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Developing an Inclusive Numeracy Assessment for a Blind Student in using the ADDIE Model

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ABSTRACT

In a society where numbers and visual representations dominate daily life, how can one assess the numeracy skills of children who are unable to perceive numbers visually? This critical question served as the foundation for research that sought to reconceptualize the nature of mathematics assessment for students with visual impairments. The primary aim of the research was to design a numeracy assessment instrument that is not only valid and reliable but also empathetic and responsive to the sensory needs of these learners. To achieve this, the instrument was developed by integrating the ADDIE instructional design model with the inclusive Merdeka Curriculum, while adapting numeracy indicators derived from the theoretical frameworks of Piaget and Bloom to suit the characteristics of visually impaired students. The results demonstrate that the finalized instrument, comprising 48 validated items tested with a visually impaired student, effectively measures numeracy competencies. This research contributes to the field by introducing a curriculum-based, multisensory assessment tool specifically created for visually impaired students in the Indonesian context.

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1. INTRODUCTION

In today's era of rapid globalization, technology serves as the primary catalyst, driven by information and directed by knowledge. To navigate increasingly complex life challenges, individuals must cultivate logical, critical, and creative thinking skills. Mathematics education plays a strategic role in fostering these abilities, as it inherently trains students to think in rational and systematic ways (Oyebanji & Idiong, 2021; Safitri, 2023). Within elementary education, mathematical literacy and critical thinking are essential, as they equip students to solve problems logically and to connect abstract concepts with real-world applications. Consequently, mathematics occupies a crucial position as the academic foundation underpinning a wide range of scientific disciplines (Ali et al., 2024; Sumarna et al., 2024).

Nevertheless, mathematics learning does not always proceed without challenges. Students with visual impairments often encounter difficulties in this subject because of its inherently abstract, multifaceted, and visualization-dependent characteristics (Ali et al., 2025; Klorina & Juandi, 2022; Rottmann et al., 2020). Their restricted access to visual information hinders the development of foundational mathematical understanding. This issue is further compounded by the limited availability of adaptive and accessible instructional media, which significantly reduces the effectiveness of mathematics learning for blind students (Maqbool, 2023; Vandana & Singla, 2024). Steps to introduce mathematical concepts to visually impaired elementary students can be implemented by concrete objects that address their sensory needs. This includes the utilization of tactile media that can be individually adapted, teaching materials in tactile form such as real objects and three-dimensional models, as well as modified multiplication boards equipped with marbles and Braille symbols. These tools enable students to engage through touch and have been shown to exert a positive impact on the learning process (Ardiansyah et al., 2023; Panglipur et al., 2024; Phutane et al., 2022; Pires et al., 2022). Within the context of numeracy assessment for visually impaired learners, it is crucial to design and implement mathematics assessments that are individualized, flexible, and responsive to students' unique needs. Such assessments are essential for accurately identifying and analyzing students' abilities, thereby informing the development of educational programs, and enhancing the overall quality of mathematics learning (Carter et al., 2025; Takele & Melese, 2022).

The development of effective and inclusive assessments, as mandated by the Merdeka Curriculum (Purnawanto, 2022), must be grounded in the Learning Outcomes of each phase and aligned with students' cognitive development stages, as outlined in Piaget's theory and Bloom's Taxonomy. Such alignment ensures that the instruments designed do not impose cognitive demands beyond children's developmental capacities. This principle is reinforced by Nugraha & Nuriadin (2025) who demonstrated that the use of concrete media and play-based activities is effective in establishing numeracy foundations at the preoperational stage. Nevertheless, implementation in Special Schools (SLB) continues to face challenges, particularly in arithmetic assessments for visually impaired students, which remain insufficient in addressing their sensory and cognitive needs. Moreover, the absence of Merdeka Curriculum–based numeracy assessment instruments developed with the ADDIE model for visually impaired learners in Indonesia is further compounded by the findings of (Rumantiningsih et al., 2020), who highlight the scarcity of tactile media. These issues underscore the urgent need to design concrete, multisensory assessment tools that align with the characteristics of visually impaired students and their developmental stage within the concrete operational period.

Building on prior research, this research seeks to address the central question: "How can an inclusive and effective numeracy assessment instrument be developed for visually impaired students, while taking into account curriculum alignment and individual needs?" This problem formulation underpins the design of assessment tools that not only aim to measure numeracy skills with accuracy but also acknowledge the visual characteristics, specific learning needs, and educational contexts of visually impaired learners. Moreover, the research question emphasizes the need to overcome challenges in creating adaptive assessments that ensure accessibility and promote the comprehensive attainment of numeracy competencies. Accordingly, this research endeavors to explore strategies for developing assessment instruments that fulfill technical standards while also demonstrating strong pedagogical value and functional relevance for visually impaired students.

This research seeks to develop a standardized, multisensory, and inclusive numeracy assessment instrument utilizing the ADDIE model, specifically designed to meet the needs of visually impaired students in special elementary schools. The development process integrates alignment with the Merdeka Curriculum, a multisensory approach grounded in cognitive theory, and responsiveness to individual needs within the framework of special education. The resulting instrument is expected to more accurately and meaningfully accommodate the learning characteristics of visually impaired students.

The novelty of this research lies in the systematic application of the ADDIE model to align the development of numeracy assessments with the framework of the Merdeka Curriculum, resulting in a multisensory instrument that was directly tested with visually impaired students through participatory collaboration involving teachers and parents. The instrument incorporates numeracy achievement indicators grounded in Piaget's cognitive development theory and Bloom's Taxonomy, which were adapted to reflect the specific learning characteristics of visually impaired students. Consequently, the instrument not only measures cognitive abilities but also ensures alignment with the concrete operational stage of development and addresses the distinct sensory needs that have frequently been overlooked in special education assessment practices.

2. METHODS

This study employs a Research and Development (R&D) design utilizing the ADDIE model as its framework. ADDIE, an acronym for Analysis, Design, Development, Implementation, and Evaluation, represents a structured framework for instructional design. According to Branch (2009), the ADDIE model represents a systematic process for designing instructional experiences through a series of deliberate phases intended to foster meaningful and structured learning. Although its implementation may be adapted to suit specific contexts or needs, the model's core components remain consistent.

In this research, the development process focused on creating a numeracy assessment instrument designed to evaluate students' numerical skills. The primary subject was a third-grade male student with visual impairment enrolled in a public special needs school in Bandung. Since infancy, the student has retained only light perception and has no additional disabilities. Additional participants included the student's homeroom teacher and parents. Data collection for the instrument was conducted through a literature review of books and scholarly articles on assessment instruments. Complementary preliminary data were also gathered through direct observation of the student and interviews with the homeroom teacher.

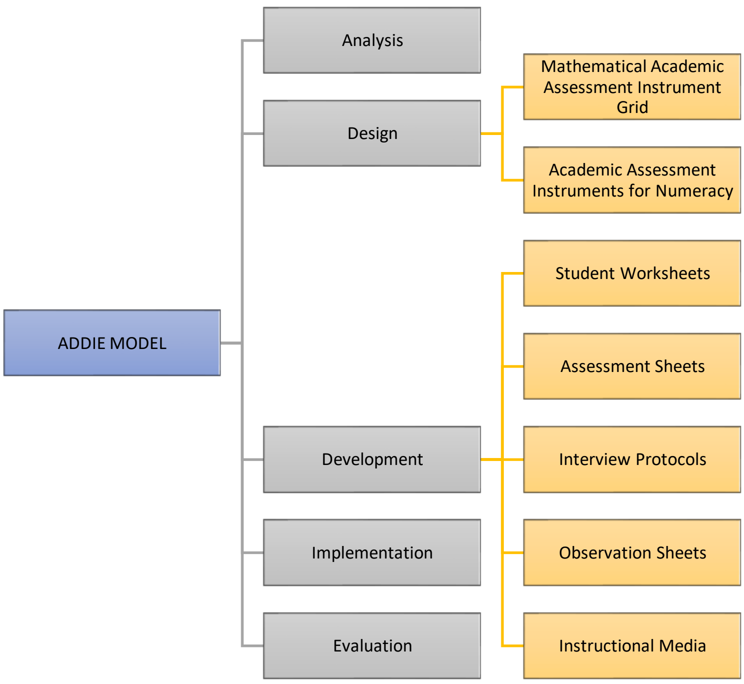

Figure 1. Flow of stages of the ADDIE development model

The numeracy assessment instrument was developed using the ADDIE model, which comprises five systematic stages, as illustrated in Figure 1.

1. Analysis Stage: This phase involved identifying the needs and characteristics of a third-grade visually impaired student, including assessment objectives, and learning environment conditions, which served as the foundation for developing the numeracy assessment instrument.
2. Design Stage: At this stage, the framework of the assessment instrument was constructed, including the development of an arithmetic instrument grid and arithmetic tasks. These were designed in reference to the Agency for Standards, Curriculum, and Educational Assessment (Badan Standar, Kurikulum, dan Asesmen Pendidikan (BSKAP)) guidelines on learning outcomes for early childhood, primary, and secondary education in the Merdeka Curriculum, as well as to Piaget's cognitive theory and Bloom's Taxonomy.
3. Development Stage: This stage focused on producing and refining the assessment instruments, such as student worksheets (Lembar Kerja Siswa (LKS)), assessment sheets, interview protocols, observation sheets, and instructional media. Validation and subsequent revisions were conducted based on expert feedback from two lecturers specializing in educational assessment.
4. Implementation Stage: In this phase, the validated and refined assessment instruments were administered through direct trials with a third-grade visually impaired student, with adjustments made to accommodate their specific needs.
5. Evaluation Stage: This stage focused on identifying the strengths and limitations of the instruments based on the outcomes of the trial, employing quantitative descriptive methods. The analysis involved calculating total scores for each item using a 0–4 rating rubric, converting these scores into percentages, and classifying achievement levels as Independent (≥76%), Instructional (50–75%), or Frustration (≤49%). The findings were then analyzed to interpret patterns of subject mastery and to provide a basis for evaluating the practical validity and field applicability of the instrument.

The research method should be included in the Introduction. The method contains an explanation of the research approach, subjects of the study, the conduct of the research procedure, the use of materials and instruments, data collection, and analysis techniques.

3. FINDINGS AND DISCUSSION

3.1. Result

3.1.1. *Analysis*

At this stage of analysis, information was gathered regarding the concept of assessment as the foundation for developing academic numeracy assessment instruments. The academic numeracy assessment was designed to measure and evaluate student's mathematical skills, including addition, subtraction, and recognition of geometric shapes. Prior to conducting field observations, several preparatory steps were undertaken, including the selection of the special school, identification of the types of disabilities, determination of student' educational levels, and the arrangement of assessment and observation permits. The observations were conducted with a visually impaired student at the third-grade level with light perception, to collect data on student characteristics such as age, grade level, and specific needs, which served as the basis for adapting the academic numeracy assessment instrument. The primary purpose of the arithmetic assessment was to identify student's needs, abilities, and challenges in mathematics in a valid and reliable manner for the purpose of student profiling. Based on the data collected, the subject was from a class consisting of four elementary school students in grades three, four, and six. During the learning activities, rulers and styluses were used as assistive tools to support student participation.

3.1.2. Design

At the design stage, the assessment instruments were developed comprehensively by interpreting the BSKAP framework for Phases A, B, and C, supported by the theoretical foundations of Bloom's Taxonomy and Jean Piaget. The assessment indicators were aligned with Phase A (Grades 1–2), Phase B (Grades 3–4), and Phase C (Grades 5–6), with a particular emphasis on numeracy competencies, including number operations, basic problem-solving, and geometry.

The strategy for implementing the academic arithmetic assessment employed three testing techniques: oral, practical, and written. The oral test comprised 12 questions in Phase A, 7 questions in Phase B, and 3 questions in Phase C. The practical test included 9 questions in Phase A, 4 questions in Phase B, and none in Phase C. For the written test, 10 questions were developed for Phase A, 22 for Phase B, and 14 for Phase C. The guidelines and instruments were adapted from the BSKAP framework and subsequently refined into academic instruments consisting of four components: (a) Aspects, (b) Question Items, (c) Questions, and (d) Success Criteria. The assessment rubric applied a holistic scoring scale ranging from 0 to 4.

(0) : No effort despite assistance
(1) : More than three errors or random responses
(2) : Two to three errors, or responses approximating the correct answer
(3) : One minor error (e.g., a single incorrect number in a sequence)
(4) : All questions answered correctly without error

Regarding concrete objects, paper materials shaped as data figures were designed as aids during the academic assessment of arithmetic, following the established instrument grid. The assessment was administered face-to-face and structured to include: (1) standardized instructions, (2) flexible time allocation based on the student's pace of completion, and (3) verification of the alignment between the questions and the intended learning indicators.

3.1.3. Development

Following the design phase, the subsequent step was the development of instruments and supporting tools to ensure the continuity of numeracy assessment. This stage involved the creation of student worksheets, assessment sheets, interview protocols, and observation guidelines tailored to the child's age and learning stage. Instructional media that facilitate numeracy assessment, such as Braille paper and concrete learning aids, were also prepared to enhance the efficiency of the process. Upon completion, the instruments were subjected to expert validation by lecturers specializing in the field, after which revisions were made to ensure alignment with the specific needs of the student.

3.1.4. Implementation

During the implementation stage, the validated and revised academic numeracy instruments were administered to the subject. Assessments were conducted only for Phases A and B, adjusted to the student's grade level. The assessment process began with Phase B and shifted to Phase A if the subject encountered difficulties at the higher phase. The implementation was carried out across eight sessions on a predetermined schedule at a State Special School in Bandung. The assessment of numeracy skills comprised written, oral, and practical tasks that had been developed in the earlier stage. Throughout the sessions, assessors ensured that participants completed the tasks independently, based on his abilities and understanding, without external intervention. In addition, assessors documented participants' behaviors, including his concentration, challenges, and responses, during the assessment.

To ensure the completeness of the data, the researchers rotated roles in each session, including:

1. Interviewer/assessor
2. Audio-recording scribe
3. Logistics coordinator
4. Photographer
5. Videographer

After all tasks were completed, examiners reviewed the student's results by cross-checking his answer sheets, video recordings, and audio recordings. Each response was then evaluated based on the scoring criteria that had been predetermined.

3.1.5. *Evaluation*

The results of the implemented arithmetic assessment instrument were subsequently evaluated. All arithmetic questions were completed (48/48 items). The total score obtained from the participant was 99, with a cumulative arithmetic ability score of 192 based on a rubric scale of 0–4 per item. The score conversion yielded 99/192 × 100% = 51.57%. This outcome indicates that the participant's mastery of arithmetic remains at the Instruction Level, suggesting that he still requires further instruction and guidance in the assessed arithmetic content.

Level	Range
Independent Level	Up to 76%
Instruction Level	50% - 75%
Frustration Level	Down to 49%

Table 1. Level and range arithmetic ability score

The strengths of the instrument include: (1) clearly formulated and detailed assessment items, (2) comprehensive coverage of question types, and (3) the integration of multiple assessment techniques (written, oral, and practical), which enabled an accurate diagnosis of participant's placement at the Instruction Level. However, several limitations were identified. These include insufficient preparation by researchers, limited availability of instructional media, inadequate classroom facilities, restricted assessment time, and external disturbances that affected the assessment process.

3.2. Discussion

The selection of SLB locations and the identification of subject characteristics—such as age, type of visual impairment, grade level, and the use of assistive devices like reglets and styluses—form the essential foundation for developing academic numeracy assessment instruments. An adaptive approach to mathematics instruction for visually impaired students, grounded in their actual needs, necessitates individualized adjustments and the integration of multisensory instructional tools within assessments. Such practices have been shown to not only enhance conceptual understanding and numeracy skills but also foster greater self-confidence (Ardiansyah et al., 2023; Faradiba et al., 2024; Ookeditse & Garegae, 2024; Rachmawati, 2015). Consistent with this perspective, Soleh et al. (2011) highlighted that the jarimatika method significantly contributes to improving mathematics achievement among visually impaired students, as it simplifies and streamlines calculation processes, enables faster and more accurate computation, and serves as a more appropriate alternative than the abacus. Nevertheless, it is important to acknowledge that this assessment was conducted with only one participant, thereby limiting its external validity.

Identification of varying degrees of visual impairment reveals significant differences in numeracy achievement. Students with low vision tend to demonstrate higher levels of numeracy achievement compared to students who are completely blind (Cappagli et al., 2022; Haslinda et al., 2025). Conversely, findings by Crollen et al. (2021) indicate that blind children may possess basic numerical abilities equivalent to, or even exceeding, those of sighted children, attributed to their stronger verbal working memory capacity. However, the present study did not include a comparative analysis between the two groups, leaving the interpretation of individual scores susceptible to potential bias.

From a design perspective, numeracy assessment instruments should be aligned with student's cognitive developmental stages and grounded in the relevant educational curriculum. Basic numeracy skills serve as a critical indicator of mathematics learning outcomes at the elementary school level (Dierkx et al., 2025). For visually impaired students, in particular, the assessment must be structured, concrete, flexible, and multimodal to effectively measure their understanding of fundamental mathematical concepts while accommodating diverse individual needs (Maruyama & Kurosaki, 2023; Nieminen, 2024; Raynal et al., 2024). This is implemented through a combination of oral, practical, and written techniques, complemented using physical aids adapted to student's developmental characteristics. Nonetheless, the current application of oral, practical, and written instruments still largely replicates conventional assessment models, albeit modified into a multisensory format.

The learning outcomes of Phases A and B in the Merdeka Curriculum (BSKAP), together with the use of a holistic rubric on a 0–4 scale, serve as an equitable reference point for assessing a visually impaired student. Revised theory of Taxonomy Bloom indicates that children aged 7–8 years are typically at the lower cognitive levels of remembering (C1) and understanding (C2), and gradually progress to applying (C3), analyzing (C4), and eventually to evaluating (C5) and creating (C6) by the ages of 11–12 years (Pepilina et al., 2024; Premana et al., 2023). In parallel, Piaget's theory of cognitive development posits that children aged 8–10 years are in the concrete operational stage, where they continue to require tangible objects and verbal instructions to complete complex tasks. As noted by Cerovac & Keane (2025), the transition from two-dimensional to three-dimensional representations may increase cognitive load. This suggests that, although the assessment is designed to be adaptive, the risk of cognitive overload among visually impaired students has not yet been fully addressed.

The assessment instruments that were designed were organized into Student Worksheets (LKS), while the assessment sheets were developed based on the success criteria outlined in the instruments. In addition, observation and interview guidelines were systematically structured to ensure that each component followed a clear and measurable assessment framework. Mathematics achievement among visually impaired students is strongly influenced using media and approaches that align with their sensory conditions (Iqbal et al., 2020; Mutmainah & Hermawati, 2021). Learning media, such as Braille paper and concrete manipulatives, were prepared to enhance the efficiency and effectiveness of the assessment process. However, their impact remains limited, as the assessment tools have not yet incorporated digital technologies or adaptive devices that are increasingly recognized as international standards, such as screen readers or electronic Braille displays.

The validation of instruments by expert lecturers serves as the foundation for determining the overall quality of the assessment process. Without adequate validation, instruments risk diverging from the intended competencies, generating biased data, and leading to potentially misleading interpretations of learning outcomes. Consequently, expert judgment—encompassing the wording of questions, the level of difficulty, the clarity of stimuli, and the appropriateness of supporting media—is essential to ensuring instrument validity. The outcomes of this validation process then serve as the basis for subsequent revisions, thereby enhancing the validity and reliability of the instrument prior to its implementation in field trials (Serlina et al., 2023; Wasidi & Mardapi, 2016).

Following the validation stage, the implementation of the academic assessment instruments aimed not only to evaluate their effectiveness, clarity, and relevance to field conditions, but also to identify potential errors that may have gone undetected during the planning stage. The numerical assessments for the visually impaired student were conducted over eight sessions on a planned yet flexible schedule, allowing adjustments to accommodate the needs of a student with special needs. Furthermore, the strategy of rotating researcher roles across sessions helped to prevent individual dominance and facilitated the evaluation of consistency in the instrument's implementation. Conducting the study at the Bandung State Special School provided an authentic context that strengthened external validity. Nevertheless, restricting the implementation to a single institution introduces limitations, as the findings may not be fully generalizable to other special education settings with differing resources and cultural contexts.

In the assessment process, researchers employed multiple techniques while also considering student's concentration, responses, and learning barriers. Structuring the questions from the most difficult to the easiest provides an indication of cognitive capacity; however, this approach carries the risk of reducing motivation when the student encounters challenges at the outset. The use of styluses, rulers, and concrete media—such as geometric paper, dolls, and balls—proved effective in linking abstract concepts to real-life experiences, though his success largely depends on the facilitator's ability to integrate these tools with cognitive objectives. Moreover, the inclusion of practical and oral tasks as alternatives to written assessments represents a relevant adaptation, although the extent to which they offer equivalent measures of student's deeper understanding requires further investigation.

The assessment process was documented through photographs, audio-video recordings, and observation notes as a means of verification to enhance the accuracy of the analysis. This approach reflects a deliberate effort to maintain data validity, although it still leaves room for subjectivity in interpretation. The assessment was conducted in a structured manner, guided by the success criteria established during the design stage, with the evaluation of each item tailored to the student's level of mastery and corresponding learning indicators. Consequently, the assessment not only emphasized final outcomes but also highlighted the process of completing tasks, student's responses, and the cognitive dynamics that emerged during implementation.

After the assessment was completed, the subject successfully finished all 48 questions. However, the final score of 51.57% indicated performance at the Instructional Level, suggesting the need for further guidance and scaffolding. This outcome was influenced by the limited effectiveness of concrete media, such as counting blocks, Braille boards, and other manipulatives, which were not yet fully optimized, thereby restricting the implementation of practical tasks. Another contributing factor was the regular classroom environment, which lacked soundproofing and introduced external disturbances that disrupted the subject's concentration and reduced the accuracy of observations, consistent with the findings of Shoaib et al. (2023). Time constraints also posed a significant challenge, as the subject required additional time to comprehend complex instructions, while the assessment schedule had to align with the school timetable. These obstacles likely prevented the student from demonstrating his full potential, which may have been higher, though still within the Instructional Level range. Consistent with Gervasoni & Peter-Koop (2020), these findings underscore the importance of time flexibility in inclusive assessments, allowing the student to perform at his best without external pressures. Collectively, these circumstances highlight the persistent gap between student's individual needs and the structural limitations of the current assessment context.

Thus, a high-test score does not necessarily indicate optimal competence; rather, it reveals limitations in the assessment design that require further review. Nevertheless, the assessment instruments employed demonstrate several strengths. The sequence of questions was developed based on measurable learning outcome indicators, encompassing various aspects of numeracy, from number operations to geometric concepts, and presented in diverse formats through multiple techniques, including oral, practical, and written tasks. This multi-method approach aligns with the principles of authentic and inclusive assessment and is consistent with the findings of Ameran & Zainal (2024), who emphasize that integrating visual, auditory, and tactile modalities in mathematics assessment provides more equitable opportunities for students with special needs to demonstrate their comprehensive understanding.

4. CONCLUSION

This study successfully developed an inclusive numeracy assessment instrument specifically designed for visually impaired elementary school students, employing the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. The instrument represents one of the first numeracy assessments constructed within the framework of the Merdeka Curriculum, addressing the learning outcomes of Phases A, B, and C through a multisensory approach that incorporates tactile and auditory modalities. Nevertheless, its future application requires broader field testing, integration with digital technologies, and stronger policy support to ensure sustainability and scalability.

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