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Adaptation of Mathematics Learning Models for Deaf Students through a Visual Communication Approach: A Case Study

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ABSTRACT

Purpose of the study: This study aimed to explore the adaptation of mathematics learning models for deaf students through a visual communication approach. Particular attention was given to instructional planning, classroom implementation, communication practices, learning media, and students' learning experiences within the context of mathematics education for students with hearing impairments.

Methodology: A qualitative approach with a case study design was employed. Participants consisted of one mathematics teacher and six eleventh-grade deaf students selected through purposive sampling. Data were collected using classroom observations, semi-structured interviews, and documentation. Data analysis followed the Miles and Huberman interactive model involving data reduction, data display, and conclusion drawing.

Main Findings: Results indicated that mathematics learning adaptation was supported by visual communication strategies, including lip movements, hand gestures, facial expressions, repeated explanations, and the Maternal Reflective Method. Various concrete learning media facilitated students' understanding of mathematical concepts. Positive student responses and active participation were observed during classroom activities. Learning outcomes demonstrated satisfactory achievement despite differences in communication abilities and mathematical competencies among students.

Novelty/Originality of this study: Novelty of this study lies in emphasizing visual communication as an integral component of mathematics learning adaptation for deaf students. Unlike previous studies focusing mainly on learning outcomes, the present study highlights how communication strategies are embedded within instructional planning, classroom interaction, and the use of learning media to support meaningful mathematics learning experiences.

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1. INTRODUCTION

Mathematics learning constitutes an essential component in developing students' logical, analytical, and problem-solving abilities, including for students with special educational needs [1]. Equal access to quality education for all learners has become a fundamental principle in the implementation of inclusive and special education. Deaf students require instructional services that are adapted to their communication characteristics and learning needs. Limitations in auditory perception encourage deaf students to rely more heavily on visual modalities in understanding information and concepts [2]. Therefore, the selection and adaptation of mathematics learning models need to consider visual communication as a crucial element in facilitating meaningful learning experiences.

Despite the importance of providing appropriate instructional services, mathematics learning for deaf students still presents various challenges in practice. Differences in language development and communication patterns often affect students' understanding of abstract mathematical concepts [3], [4]. Teachers are required to adapt instructional strategies, media, and learning interactions to accommodate students' characteristics. However, not all learning models can effectively address the diverse needs of deaf students in mathematics classrooms. Consequently, the implementation of mathematics learning for deaf students demands approaches that emphasize visual communication and active student engagement.

Several previous studies have reported that inquiry-based learning contributes positively to improving students' mathematical understanding and learning outcomes [5], [6]. Research conducted on deaf students also indicates that inquiry learning encourages active participation and promotes conceptual comprehension. Previous studies have mainly focused on the effectiveness of learning models in improving academic achievement. Other studies have highlighted the importance of instructional media and teacher support in special education settings [7]. Nevertheless, the majority of these studies tend to emphasize learning outcomes rather than exploring how learning models are adapted through visual communication practices during classroom instruction.

This condition indicates the existence of a research gap concerning the adaptation process of mathematics learning models for deaf students [8]. Existing studies have not sufficiently described how visual communication is integrated into planning, implementation, and classroom interactions. Moreover, limited studies have examined the ways teachers modify learning activities to accommodate the communication characteristics of deaf students [9], [10]. Research concerning mathematics learning adaptation at the senior high school level for deaf students also remains relatively scarce. As a result, empirical evidence regarding the practical implementation of visually oriented learning models in special education contexts is still limited.

Understanding the adaptation of mathematics learning models is important for improving the quality of educational services provided to deaf students [11], [12]. Appropriate instructional adaptations can facilitate students' conceptual understanding and enhance their participation in classroom activities. Findings from such studies may provide practical insights for teachers in designing more accessible and responsive mathematics instruction. Furthermore, the results can contribute to the development of inclusive pedagogical practices that acknowledge the unique characteristics of students with hearing impairments [13], [14]. Therefore, investigating mathematics learning adaptation through visual communication approaches becomes increasingly relevant in strengthening the implementation of special education.

The novelty of this study lies in its emphasis on the adaptation process of mathematics learning models through a visual communication approach for deaf students [15]. Unlike previous studies that predominantly focus on learning outcomes, this study explores how visual communication is manifested in instructional planning, classroom implementation, and the use of learning media [16]. The study also provides an in-depth understanding of teachers' instructional practices in responding to the communication needs of deaf students. By employing a case study approach, the research presents contextual and comprehensive descriptions of mathematics learning practices in special education settings [17], [18]. Hence, this study is expected to enrich the discourse on mathematics education and special education by providing empirical evidence regarding visually oriented instructional adaptations for deaf students.

2. RESEARCH METHOD

2.1 Research Design

A qualitative approach employing a case study design was adopted to explore the adaptation of mathematics learning models for deaf students through a visual communication approach [19], [20]. This design enabled an in-depth understanding of instructional practices within their natural context. Attention was directed toward the planning, implementation, and communication processes involved in mathematics learning activities. Particular emphasis was placed on how visual communication facilitated students' understanding of mathematical concepts [21]. Accordingly, a case study design was considered appropriate for obtaining comprehensive and contextual findings.

2.2 Participants and Research Setting

Participants involved in this study consisted of one mathematics teacher and six eleventh-grade deaf students in a special education school [22]. Purposive sampling was employed because the participants possessed relevant experiences related to the research focus [23]. Data collection was conducted during mathematics instruction on plane geometry topics. Learning activities were observed in their natural classroom setting to capture authentic interactions between teachers and students. Such a setting provided valuable information regarding the adaptation of learning models through visual communication practices.

2.3 Data Collection Techniques

Data collection relied on classroom observations, semi-structured interviews, and documentation. Classroom observations were conducted to identify interaction patterns, instructional activities, and the use of visual communication during mathematics learning. Semi-structured interviews with the mathematics teacher were carried out to obtain detailed information concerning instructional planning and learning adaptations [24]. Documentation served as complementary evidence through the examination of lesson plans, students' records, and other supporting materials. Combining these techniques contributed to the credibility and comprehensiveness of the collected data.

Table 1. Research Procedures

Stage	Activities	Data Sources
Preparation	Determining research focus and participants	Teacher and students
Data Collection	Observation, interviews, and documentation	Classroom activities and documents
Data Analysis	Data reduction, data display, and conclusion drawing	Observation notes, interview transcripts, and documents
Interpretation	Interpreting findings and formulating conclusions	Integrated research data

2.3 Data Analysis

Data analysis followed the interactive model proposed by Miles and Huberman, consisting of data reduction, data display, and conclusion drawing. Relevant information obtained from observations, interviews, and documentation was first organized and categorized according to the research objectives [25]. Subsequently, the data were presented systematically to identify emerging themes and patterns. Interpretation of the findings was conducted through continuous verification to ensure consistency and trustworthiness. Through this analytical process, a comprehensive understanding of mathematics learning adaptation for deaf students was achieved.

Figure 1. Research Procedure

3. RESULTS AND DISCUSSION

3.1 Adaptation of Mathematics Learning Planning

Findings revealed that mathematics instruction for deaf students was planned based on the 2013 Curriculum with several adjustments according to students' characteristics. Lesson plans prepared by the teacher included learning objectives, learning activities, assessment procedures, and learning resources. Although the inquiry learning model had been incorporated into the lesson plans, specific adaptations for deaf students were not explicitly described. Learning activities emphasized contextual examples to facilitate students' understanding of plane geometry concepts. These findings indicate that instructional planning complied with curriculum requirements but still required more explicit integration of visual communication strategies.

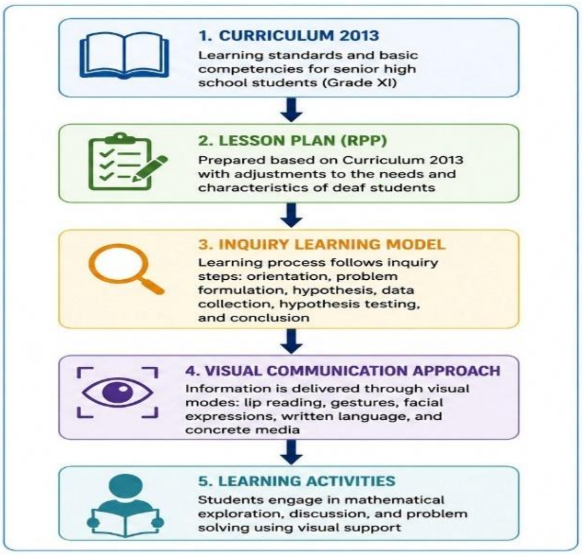

Figure 2. Components of Mathematics Learning Adaptation

3.2 Implementation of Mathematics Learning through Visual Communication

Classroom observations demonstrated that visual communication played an essential role during mathematics instruction. Students relied heavily on teachers' lip movements, hand gestures, and facial expressions to understand mathematical explanations. The teacher repeatedly explained important concepts and applied the Maternal Reflective Method (MMR) to support communication processes. Active interactions between teachers and students were observed despite the limitations in hearing ability experienced by students. Consequently, visual communication became an important medium that facilitated students' participation and understanding during learning activities.

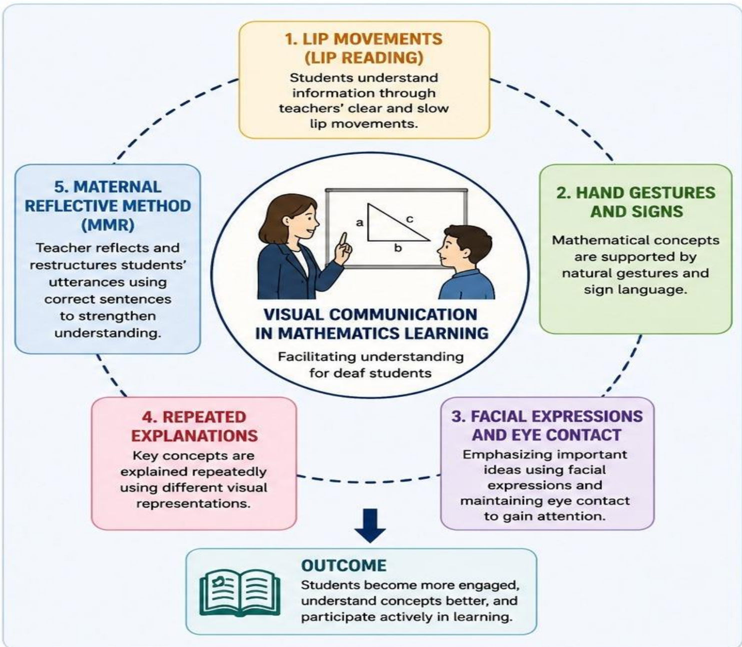

Figure 3. Visual Communication Strategies in Mathematics Learning

3.3 Utilization of Learning Media and Student Responses

Various concrete objects and contextual media were utilized to support students' understanding of mathematical concepts. Whiteboards, rulers, books, desks, and cardboard were frequently used to explain perimeter and area concepts. Students showed positive responses toward the learning process, particularly regarding the clarity of teachers' explanations and motivational support. Most students demonstrated enthusiasm and confidence when participating in classroom activities. Overall, the learning environment encouraged active engagement and supported students' mathematical learning experiences.

Table 2. Learning Media Used in Mathematics Instruction

Learning Media	Function
Whiteboard	Explaining mathematical concepts
Ruler	Measuring objects
Books	Learning resources
Desk	Providing contextual examples
Cardboard	Illustrating geometric shapes

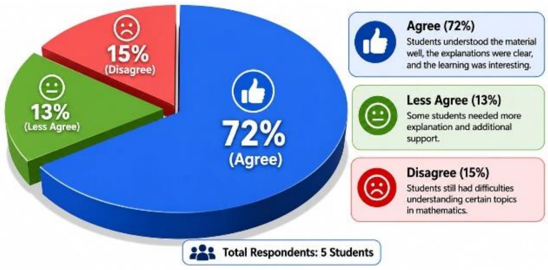

Figure 4. Students' Responses toward Mathematics Learning

3.4 Learning Outcomes and Emerging Findings

Learning outcomes indicated that most students achieved satisfactory scores and actively participated in mathematics instruction. Variations in achievement levels were influenced by differences in communication abilities and mathematical skills among students. Some students still experienced difficulties in arithmetic operations and required additional assistance from the teacher. Nevertheless, students demonstrated strong motivation and actively communicated during classroom interactions. An important finding of this study revealed that visual communication contributed to maintaining students' engagement and supported the adaptation of mathematics learning practices for deaf students.

Table 3. Mathematics Learning Outcomes of Deaf Students

Participant	Score
Der	76.92
Tan	73.08
Lit	73.08
Hen	65.38
Nur	53.85

Findings revealed that the adaptation of mathematics learning for deaf students was reflected in instructional planning, classroom interaction, and communication practices. Implementation of inquiry learning was supported by various visual communication strategies during mathematics instruction. Lip movements, hand gestures, facial expressions, and repeated explanations facilitated students' understanding of mathematical concepts. Active interaction between teachers and students remained evident despite the hearing limitations experienced by learners. Consequently, visual communication served as an essential element in supporting mathematics learning adaptation for deaf students.

Results also demonstrated the importance of learning media and students' responses during mathematics instruction. Various concrete and contextual objects assisted students in understanding abstract mathematical concepts more effectively. Positive responses shown by students indicated their enthusiasm and active participation throughout the learning process. Differences in learning outcomes were associated with variations in communication abilities and mathematical competencies among students. Overall, these findings suggest that visually oriented learning practices contributed to creating a more accessible learning environment.

Consistent with previous studies, instructional adaptation and inquiry-based learning have been reported to enhance students' participation and conceptual understanding [26], [27]. Earlier research has emphasized the importance of teacher support and active learning strategies in mathematics education for students with special educational needs. Studies involving deaf students have also highlighted the contribution of visual representations and communication to the learning process [28], [29]. Nevertheless, most existing studies have concentrated primarily on learning outcomes rather than on the adaptation process itself [30]. Evidence obtained from this study therefore strengthens the view that visual communication plays a central role in mathematics learning for deaf students.

An important contribution of this study lies in its emphasis on visual communication as an integral component of mathematics learning adaptation [31]. Unlike previous studies that mainly examined the effectiveness of learning models, the present study explored how communication strategies were embedded within instructional practices. Findings indicate that visual communication functioned not merely as a supporting tool but as a fundamental aspect of classroom interaction [32]. Use of a case study approach also provided a contextual understanding of teachers' efforts in responding to the communication characteristics of deaf students. Accordingly, this study offers additional insights into visually oriented instructional practices in mathematics and special education.

Practical implications emerging from this study extend to the development of more inclusive learning environments. Mathematics teachers are encouraged to integrate visual communication strategies into instructional activities to accommodate the specific needs of deaf students [33]. Appropriate instructional adaptations may enhance students' participation, motivation, and conceptual understanding [34], [35]. Findings of this study may also provide useful references for schools and educational practitioners in designing accessible learning experiences. Strengthening visual communication in mathematics classrooms can therefore contribute to improving the quality of educational services for students with hearing impairments.

Several limitations need to be considered when interpreting the findings of this study. First, participation was limited to a small number of students and one teacher, restricting the generalizability of the results. Second, investigation was conducted within a single case study setting with specific participant characteristics. Third, the research focused only on mathematics learning within a limited range of instructional materials. Future studies are recommended to involve broader contexts, more participants, and different mathematical topics to obtain a more comprehensive understanding of instructional adaptation for deaf students.

4. CONCLUSION

Findings of this study demonstrate that the adaptation of mathematics learning models for deaf students through a visual communication approach plays an important role in facilitating classroom interaction and supporting students' understanding of mathematical concepts. Various communication strategies, including lip movements, hand gestures, facial expressions, repeated explanations, and the use of concrete learning media, contributed to creating a more accessible learning environment for students with hearing impairments. Results obtained from this study confirm the importance of integrating visual communication into instructional practices to accommodate the specific characteristics and learning needs of deaf students. An important contribution of this study lies in highlighting visual communication as an integral component of mathematics learning adaptation rather than merely a supporting element in classroom activities. Practical implications emerging from the findings provide valuable references for teachers and educational institutions in developing more inclusive and responsive mathematics instruction. Future studies are recommended to involve broader educational contexts, larger numbers of participants, and various mathematical topics in order to enrich the understanding and application of instructional adaptations for deaf students.

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