explain problems that completion counts alone cannot capture. Criteria for progressing to a larger trial would need to be agreed with the school in advance.

An implementation record can describe the materials used, the delivery sequence, the staff involved, and any changes made between sessions. Structured reporting guidance for interventions helps distinguish what was planned from what was actually delivered [56]. Pairing implementation records with student and teacher accounts can show where accounts converge or differ. For example, a clip may have been delivered to every learner while interviews reveal that some students could only view it on a shared device at particular times. Both observations are needed to interpret access.

A subsequent outcome study would ask whether students can use their understanding on unfamiliar items. An outcome measure could include signed, pictorial, and symbolic forms with common scoring criteria and explicit checks of language access. A transfer item would change the numbers, context, or representation while preserving the mathematical relation. Recording which items students attempted, how they responded, and whether prompts were provided would help distinguish conceptual improvement from familiarity with the lesson example. A design with an appropriate comparison and documented implementation would be needed to estimate an effect of the model.

4.7. Design Checks Before a Pilot

The design team should first identify which features need to be consistent across classrooms and which can be adapted.

The common features would include the mathematical goal, an accessible presentation of the task, an opportunity to connect representations, and a check that informs the next activity. The choice of signs, the physical or virtual format of the number line, and the pace of replay could vary. This distinction would allow teachers to accommodate local communication and resources while retaining the mechanism the model is intended to test. It would also clarify what to record if an apparently successful session relies on substantially more teacher support than the model anticipates. Students can help identify practical barriers in a short walk-through before the pilot. A student could view a signed explanation, show where to find the worked example, and demonstrate how to answer a follow-up question. An observer would record where the student changes screens, needs help, or cannot see the relevant sign and representation together. An independent second attempt could show whether a change in instructions, layout, or navigation has resolved the specific barrier. The same walk-through can be offered using the offline equivalent. For remote activities, the design team can ask whether the student can pause, repeat, and resume from the same step, and whether the next classroom task assumes access to any material that the learner did not receive.

A progression decision should be tied to the kinds of problems uncovered. A lesson with accessible materials but inconsistent teacher follow-up calls for a different revision from a lesson in which pupils cannot independently retrieve the materials. As an example, recurrent trouble reading a number line on a small screen would warrant changing the display and repeating the access check. Recurrent difficulty matching a movement to the written expression after access has been confirmed would instead warrant revisiting how the representations are linked. Before collecting pilot data, the team should agree which recurring problems require redesign and which can be handled through routine adjustments [52, 55]. Keeping a log of problems and responses would make that decision auditable.

4.8. What to Measure After Access Has Been Established

Assessment should specify which parts of a task may be made accessible and which parts express the mathematical skill under study. In the integer example, translating the description into signs can preserve access to the situation, while indicating the correct direction of movement would provide part of the mathematical answer. For each item, assessors can identify allowable access support and define the content that must still be inferred by the learner. If an item assesses interpretation of written mathematical notation, its signed version can explain the instructions while preserving the notation to be interpreted. If the objective is conceptual understanding, the learner can demonstrate the relation using a drawing, movement, signed explanation, or equivalent notation. The inference about achievement then depends on the relation shown, while the response mode remains available for interpreting performance [3, 17].

A pilot scoring guide could make that inference explicit. One criterion would concern the initial position or quantity. A second would concern whether the student represents the direction and magnitude of change correctly. A third would concern the connection between the representation and the resulting expression. An incomplete response can then be described in terms of the feature it establishes. For example, identifying the correct starting point and magnitude with an incorrect direction provides a different basis for feedback than arriving at the correct endpoint without showing a relationship between the quantities. The guide should record prompts in a separate field so that a correct answer with content assistance can be distinguished from a correct answer reached with access support alone. Reviewing several responses in different modes would help teachers agree how to apply the criteria [45, 46].

Outcome interpretation also depends on the conditions under which responses are obtained. If early items use a teacher demonstration and later items rely on independent use of a clip, any difference in scores may reflect the support provided as well as changes in understanding. Comparable assessment conditions and a record of permissible prompts would help address this problem. A subsequent study could report accessible item completion, performance on familiar and unfamiliar tasks, and whether students could explain a relation with less assistance. In a small pilot, these observations would identify where the materials or assessment need revision and whether the measures can be used consistently. Estimating the size of a learning effect would require a study designed for that question.

Learner feedback should also shape the choice of outcome tasks. Some students may explain an integer relation fluently when they can sign and point to the number line, while others may prefer to label the same relation directly. Asking students to explain which part of an instruction or display they found difficult can reveal ambiguity that an accuracy score alone would miss. Combining those explanations with item responses and records of support could clarify whether the next design cycle should revise the language, the visual material, the teaching sequence, or the measure itself. This is particularly important here because the define phase drew on adults' perspectives and classroom observations, with limited direct evidence about how students interpreted the proposed materials.

4.9. Scope and Next Steps

The findings describe one public special school. Teacher, family, and health professional interviews contributed different forms of evidence. Student perspectives were not directly elicited through interviews, and the available records did not include the full diagnostic or questionnaire results. As a result, the proposed pathways should be refined with deaf students and teachers before judging feasibility or impact. The next stage should document participation counts, test task and language accessibility with students, assess the practicality of the in-person and asynchronous sequence, and then examine changes in conceptual understanding with a suitable evaluation design.

5. Conclusion

At SLB Negeri Kota Metro, the needs assessment identified four priorities for Grade 7 mathematics instruction with deaf students: accessible communication, explicit connections between representations, responsive scaffolding, and opportunities to revisit material. These priorities informed a preliminary design that pairs guided in-person mathematics with signed, replayable explanations and tiered asynchronous practice. The proposed lesson sequence and pilot indicators provide a starting point for refinement with students and teachers. Evidence of gains in conceptual understanding will require a subsequent evaluation.

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Author Contributions
I'in Fidiyanti: Conceptualization, Investigation, Formal analysis, Writing – original draft. Baiduri: Supervision, Writing – review and editing. Elly Purwanti: Supervision, Writing – review and editing. Yus Mochamad Cholily: Supervision, Writing – review and editing. Moh. Mahfud Effendi: Supervision, Writing – review and editing.

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Data Availability
Anonymized interview transcripts and observation instruments are available from the corresponding author upon reasonable request, subject to participant consent and confidentiality safeguards.

Use of Artificial Intelligence
ChatGPT (OpenAI) assisted with English translation, manuscript restructuring, literature discovery, the expansion of the discussion and proposed pilot procedures, and the presentation of findings in tables and a schematic. The study's original data collection and coding were carried out by the research team.

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