JPM UNILA
Jurnal Pendidikan Matematika Universitas Lampung
Vol. 14, No. 2, 2026, pp. 147 – 156
https://jurnal.pbs.fkip.unila.ac.id/index.php/jpm/
ISSN: 2715-856X

An Ethnographic Study of Abacus Use Among Visually Impaired Individuals in Solving Addition and Subtraction Problems

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ARTICLE INFO

Article history
Received: 21 December, 2025
Revised: 3 March, 2026
Accepted: 27 June, 2026
Published: 29 June, 2026

Keywords
abacus;
addition;
ethnography;
subtraction;
visually impaired

ABSTRACT

This study explores the use of the abacus (sempoa) as a tactile learning tool by visually impaired elementary school students in solving addition and subtraction problems. Employing a qualitative case study approach with an ethnographic orientation, this research involved three visually impaired elementary school students selected through purposive sampling. The participants were chosen based on three criteria: having visual impairment, possessing prior experience in using the abacus, and being actively involved in learning addition and subtraction operations. Data were collected through participant observation, in-depth interviews, and analysis of modified abacus artifacts. The findings reveal that the abacus functions as a "tactile cognitive map," enabling students to bridge abstract mathematical concepts and physical reality. Students employed a consistent two-handed technique, where the left hand guided place value and the right hand executed bead movements. Addition involved moving beads toward the center bar, whereas subtraction involved moving them away, reflecting complex mental restructuring during "carrying" and "borrowing" tasks. The effectiveness of abacus use depended on fingertip sensitivity, procedural consistency, and working memory. Ultimately, the abacus supported students' independence, confidence, and participation in inclusive mathematics learning.

How to Cite: Mutmainah, S., W., & Suliani, M. (2026). An Ethnographic Study of Abacus Use Among Visually Impaired Individuals in Solving Addition and Subtraction Problems. *Jurnal Pendidikan Matematika Universitas Lampung*, *14*(2), 147-156. http://dx.doi.org/10.23960/mtk/v14i2.pp147-156

INTRODUCTION

Learning mathematics often poses significant challenges for students with visual impairments because many mathematical concepts are commonly introduced through visual symbols, spatial representations, and written procedures. Concepts such as place value, addition, subtraction, carrying, and borrowing require students to understand abstract numerical relationships that are often difficult to access without visual support. Therefore, for visually impaired students, these abstract concepts need to be transformed into forms that can be explored through touch, movement, and verbal explanation. Assistive tools such as the abacus (sempoa) play an important role in this process because they provide tactile representations of numbers and arithmetic operations, allowing students to construct mathematical meaning through direct physical interaction with beads and place-value columns (Amato et al., 2013; Maričić & Lazić, 2020).

Previous studies have shown that the abacus can support students' understanding of number concepts, arithmetic procedures, and mathematical independence. The abacus enables learners to manipulate beads, recognize place-value positions, and represent numerical relationships through concrete actions. In the context of students with visual impairments, tactile learning tools are particularly important because they help bridge the gap between abstract mathematical ideas and physical experiences that can be accessed through the hands. Research on multisensory learning, assistive technology, and mathematics education has emphasized the importance of concrete and tactile media in supporting inclusive learning environments, especially for students who rely heavily on non-visual sensory channels (Due, 2024; Sedaghatjou, 2018).

However, much of the existing literature has focused on the general benefits of abacus use, its effectiveness in improving calculation skills, or its role as an instructional aid in mathematics learning (Mahendra et al., 2022; Rahmi et al., 2020). Previous studies have also discussed the use of the abacus in supporting arithmetic operations and addressing students' learning difficulties, particularly in addition and subtraction (Pradana & Ummah, 2020; Sari & Kaltsum, 2023). Although these studies are valuable, they tend to emphasize learning outcomes, instructional effectiveness, or the general function of the abacus as a teaching medium. Less attention has been given to how visually impaired students actually use the abacus in natural learning situations, particularly through their micro-tactile interactions, hand positioning, bead manipulation, body movements, verbal expressions, and problem-solving routines.

This gap is important because abacus use among visually impaired students is not merely a mechanical process of moving beads. It involves a complex coordination of tactile sensitivity, spatial orientation, working memory, procedural discipline, and embodied mathematical reasoning. The way students position their fingers, use both hands, locate place-value columns, shift beads during addition, and manage carrying and borrowing during subtraction reflects a distinctive technical learning culture. These micro-level practices are often difficult to capture through surveys, tests, or general classroom observations. Therefore, an ethnographic orientation is valuable because it allows researchers to examine students' repeated routines, embodied strategies, and meaning-making processes within their actual learning context.

Based on this gap, the present study explores how visually impaired elementary school students use the abacus to solve addition and subtraction problems. Unlike studies that primarily evaluate learning outcomes or measure the effectiveness of instructional tools, this research focuses on the tactile and embodied processes through which students construct mathematical understanding. Specifically, the study investigates how students coordinate hand movements, interpret bead positions, perform carrying and borrowing, and develop independence during arithmetic problem-solving. Through a qualitative case study with an ethnographic orientation, this research aims to reveal the micro-tactile strategies and technical learning culture that shape abacus use among visually impaired students. Accordingly, this study is guided by the following research questions: (i) How do visually impaired elementary school students use tactile strategies when solving addition and subtraction problems with the abacus?, (ii) How do students coordinate hand movements, bead manipulation, and place-value orientation during carrying and borrowing processes? (iii) How does abacus use support students' independence and confidence in mathematics learning?.

METHOD

This study employed a qualitative case study design with an ethnographic orientation to explore how visually impaired elementary school students used the abacus (sempoa) in solving addition and subtraction problems. Participants were selected using purposive sampling and consisted of three visually impaired elementary school students aged 7-12 years. The inclusion criteria were students diagnosed with visual impairment, having prior experience using the abacus, actively engaging in addition and subtraction learning, and being able to communicate their experiences during interviews. Students without prior abacus experience or those unable to participate consistently in observation sessions were excluded. Consent was obtained from the school and parents or guardians, and students' willingness to participate was confirmed before data collection.

Data were collected through participant observation, in-depth interviews, and artifact analysis. Observations were conducted over 30 days, consisting of 2 sessions, each lasting approximately 30 minutes. The researcher positioned herself as a participant observer in the mathematics learning environment, observing students' tactile interactions, hand movements, bead manipulation, place-value orientation, and strategies during carrying and borrowing, while minimizing direct intervention. Interviews were conducted to explore students' experiences, difficulties, and perceptions of abacus use. Artifact analysis focused on the tactile features of the modified abacus, including bead texture, resistance, and arrangement.

Data were analyzed using the framework of Miles et al. (2014), involving data condensation, data display, and conclusion drawing and verification. Triangulation was conducted by comparing observation data, interview transcripts, and artifact analysis. Students' observed bead manipulation strategies were compared with their verbal explanations and the physical features of the abacus. Consistent patterns across these data sources were used to establish credible findings.

RESULTS AND DISCUSSION

Drawing from participant observations and in-depth interviews, the findings reveal that for visually impaired students, the abacus serves as more than a simple counting device; it functions as a tactile cognitive mapping instrument. Through repeated tactile interaction with the beads, students constructed spatial representations of numbers and arithmetic procedures. This finding was supported by the students' interview responses. One participant stated, "When I touch the beads, I can know the position of the ones and tens. My fingers help me remember the numbers" (S1, translated from Indonesian). Another participant explained, "The abacus makes it easier because I can feel the beads and check my answer by myself" (S2, translated from Indonesian). These statements indicate that the abacus helped students transform abstract numerical concepts into tactile and spatial experiences.

Observation data also showed that students did not use the abacus randomly. They followed repeated hand routines when solving arithmetic problems. The left hand was generally used to locate and maintain orientation to the place-value columns, while the right hand was used to move the beads. This pattern was confirmed by one participant, who stated, "My left hand holds the place, and my right hand moves the beads. If my left hand moves away, I can get confused" (S3, translated from Indonesian). This quote suggests that the two-handed technique functioned as a strategy for maintaining spatial orientation and procedural accuracy.

a. Tactile Interaction and Finger Positioning

During the problem-solving process, visually impaired students consistently employed a two-handed technique. The left hand typically served as a guide or anchor, marking place-value columns such as units, tens, and hundreds, while the right hand executed the actual movement of the beads. This tactile engagement allowed learners to recognize the position and value of each bead, thereby constructing a mental representation of numbers and mathematical operations.

The interview data strengthened this observation. One participant explained, "I know the number from the place of the bead. I touch it first, then I know whether it is ones or tens" (S1, translated from Indonesian). This statement indicates that students relied on tactile orientation to understand numerical position and value. Such mental scaffolding is vital in transcending visual limitations, effectively enabling students to "visualize" numerical structures through touch (Ramayanti & Iranda, 2022). This tactile phase is foundational because mathematics instruction for children with visual impairments must originate from tangible objects that can be physically explored and manipulated (Due, 2024; Sedaghatjou, 2018).

This approach also aligns with multisensory learning principles, which emphasize the necessity of concrete experiences in building abstract concepts, particularly within inclusive educational settings (Ameran & Zainal, 2024; Esplendori et al., 2022). In this study, tactile interaction was not merely a sensory activity but a structured cognitive process through which students organized place value, controlled bead movement, and maintained calculation accuracy.

b. The Addition Process

During addition operations, students tended to move beads toward the center bar. This movement formed a repeated tactile routine that helped them represent the accumulation of numerical value. When carrying was required, students shifted attention to the adjacent column and adjusted the beads carefully. One participant described this process as follows: “When the beads are not enough, I move to the next place. I touch it first, then I continue counting” (S1, translated from Indonesian). This shows that carrying was not merely a procedural step but involved tactile checking, place-value awareness, and working memory.

Observation data showed that students performed the carrying process with deliberate and measured movements. They first checked the current column through touch, then moved to the next place-value column before continuing the calculation. This pattern indicates that students had internalized the relationship between bead movement and place-value structure. The addition process therefore involved both physical manipulation and mathematical abstraction.

This finding is consistent with pedagogical approaches that prioritize concrete experiences as the foundation for understanding abstract concepts (Mutmainah et al., 2024). The repetitive tactile interaction with the beads facilitated an intuitive understanding of number composition and decomposition, both of which are essential for mastering more advanced arithmetic concepts. In addition, the abacus helped reduce cognitive load by externalizing numerical information into a tactile-spatial form, allowing students to focus on the active mathematical operation (Wang, 2020; Wang et al., 2021). Abacus use also supports spatial working memory, which is important for tracking bead positions and managing numerical information during calculations (Bjørnebye, 2019; Wang et al., 2021).

c. The Subtraction Process

In subtraction, students moved beads away from the center bar. The borrowing process appeared more demanding because students had to coordinate tactile memory and column orientation. One participant explained, “Borrowing is harder because I have to remember the number before and touch the next column carefully” (S2, translated from Indonesian). This statement supports the observation that subtraction required more intensive cognitive restructuring than addition, especially when students needed to borrow from a higher place-value column.

During observation, borrowing was often accompanied by distinctive behavioral cues, such as pauses, repeated touching of the bead column, soft verbal counting, or subtle head movements. These behaviors indicated that students were reallocating attention and verifying the correct place-value position before moving the beads. Thus, borrowing was not simply a mechanical action; it involved compensatory strategies, tactile verification, and deeper internalization of abstract place-value concepts.

As a concrete manipulative, the abacus enabled visually impaired students to internalize abstract mathematical principles through tactile interaction, thereby reinforcing their understanding of multi-step arithmetic operations (Ross et al., 2020). The use of the abacus as a tangible learning medium helped bridge the gap between abstract theory and students lived tactile reality. This is in line with the pedagogical principle that abstract material should be made perceptible to support comprehension. Furthermore, physical gestures and manipulative-based learning can strengthen mental representations in mathematical tasks (Cho & So, 2018).

d. Insights into Learning Culture

The findings also reveal that abacus use supported students’ confidence and independence in inclusive mathematics learning. The abacus served as a communicative bridge that connected abstract mathematical concepts with a physical reality that students could navigate through touch. The precision required to sense bead positions fostered autonomy because students could verify their answers independently rather than relying entirely on teacher assistance.

This interpretation was supported by one participant who stated, “I feel more confident because I can count by myself with the abacus” (S3, translated from Indonesian). Another participant explained, “If I forget the answer, I touch the beads again and check it” (S2, translated from Indonesian). These statements suggest that the abacus helped students monitor their own work and develop self-directed strategies during problem-solving activities.

These findings resonate with prior literature suggesting that inclusive pedagogical approaches and the strategic use of assistive tools can enhance both academic participation and self-assurance in mathematics learning (Ali et al., 2024). The role of the abacus in this study was not limited to computation; it also supported discipline, carefulness, and responsibility in completing arithmetic tasks. Similar findings have been reported in studies showing that concrete instructional aids can support motivation, self-directed learning, and student engagement (Anuli et al., 2022; Erin & Koenig, 1997; Mutmainah et al., 2024).

e. Synthesis of Findings

Overall, the use of the abacus by visually impaired students represents a process of transforming abstract numerical information into a spatial-tactile framework. These interview excerpts and observation findings strengthen the interpretation that the abacus functions as a tactile cognitive map for visually impaired students. The tool allows students to externalize numbers through touch, coordinate hand movements, and develop greater independence in arithmetic problem-solving. The success of this tactile-cognitive process depends on three critical factors:

First, fingertip tactile sensitivity plays an essential role. Students with visual impairments rely on tactile perception to distinguish bead positions, identify place-value columns, and differentiate the upper beads representing a value of five from the lower beads representing a value of one. This sensitivity enables them to maintain accuracy during calculation.

Second, procedural consistency is necessary to preserve the integrity of the abacus display. Disciplined hand positioning helps prevent accidental bead displacement and ensures that every manual manipulation reflects the intended arithmetic operation. This finding supports the idea that accuracy in finger placement is closely connected to cognitive processing and mathematical reasoning (Maqbool, 2023; Masriani et al., 2024; Rahmi et al., 2020).

Third, working memory capacity is required because students must temporarily hold numerical values while simultaneously manipulating the beads. During carrying and borrowing, students need to remember the current value, locate the correct place-value column, and adjust the beads accordingly. This multimodal interaction integrates tactile, motor, and cognitive processes, allowing students to construct robust mental representations of numbers.

In summary, the abacus does not merely function as a calculative aid. It acts as a tactile cognitive map, a procedural guide, and a medium for developing independence among visually impaired students. By coordinating touch, movement, memory, and mathematical reasoning, students are able to construct meaningful strategies for solving addition and subtraction problems in an accessible and embodied way.

CONCLUSION

The findings of this study demonstrate that the abacus is far more than a traditional calculating tool; it serves as a 'communicative bridge' that transforms abstract mathematical concepts into a tactile physical reality for students with visual impairments. Through its use, these students construct 'tactile cognitive maps,' where each deliberate movement of a bead represents a profound understanding of place value and numerical structure.

The core insights from this research are summarized as follows:

1. **Strategic Cognitive Development:** Students cultivate robust cognitive strategies through consistent two-handed techniques, which act as a vital mechanism for ensuring computational accuracy.
2. **Internalization of Arithmetic Logic:** The processes of addition and subtraction transcend mere manual manipulation; they involve a deep internalization of 'carrying' and 'borrowing' concepts, clearly evidenced by the students’ distinctive body language and intense mental focus.
3. **Pillars of Success:** Mastery of the abacus is predicated on three essential factors: fingertip tactile sensitivity, procedural discipline to ensure the integrity of the bead 'display' and a sufficient working memory capacity to store temporary numerical data.

Ultimately, proficiency in abacus use is shown to significantly bolster confidence, precision, and autonomy among students within inclusive educational settings. Moving forward, it is recommended that the integration of the abacus into special education curricula be actively encouraged. Such an initiative is crucial to ensuring that visually impaired students can achieve numerical competencies that are on par with those of their sighted peers.

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