METHODOLOGY OF INCLUSIVE MATHEMATICS TEACHING FOR GRADE 5–6 STUDENTS (FOR CHILDREN WITH VISUAL AND HEARING IMPAIRMENTS)

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List of Abbreviations

GCD – Greatest Common Divisor

ICT – Information and Communication Technologies

LCM – Least Common Multiple

SDU – SDU University

STEM – Science, Technology, Engineering, and Mathematics

ABSTRACT

This thesis develops and experimentally justifies a methodology for inclusive mathematics teaching for Grade 5–6 students with visual and hearing impairments. The purpose of the study is to make lower secondary mathematics accessible without reducing the academic level of the curriculum. The study addresses the question of how mathematical content can be taught through adapted forms of perception, representation, communication, guided practice, assessment, and response. The research hypothesis is that the use of tactile, visual, written, oral, step-by-step, and practical forms of teaching improves students' access to mathematical content, engagement, and individual learning progress.

The theoretical framework is based on the concept of inclusive mathematics teaching as a subject-methodological system in which mathematical content is preserved while the routes of access and expression are adapted to learners' sensory and communicative needs. The research methods included theoretical analysis, analysis of educational documents and Grade 5–6 mathematics content, modelling, a small-scale case-based pedagogical experiment, pre-test and post-test comparison, observation, qualitative analysis, and descriptive quantitative analysis.

The findings showed positive dynamics in students' mathematical achievement, accessibility to learning materials, engagement, and ability to demonstrate understanding through adapted response formats. The study also showed that errors decreased when mathematical tasks were presented through accessible routes. The practical significance of the study lies in providing adapted tasks, teaching methods, observation tools, and assessment procedures that can support mathematics teachers in planning inclusive lessons for students with visual and hearing impairments.

Keywords: inclusive education, mathematics teaching, visual impairment, hearing impairment, Grade 5–6, adapted tasks, accessible assessment.

АҢДАТПА

Бұл диссертациялық жұмыста көру және есту қабілеті бұзылған 5–6-сынып оқушыларына математиканы инклюзивті оқытудың әдістемесі әзірленіп, тәжірибелік тұрғыдан негізделді. Зерттеудің мақсаты – математика пәнінің академиялық мазмұнын сақтай отырып, оны барлық оқушылар үшін қолжетімді ету. Зерттеуде математикалық материалды қабылдау, түсіну, меңгеру және білім нәтижелерін көрсету тәсілдерін оқушылардың сенсорлық және коммуникативтік ерекшеліктеріне бейімдеу мәселесі қарастырылды. Болжам бойынша, тактильді, көрнекі, жазбаша, ауызша және практикалық оқыту әдістерін қолдану математикалық мазмұнға қолжетімділікті арттырып, оқу жетістіктерін жақсартады.

Зерттеудің теориялық негізі инклюзивті математиканы оқытуды пәндік-әдістемелік жүйе ретінде қарастыруға сүйенеді. Зерттеу барысында теориялық талдау, оқу бағдарламалары мен математикалық мазмұнды саралау, модельдеу, кейс-негізді педагогикалық эксперимент, тест нәтижелерін салыстыру, бақылау және сапалық-сандық талдау әдістері қолданылды.

Нәтижелер оқушылардың математикалық жетістіктері мен сабаққа қатысу белсенділігінің артқанын, оқу материалдарының қолжетімділігі жақсарғанын және бейімделген жауап беру форматтарының түсінгенін көрсетуге мүмкіндік бергенін көрсетті. Сонымен қатар, тапсырмалар қолжетімді түрде ұсынылған жағдайда қателер санының азайғаны анықталды.

Зерттеудің практикалық маңызы мұғалімдерге көру және есту қабілеті бұзылған оқушыларға арналған инклюзивті математика сабақтарын ұйымдастыруға көмектесетін бейімделген тапсырмалар, оқыту әдістері, бақылау құралдары мен бағалау рәсімдерін ұсынуымен сипатталады.

Түйінді сөздер: инклюзивті білім беру, математиканы оқыту, көру қабілетініңбұзылуы, есту қабілетінің бұзылуы, 5–6-сынып, бейімделген тапсырмалар, қолжетімді бағалау.

АННОТАЦИЯ

В диссертационной работе разработана и апробирована методика инклюзивного обучения математике учащихся 5–6 классов с нарушениями зрения и слуха. Цель исследования – обеспечение доступности математического образования без снижения требований учебной программы. Рассматриваются способы адаптации восприятия, представления и демонстрации математических знаний с учётом особенностей обучающихся.

Теоретической основой исследования является концепция инклюзивного обучения математике, предполагающая сохранение содержания обучения при адаптации способов его освоения. В работе использованы теоретический анализ, изучение образовательных документов, моделирование, педагогический эксперимент, тестирование, наблюдение и анализ полученных данных.

Результаты исследования показали улучшение математических достижений учащихся, повышение доступности учебных материалов и активности на уроках. Установлено, что адаптированные формы представления заданий и ответов способствуют более успешному усвоению математического содержания и снижению количества ошибок.

Практическая значимость исследования заключается в разработке адаптированных заданий, методов обучения и оценивания для организации инклюзивного обучения математике учащихся с нарушениями зрения и слуха.

Ключевые слова: инклюзивное образование, обучение математике, нарушение зрения, нарушение слуха, 5–6 классы, адаптированные задания, доступное оценивание.

1. INTRODUCTION

The relevance of the research is determined by the increasing importance of inclusive education in contemporary secondary schools and by the need to ensure real access to mathematical content for students with special educational needs. Inclusive education is one of the priority directions in the development of modern education, as it is based on the principles of equal access, educational justice, and meaningful participation of every learner in the educational process. In the Republic of Kazakhstan, inclusive education is supported by national educational policy, legal regulations, and institutional reforms aimed at creating equal learning opportunities for students with special educational needs. However, the effectiveness of inclusive education is determined not only by the formal presence of such students in the classroom, but also by their actual access to curriculum content, classroom communication, learning activities, assessment procedures, and opportunities to demonstrate academic achievement.

This issue becomes especially important in mathematics education. Mathematics is a subject in which knowledge is expressed through numbers, symbols, formulas, diagrams, tables, geometric figures, coordinate representations, algorithms, and word problems. In Grades 5 and 6, students move from relatively concrete arithmetic operations to more abstract mathematical concepts, including divisibility, fractions, common divisors and multiples, numerical equalities, linear equations, geometry, coordinate representation, and text-based problems. These topics require symbolic reasoning, spatial imagination, understanding of mathematical language, and the ability to follow multi-step procedures.

For students with visual impairments, mathematical learning may be complicated by board writing, small symbolic notation, diagrams, geometric figures, coordinate grids, tables, and visually presented models. For students with hearing impairments, the main barriers are often connected with oral explanations, rapid classroom communication, mathematical terminology, and insufficient written or visual support.

These difficulties should not be interpreted as evidence of reduced mathematical ability. They indicate that the forms through which mathematical content is presented, practised, and assessed may not fully correspond to the sensory and communicative needs of these learners.

In general education schools, this problem becomes particularly relevant because students with visual or hearing impairments are expected to study the same curriculum as their classmates, while teachers often do not have enough subject-specific methodological tools for adapting mathematics instruction. General pedagogical recommendations on inclusion are not sufficient for mathematics lessons, since mathematical content has its own symbolic, visual, linguistic, spatial, and procedural structure. Therefore, inclusive mathematics teaching requires a special methodology that preserves the academic level of the curriculum while adapting the routes through which students perceive, understand, practise, and demonstrate mathematical content.

At the same time, in general education schools, the methodological problem remains that mathematics teachers often have to teach students with visual and hearing impairments within the common classroom setting without sufficient subject-specific adapted tasks, validated diagnostic tools, and clear procedures for comparing students' progress before and after the intervention. This creates the need for a methodology that is not only theoretically grounded but also practically applicable in real Grade 5 and Grade 6 mathematics lessons.

The relevance of the present research is determined by the need to develop and justify a methodology for inclusive mathematics teaching for Grade 5 and Grade 6 students with visual and hearing impairments in a general education school setting. The proposed methodology is focused on accessible representation of mathematical content, step-by-step explanation, tactile and visual support, written algorithms, adapted tasks, differentiated assessment, and comparison of students' results through pre-test and post-test procedures.

The contradiction of the research is that, on the one hand, inclusive education requires students with visual and hearing impairments to have access to the same

mathematical learning outcomes as their peers, while, on the other hand, lower secondary mathematics is still frequently taught through visual, oral, symbolic, spatial, and abstract forms that may not be accessible to these learners without special methodological adaptation.

This contradiction creates the following research problem: how to organize mathematics teaching for Grade 5 and Grade 6 students with visual and hearing impairments in a general education school so that the academic content is not simplified, but becomes accessible through adapted forms of perception, representation, communication, guided practice, assessment, and reflection.

The aim of the research is to develop and experimentally justify a methodology for inclusive mathematics teaching for Grade 5 and Grade 6 students with visual and hearing impairments in a general education school setting.

The object of the research is the process of teaching mathematics in Grades 5 and 6 in the context of inclusive education.

The subject of the research is the methodology of inclusive mathematics teaching for Grade 5 and Grade 6 students with visual and hearing impairments, including adapted teaching methods, accessible learning materials, pre-test and post-test tasks, assessment criteria, and procedures for evaluating the effectiveness of the methodology.

The research objectives are formulated in accordance with the aim of the study:

1. To analyse the current state of inclusive education in secondary schools and identify the main barriers that students with visual and hearing impairments face in mathematics learning.
2. To determine the didactic conditions necessary for making Grade 5 and Grade 6 mathematics accessible to students with visual and hearing impairments without reducing the academic level of the curriculum.
3. To define the concept and content structure of inclusive mathematics teaching for lower secondary school students.

4. To develop adapted methods, tasks, and learning materials for teaching selected Grade 5 and Grade 6 mathematics topics to students with visual and hearing impairments.

5. To organize a small-scale pedagogical experiment in a general education school involving lower secondary students with sensory impairments and to conduct pre-test and post-test assessment.

6. To analyse the obtained results and evaluate the effectiveness of the proposed inclusive mathematics teaching methodology.

The research hypothesis is that if Grade 5 and Grade 6 mathematics content is presented through tactile, visual, written, oral, step-by-step, and practically oriented forms without reducing its academic level, then students with visual and hearing impairments will demonstrate improved access to mathematical content, higher engagement in learning activities, and positive progress in pre-test and post-test results.

In particular, it is assumed that the use of tactile materials, enlarged and clearly structured visual materials, written algorithms, step-by-step instructions, oral description, accessible response formats, and adapted pre-test and post-test tasks will help students overcome sensory and communicative barriers in mathematics learning. As a result, students will be able to understand mathematical concepts more clearly, complete adapted tasks more independently, and demonstrate their mathematical understanding through accessible forms of response.

The theoretical significance of the research consists in clarifying the concept of inclusive mathematics teaching as a subject-methodological system. The study shows that accessibility in mathematics should not be considered as an external support measure added after the lesson is planned. Rather, accessibility should be treated as an integral part of the organization of mathematical content, explanation, practice, and assessment.

The research contributes to the development of inclusive mathematics didactics by identifying the barriers, learning needs, didactic conditions, and directions of content adaptation necessary for teaching Grade 5 and Grade 6 students with visual and

hearing impairments. The study also theoretically substantiates the idea that mathematical content can be preserved at the same academic level while the forms of access, representation, communication, and response are adapted to students' sensory and communicative needs.

In addition, the research specifies the subject-specific nature of inclusive mathematics teaching. It demonstrates that mathematics adaptation should be based not only on general characteristics of visual or hearing impairments, but also on the structure of mathematical content itself, including symbols, diagrams, terminology, algorithms, geometric representations, coordinate models, and word problems.

The practical significance of the research is determined by the development of methodological recommendations, adapted teaching approaches, diagnostic instruments, pre-test and post-test tasks, observation tools, and examples of accessible mathematics tasks for students with visual and hearing impairments.

The proposed materials can be used by mathematics teachers working in general education schools where students with special educational needs study together with their peers. The practical materials are oriented toward Grade 5 and Grade 6 mathematics topics, including divisibility, fractions, numerical equalities, linear equations, geometry, coordinate representation, and word problems. They may also be adapted for other topics and educational contexts.

Special practical value is given to the pre-test and post-test system, which makes it possible to compare students' initial and final results and evaluate the effectiveness of the proposed methodology. The validity of the diagnostic tasks is ensured by their correspondence to the Grade 5 and Grade 6 mathematics curriculum, the parallel structure of pre-test and post-test tasks, expert review, and adaptation of task formats for students with visual and hearing impairments.

The practical materials developed in the study may help teachers plan inclusive mathematics lessons more systematically. In particular, they support the teacher in identifying barriers within a specific mathematical topic, selecting appropriate tactile, visual, written, oral, or practical forms of representation, organizing step-by-step

guided practice, and assessing students' understanding without lowering the conceptual level of mathematical tasks.

The research methods include theoretical analysis of scientific and methodological literature, analysis of legal and educational documents, analysis of Grade 5 and Grade 6 mathematics textbooks, modelling, pedagogical experiment, testing, observation, comparison of pre-test and post-test results, qualitative analysis of students' learning difficulties, and descriptive quantitative analysis of diagnostic data.

The theoretical methods were used to analyse inclusive education, mathematics didactics, sensory impairments, adapted instruction, accessible assessment, and methodological approaches to teaching mathematics in lower secondary school.

The empirical methods were used to organize and evaluate the experimental part of the research. The experimental work was organized in a general education school with the participation of lower secondary students with sensory impairments. The study focused on individual learning progress, which was measured through pre-test and post-test comparison. The main diagnostic instruments included pre-test and post-test tasks, an accessibility and engagement observation checklist, adapted lesson materials, and analysis of students' task performance.

The data analysis methods included comparison of pre-test and post-test scores, identification of individual learning progress, analysis of task completion, and interpretation of changes in students' access to mathematical content, engagement, and achievement.

The scientific novelty of the research lies in the development of a practically oriented methodology for adapting Grade 5 and Grade 6 mathematics teaching to the needs of students with visual and hearing impairments in a general education school setting, and in evaluating its effectiveness through individual pre-test and post-test comparison.

The novelty of the study is reflected in the following points.

First, the study substantiates inclusive mathematics teaching as a subject-methodological system in which mathematical content is preserved, while the forms of access, explanation, practice, and assessment are adapted.

Second, the study identifies the main barriers faced by students with visual and hearing impairments in learning Grade 5 and Grade 6 mathematics, including visual-symbolic barriers, communicative barriers, linguistic barriers, spatial barriers, and procedural barriers.

Third, the study proposes adapted methods and tasks for teaching selected Grade 5 and Grade 6 mathematics topics through tactile, visual, written, oral, step-by-step, and practical forms.

Fourth, the study develops a diagnostic approach based on pre-test and post-test comparison, which allows the effectiveness of inclusive mathematics teaching to be evaluated through students' individual progress.

Fifth, the study demonstrates that the effectiveness of inclusive mathematics teaching depends not on simplifying mathematical content, but on creating accessible ways for students to perceive, process, practise, and demonstrate the same mathematical concepts.

The following provisions are submitted for defense:

1. Inclusive mathematics teaching for students with visual and hearing impairments should preserve the academic content of mathematics while adapting the routes of access, representation, communication, practice, and assessment.

2. Students with visual and hearing impairments face subject-specific barriers in Grade 5 and Grade 6 mathematics because mathematical content is often presented through visual, oral, symbolic, spatial, and language-based forms.

3. The use of tactile materials, visual algorithms, written instructions, step-by-step explanation, adapted tasks, and accessible assessment formats makes it possible to improve students' access to mathematical content without lowering the conceptual level of the curriculum.

4. The effectiveness of the proposed methodology can be evaluated through pre-test and post-test comparison, observation of accessibility and engagement, and analysis of students' ability to complete mathematical tasks in adapted formats.

5. Inclusive mathematics teaching becomes more effective when the teacher begins lesson planning with the analysis of barriers within the mathematical topic itself and then selects appropriate forms of representation, communication, practice, and assessment.

The research was carried out in three stages. At the first stage, theoretical and analytical work was conducted. Scientific and methodological literature on inclusive education, mathematics teaching, visual impairment, hearing impairment, adapted instruction, and accessible assessment was analysed. Legal and educational documents related to inclusive education in Kazakhstan were also examined. In addition, Grade 5 and Grade 6 mathematics content was analysed in order to identify topics that may create difficulties for students with visual and hearing impairments.

At the second stage, the methodological basis of the research was developed. The main barriers in learning mathematics were identified, didactic conditions for inclusive mathematics teaching were determined, and adapted teaching methods and tasks were prepared. Pre-test and post-test tasks were designed according to the Grade 5 and Grade 6 mathematics curriculum. The tasks were structured in parallel form so that they measured the same mathematical skills before and after the intervention.

At the third stage, the experimental work was organized at KSU Secondary School No. 15. The study involved lower secondary students with visual and hearing impairments. At the beginning of the experiment, pre-test assessment was conducted to identify students' initial level of mathematical achievement. During the intervention, adapted teaching methods, tactile and visual materials, written algorithms, step-by-step explanation, and accessible tasks were used. At the end of the experiment, post-test assessment was conducted, and the obtained results were compared with the initial data. The effectiveness of the methodology was evaluated on the basis of students' progress,

accessibility of learning materials, engagement in mathematical activity, and ability to demonstrate understanding through adapted response formats.

The structure of the dissertation consists of an introduction, two chapters, a conclusion, references, and appendices.

The first chapter examines the theoretical foundations of inclusive mathematics teaching for lower secondary school students. It analyses the current state of inclusive education, identifies the main barriers faced by students with visual and hearing impairments in mathematics learning, and determines the didactic conditions necessary for accessible mathematics teaching. The chapter also clarifies the concept and content structure of inclusive mathematics teaching for Grade 5 and Grade 6 students.

The second chapter presents the methodology and experimental work. It describes adapted methods and forms of teaching Grade 5 and Grade 6 mathematics to students with visual and hearing impairments, explains the organization of the pedagogical experiment in a general education school, and analyses the results obtained through pre-test and post-test assessment.

2. LITETATURE REVIEW

2.1 Analysis of the Current State of Inclusive Education in Secondary Schools

Inclusive education is one of the key socio-pedagogical directions in the modernization of contemporary secondary education. Its meaning is not limited to the formal placement of students with special educational needs in mainstream classrooms. Inclusion refers to the organization of an educational environment in which every learner can access curriculum content, understand teacher explanations, participate in classroom interaction, complete learning tasks, and demonstrate learning outcomes in appropriate forms. Therefore, inclusive education includes not only physical access to school but also content, communicative, methodological, and assessment accessibility.

In mathematics education, inclusion has a specific subject-related meaning. Participation in a mathematics lesson depends not only on classroom presence but also on the learner's involvement in mathematical activity, interaction, reasoning, and problem solving. Stylianidou (2022) emphasizes that inclusion in mathematics is expressed through participation in mathematical discourse and learning activity. Matobako (2021) argues that the central issue in inclusive mathematics classrooms is whether learners have a genuine opportunity to learn mathematics. These positions are important for the present study because students with visual and hearing impairments face not only general educational barriers but also subject-specific barriers connected with the symbolic, visual, linguistic, and communicative nature of mathematical content.

The legal foundations of inclusive education in the Republic of Kazakhstan are established through a system of normative documents that guarantee equal access to education for children with special educational needs. The Law of the Republic of Kazakhstan "On Education" establishes the right of every learner to quality education and defines accessibility as one of the core principles of the national education system (Law of the Republic of Kazakhstan No. 319-III, 2007). The Law of the Republic of

Kazakhstan “On Social and Medical-Pedagogical Correctional Support for Children with Disabilities” provides for the creation of special educational conditions, including instructional methods, technical aids, and psychological and pedagogical support (Law of the Republic of Kazakhstan No. 343-II, 2002). These provisions form the legal basis for educating students with visual and hearing impairments in inclusive settings.

The State Compulsory Education Standards approved by Order No. 348 of the Minister of Education of the Republic of Kazakhstan require all learners to achieve established learning outcomes (Order of the Minister of Education of the Republic of Kazakhstan No. 348, 2022). In inclusive education, this requirement should not be interpreted as a mechanical reduction of curriculum content. It indicates the need to ensure access to the same academic content through appropriate educational conditions. The Concept for the Development of Inclusive Policy in the Republic of Kazakhstan for 2025–2030 also defines inclusion as a long-term direction of educational development and emphasizes accessible environments, pedagogical support, and adaptation of the learning process (Government of the Republic of Kazakhstan, 2024). Thus, inclusive education is institutionally established in Kazakhstan at the normative level, but legal guarantees alone do not ensure the full accessibility of subject content in classroom practice.

Kazakhstani studies show that one of the main problems of inclusive education lies in the transition from normative recognition to real school-level implementation. Researchers emphasize that inclusive education requires not only legal regulation but also teacher readiness, methodological resources, psychological-pedagogical support, adapted materials, and coordinated work within the school environment (Mukatova & Mukhamedkhanova, 2017; Arinova & Алшынбекова, 2018). The readiness of teachers to work with students with special educational needs is considered an essential condition for transforming inclusion from a formal policy requirement into everyday classroom practice (Lekerova & Movkebayeva, 2020). This issue is especially significant in mathematics, where access to learning depends not only on general

school conditions but also on the availability of symbolic, visual, linguistic, and communicative forms of mathematical representation.

The current state of inclusive education should therefore be evaluated through both the existence of a regulatory framework and the degree of its implementation at school and subject levels. Studies on inclusive education show that the effectiveness of inclusion depends on teachers' professional preparation, school-based support systems, adapted learning materials, and the availability of methodological and technical resources (Makoelle & Burmistrova, 2025; Mamerkhanova & Sakayeva, 2025). Mathematics teaching makes this problem more visible because mathematical content is often presented through symbolic notation, visual models, oral explanations, and abstract concepts. A school may formally provide an inclusive environment, but mathematics instruction cannot be considered fully inclusive unless learners can access mathematical information, understand task requirements, participate in classroom activity, and demonstrate mathematical understanding.

International research also confirms that mathematics teachers often experience difficulties in organizing instruction for students with sensory impairments. Mungunda (2023) identifies a lack of specialized tools and methodological preparation among mathematics teachers working with students with visual impairments. Tshabalala (2023) shows that communicative accessibility is a central condition for teaching mathematics to students with hearing impairments in inclusive settings. These findings indicate that the quality of inclusive education should be evaluated not only by the presence of students with special educational needs in mainstream classrooms but also by their actual access to subject content and participation in learning activity.

The normative and pedagogical foundations of inclusive education in secondary school are summarized in Table 2.1.1.

Table 2. 1. 1. Normative and Pedagogical Foundations of Inclusive Education in Secondary School

Basis / source	Key provision	Relevance to inclusive mathematics teaching
Law of the Republic of Kazakhstan "On Education"	Equal right to quality education and accessibility of education for all learners	Establishes the general legal basis for inclusive education in secondary schools
Law of the Republic of Kazakhstan "On Social and Medical-Pedagogical Correctional Support for Children with Disabilities"	Special educational conditions, technical aids, and psychological-pedagogical support	Justifies the need for support for students with visual and hearing impairments
State Compulsory Education Standards	Achievement of established learning outcomes by all learners	Shows that mathematical content should not be reduced but made accessible
Concept for the Development of Inclusive Policy for 2025–2030	Accessible environment, pedagogical support, and adaptation of the learning process	Defines inclusion as a long-term direction of educational development
Kazakhstani studies on inclusive education	Teacher readiness, methodological resources, and school-level support	Reveals the gap between normative inclusion and real access to subject learning

Note. Developed by the author based on the national regulatory documents of the Republic of Kazakhstan (2002, 2007, 2022, 2024) and studies by Stylianidou (2022), Matobako (2021), Mungunda (2023), and Tshabalala (2023).

Mathematics is characterized by a high degree of symbolic, visual, linguistic, and abstract content. Mathematical understanding is constructed through verbal explanations, formulas, symbols, graphs, diagrams, tables, geometric models, coordinate systems, and word problems.

For students with visual impairments, board writing, small symbols in textbooks, graphs, diagrams, and geometric representations may restrict access to essential mathematical information. For students with hearing impairments, oral explanations, classroom discussions, mathematical terminology, and immediate verbal feedback may create communicative barriers. These difficulties should not be interpreted as limitations of learners' cognitive potential. They reflect a mismatch between the form in which mathematical information is presented and the learner's available perceptual and communicative channels.

The problem becomes particularly evident in Grades 5 and 6. At this stage, students move from relatively concrete arithmetic content to more abstract and symbolic mathematical material. Topics such as fractions, decimals, percentages, equations, coordinate planes, diagrams, geometric figures, and word problems require symbolic thinking, spatial reasoning, comprehension of mathematical language, and the ability to establish logical relationships between quantities. Therefore, inclusive mathematics teaching in Grades 5 and 6 requires a clear understanding of how mathematical content is perceived, processed, represented, and expressed by students with visual and hearing impairments.

The legal and organizational foundations of inclusive education have been established, but they do not automatically resolve subject-specific barriers in mathematics classrooms. The quality of inclusion in mathematics is determined by whether the learner can access mathematical content, understand mathematical language, participate in problem solving, and interact meaningfully with the teacher

and classmates. Inclusive barriers should therefore be understood not as direct consequences of individual impairments but as barriers that arise when instruction, content representation, and communication do not correspond to the learner's perceptual and communicative capacities.

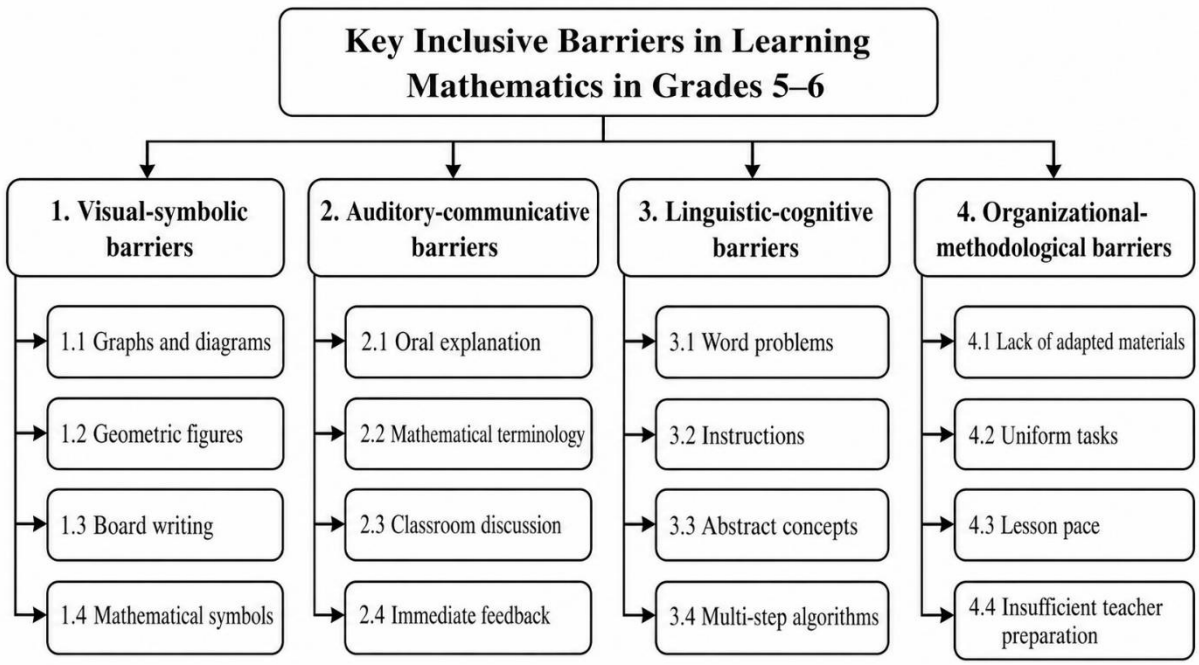
For students with visual impairments, the primary barriers are connected with the visual-symbolic nature of mathematical content. A substantial part of mathematical information is conveyed through board writing, textbook notation, formulas, tables, graphs, diagrams, geometric figures, and coordinate systems. When these materials rely mainly on visual perception, students may have difficulty reconstructing mathematical relationships, such as the position of a point on a coordinate plane, the comparison of values in a diagram, or the properties of a geometric figure. Mungunda (2023) highlights the methodological difficulties teachers encounter when explaining graphical and geometric content to students with visual impairments. Bayram (2014) identifies graphing, note-taking, problem solving, and classroom participation as key areas of difficulty for visually impaired students. Emerson and Anderson (2018) emphasize that visual mathematical information requires accurate and structurally clear verbal representation.

For students with hearing impairments, the primary barriers are auditory and communicative. Mathematics instruction frequently relies on oral explanation, verbal analysis of solution procedures, immediate feedback, and classroom discussion. When communication is not fully accessible, students may miss not only individual words but also the logical development of mathematical reasoning. Mathematical terminology creates additional difficulties because terms such as equal, greater than, less than, ratio, numerator, denominator, coordinate, perimeter, and area have precise subject-specific meanings. Tshabalala (2023) identifies communication gaps between teachers and students as a central barrier in inclusive mathematics classrooms for learners with hearing impairments. Kabethi (2021) also emphasizes that the linguistic accessibility of mathematical tasks and instructions influences learning outcomes.

Students with visual and hearing impairments also encounter shared linguistic-cognitive and organizational-methodological barriers. Understanding word problems, identifying relevant information, performing multi-step procedures, applying mathematical terminology accurately, and explaining solution strategies are complex tasks for many students in Grades 5 and 6. For students with sensory impairments, these tasks become more difficult when instructional materials are not accessible, lesson pace is rigid, task formats are uniform, and teachers lack the necessary preparation. Kazakhstani research on children with special educational needs also shows that educational difficulties are closely connected with the accessibility of school conditions, psychological-pedagogical support, and the organization of the learning environment (Dzhangeldinova, 2023). Thus, barriers in inclusive mathematics learning should be considered as an interconnected system.

The key inclusive barriers in learning mathematics in Grades 5 and 6 are illustrated in Figure 2.1.1.

Figure 2. 1. 1. Key Inclusive Barriers in Learning Mathematics in Grades 5 and 6



Note. Developed by the author based on Matobako (2021), Mungunda (2023), Bayram (2014), Tshabalala (2023), Stylianidou (2022), Kabethi (2021), and Emerson and Anderson (2018).

The analysis of inclusive barriers shows that the learning difficulties of students with sensory impairments should not be interpreted as individual deficits or reduced learning capacity. They should be understood as pedagogical indicators that reveal the conditions necessary for access to mathematical content. In this context, specific learning needs do not mean simplified education. They refer to the conditions that allow students to work with the same mathematical content through appropriate perceptual, linguistic, communicative, and organizational pathways.

Consequently, for students with visual impairments, the central learning need is not the simplification of mathematical content but access to its spatial and symbolic structure. These students need ways to understand mathematical symbols, spatial relations, graphical information, geometric figures, coordinate planes, and measurement relations. This is particularly important in geometry, coordinates, diagrams, and fraction models, where mathematical meaning is closely connected with spatial relationships.

For students with hearing impairments, specific learning needs are primarily related to the accessibility of mathematical language and classroom communication. These students need clear mathematical terminology, understandable instructions, stable written or visual support for oral explanation, and opportunities to follow the logic of mathematical reasoning. Their needs are not limited to receiving information; they must also be able to ask questions, explain solutions, justify reasoning, and participate in mathematical discourse.

Students with visual and hearing impairments also share common learning needs related to the organization of learning activity. In Grades 5 and 6, mastering mathematical concepts requires a clear task structure, sufficient time for perception and processing, support in understanding word problems, and opportunities for active participation. These needs are especially important because students at this stage are

still developing independent learning strategies and often rely on teacher explanation, textbook representations, board work, examples, and peer interaction.

The possibility to express mathematical understanding is also a significant learning need. This need is important because learning mathematics includes not only receiving information but also explaining solution procedures, justifying mathematical relationships, and interpreting results.

The main learning needs of students with visual and hearing impairments in mathematics are presented comparatively in Table 2.1.2.

Table 2. 1. 2. Learning Needs of Students With Visual and Hearing Impairments in Mathematics

Need dimension	Students with visual impairments	Students with hearing impairments
Perception of mathematical information	Access to graphs, diagrams, formulas, and geometric objects in forms that reveal their mathematical structure	Access to teacher explanation and task conditions through clear and stable forms
Mathematical language	Understanding symbols, formulas, notation, and their relations	Understanding terminology, instructions, questions, and mathematical statements accurately
Spatial understanding	Comprehending geometric figures, coordinates, measurement, and direction	Understanding spatial concepts through mathematical language and visual models
Participation in learning activity	Engagement in problem solving, discussion, and interpretation of mathematical relations	Participation in classroom discussion, questioning, and explanation of reasoning

Note. Developed by the author based on Matobako (2021), Matobako and Jita (2022), Mungunda (2023), Bayram (2014), Tshabalala (2023), Stylianidou (2022), Kabethi (2021), and Emerson and Anderson (2018).

The current state of inclusive mathematics teaching in secondary education can therefore be characterized by a contradiction between the established legal and organizational foundations of inclusion and the unresolved subject-specific barriers that arise in mathematics classrooms. For students with visual and hearing impairments in Grades 5 and 6, these barriers are connected with access to mathematical content, comprehension of mathematical language, perception of symbolic and visual representations, classroom communication, and participation in mathematical activity. This contradiction substantiates the need to identify didactic conditions that can ensure accessible, participatory, and methodologically grounded mathematics teaching. The following section examines these didactic conditions in relation to the presentation of learning material, organization of an inclusive mathematics lesson, and assessment and feedback.

2.2 Didactic Conditions for Inclusive Mathematics Teaching in Secondary Education

The previous section identified the main subject-specific barriers and learning needs that determine the organization of inclusive mathematics teaching in Grades 5 and 6. On this basis, the present section focuses not on the repeated description of these barriers, but on the didactic conditions that respond to them. Inclusive mathematics teaching in secondary education requires a coherent system of conditions related to three interconnected directions: accessible presentation of mathematical learning material, methodological organization of an inclusive mathematics lesson, and inclusive assessment with feedback. These directions form a didactic sequence: mathematical content must first be presented in an accessible and conceptually accurate form; then it must be included in students' active mathematical work; finally, the results of this work must be assessed fairly and used to support further learning.

2.2.1 Didactic Conditions for the Accessible Presentation of Mathematical Learning Material

Accessible presentation of mathematical learning material does not mean simplifying content or lowering academic requirements. It means preserving the core meaning of a mathematical concept while presenting it in a form that corresponds to students' perceptual and communicative capacities. In inclusive mathematics teaching, accessibility is not an additional technical adjustment but an initial didactic condition that determines whether the learner can enter the mathematical content of the lesson.

In the present study, accessible presentation is considered as a system of four interrelated didactic principles: multimodality, logical structure, subject accuracy, and representational equivalence. Multimodality responds to the need to present mathematical information through more than one perceptual channel. Logical structure ensures that a concept, example, rule, and task are introduced in a clear and sequential manner. Subject accuracy preserves the mathematical meaning of a concept without replacing it with a simplified or distorted version. Representational equivalence ensures that when mathematical content is transferred from one form to another, the same conceptual relationship remains available to the learner.

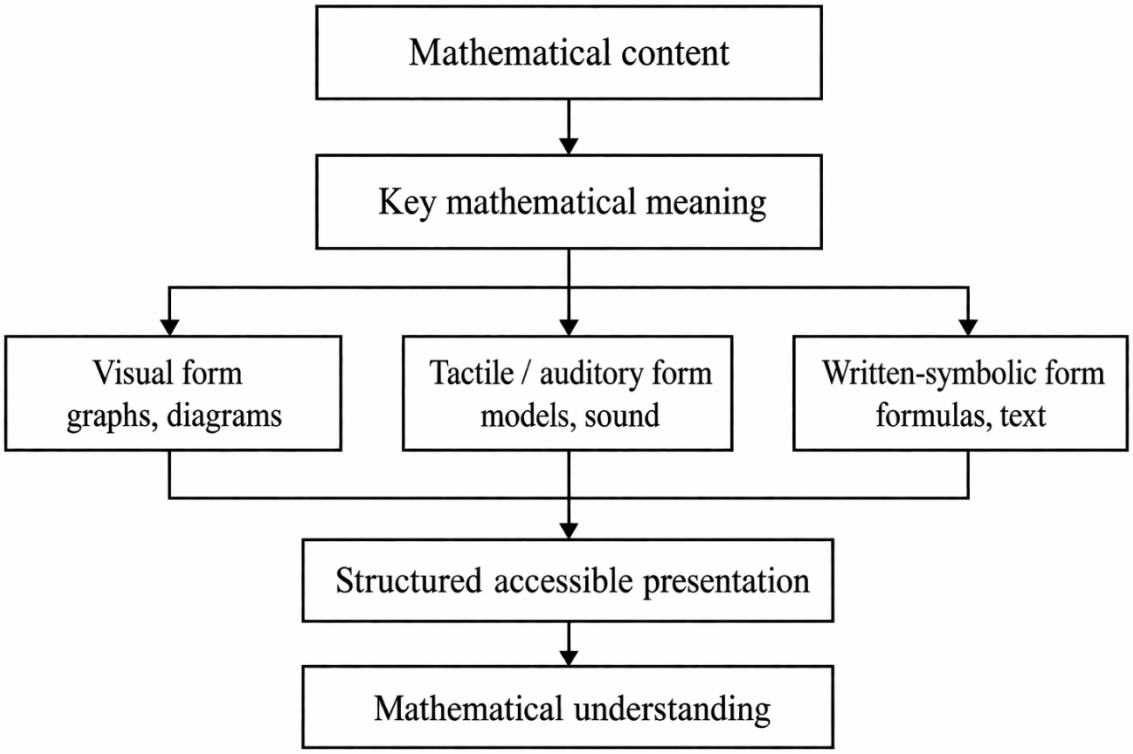
These principles are not isolated recommendations; together they form a didactic mechanism for maintaining access to mathematical meaning. For example, when a diagram is described verbally or transformed into tactile form, the student should still understand comparison, proportion, direction, quantity, or spatial relation, not merely the external appearance of the object. In the same way, when a symbolic expression is explained through words, the explanation should preserve the mathematical relation represented by the symbols.

Matobako (2021) shows that access to mathematical concepts in inclusive classrooms is closely connected with the availability of accessible learning materials and teacher support. Stylianidou (2022) emphasizes that mathematical meaning is constructed through language, interaction, sensory experience, material tools, and semiotic representations. Therefore, in Grades 5 and 6, the teacher should identify the

core mathematical meaning before selecting the form of presentation. A fraction, an equation, a coordinate point, or a diagram should be presented not as an isolated sign or image, but as a mathematical relationship that can be understood, interpreted, and used in problem solving.

Figure 2.2.1.1. presents the didactic logic of accessible presentation of mathematical learning material.

Figure 2. 2. 1. 1. Didactic Conditions for Accessible Presentation of Mathematical Content



Note. Developed by the author based on Matobako (2021), Mungunda (2023), Stylianidou (2022), Rule et al. (2011), Leuders (2016), and Klingenberg and Holkesvik (2020).

For students with visual impairments, the main didactic condition is the presentation of visual mathematical information in a semantically equivalent form. Large print, contrast, additional time, tactile materials, verbal description, or digital tools may support accessibility, but their value depends on whether they reveal the

mathematical structure of the object. Emerson and Anderson (2018) note that structure and accuracy are essential when visual mathematical information such as graphs, tables, and diagrams is described verbally. Rule et al. (2011) show that adapted materials can increase students' participation in secondary science and mathematics lessons, while Leuders (2016) emphasizes the role of tactile and acoustic materials in inclusive mathematics classrooms. Thus, the teacher should focus not on replacing a visual object mechanically, but on making its relations, direction, measurement, and symbolic meaning accessible.

For students with hearing impairments, accessible presentation depends primarily on the stable organization of mathematical language. Mathematical terms, symbols, rules, and algorithms should be connected explicitly. Tshabalala (2023) shows that communication access is a key condition for teaching mathematics to students with hearing impairments. At the level of content presentation, this means that oral explanation should be supported by written terms, visible symbolic notation, structured algorithms, and clear task conditions. For example, the equal sign should be presented as a relation of equivalence, not only as a separator between two expressions; the terms numerator and denominator should be introduced as meaningful components of the structure of a fraction, not as words to be memorized mechanically.

Differentiation strengthens accessible presentation when it is understood not as assigning different mathematical goals to different students, but as varying the route toward a common mathematical goal. In Kazakhstani studies on mathematics education, differentiated teaching is considered an important condition for connecting common learning objectives with students' individual possibilities (Dauletkulova, n.d.; Khumyrbek & Sydykhov, n.d.). In inclusive mathematics teaching, differentiation regulates the form and sequence through which the student approaches the same mathematical concept while preserving the academic content of the lesson.

Accessible presentation of mathematical learning material is the initial didactic condition of inclusive mathematics teaching. It is based on multimodality, logical structure, subject accuracy, and representational equivalence. However, accessible

material alone does not ensure full inclusion. It becomes pedagogically effective only when it is integrated into the organization of mathematical activity during the lesson.

2.2.2 Methodological Conditions for Organizing an Inclusive Mathematics Lesson

Accessible learning material creates the basis for inclusion, but it does not by itself ensure a fully inclusive mathematics lesson. Its potential is realized when students use the material in mathematical activity, participate in discussion, ask questions, solve problems, and justify solutions. Thus, lesson organization is interpreted in this study as the transformation of accessible material into accessible mathematical activity.

An inclusive mathematics lesson should be based on the interrelation of explanation, guided activity, joint performance, independent work, and discussion. This structure allows the teacher to lead students from initial perception of a concept to its application and justification. In Grades 5 and 6, such organization is especially important because students are developing the ability to move from a concrete example to a rule, from a rule to an algorithm, and from an algorithm to independent problem solving. The methodological sequence may therefore be expressed as concept explanation → worked example → guided performance → independent application → discussion and justification.

Step-by-step explanation and scaffolding have particular methodological significance. Scaffolding is not the provision of a ready answer. It is temporary and purposeful pedagogical support that helps the student move toward independent mathematical activity. The teacher clarifies the concept, organizes joint performance, uses guiding questions, identifies errors, and gradually transfers responsibility to the student. Pfister, Moser Opitz, and Pauli (2015) show that scaffolding is an important component of mathematics teaching in inclusive classrooms. Mungunda (2023) also emphasizes that teacher preparation and methodological decisions during the lesson influence the quality of mathematics learning for students with visual impairments, while Tshabalala (2023) highlights the role of teacher explanation, interaction, and support in teaching students with hearing impairments.

For students with visual impairments, the central methodological condition is direct inclusion in mathematical activity. The issue is not only how the material is presented, but how the student works with it. Board writing, changes in a model, solution steps, or spatial relations should be verbally mediated with precision, while the student's activity should be monitored in stages. Abrahamson et al. (2019) emphasize the importance of collaborative participation and multimodal interaction in the mathematical learning of students with visual impairments. Adapted material becomes meaningful when the student uses it to identify relations between mathematical objects, solve problems, and justify conclusions.

For students with hearing impairments, the central methodological condition is communication access understood as participation in mathematical dialogue. Communication access should not be reduced to comprehension of the teacher's speech. It should include the opportunity to ask questions, respond, clarify reasoning, explain solution steps, and participate in mathematical discourse. Le Hanie (2017) shows that interaction between the teacher and students influences the learning outcomes of students with hearing impairments in inclusive mathematics classrooms. The teacher should therefore coordinate oral explanation with written terms, symbols, visible solution steps, and organized questioning, but the main aim is not only reception of information; it is the student's active use of mathematical language.

Psychological and pedagogical support is also important for organizing inclusive learning activity. In the Kazakhstani context, such support is considered a condition for students' participation in the educational process and for the coordination of teacher assistance, individual support, and classroom inclusion (Akhanova, 2021). In mathematics lessons, this support should be connected with the logic of the subject: the student should receive assistance not only in behavior or communication, but also in understanding the task, following the reasoning, correcting errors, and moving toward independent solution.

The main methodological conditions for organizing an inclusive mathematics lesson are systematized in Table 2.2.2.1. The methodological conditions for organizing

an inclusive mathematics lesson are directed toward students' active participation in mathematical activity.

Table 2. 2. 2. 1. Methodological Conditions for Organizing an Inclusive Mathematics Lesson

Methodological condition	Manifestation in the lesson	Inclusive meaning
Step-by-step explanation	The concept, example, algorithm, and task are presented in a logical sequence	Prevents exclusion caused by fragmented or unclear explanation
Scaffolding	The teacher uses guiding questions, prompts, and joint performance	Supports transition from dependent performance to independent mathematical action
Communication access	Terms, questions, responses, and explanations are organized clearly	Enables participation in mathematical dialogue and reasoning
Participation support	Each student has a mathematically meaningful role in individual, pair, or group work	Prevents passive observation and supports active engagement in problem solving
Flexible pace	Time for perception, thinking, performance, and response is regulated	Takes into account student-specific features of processing and justification
Teacher monitoring	The teacher observes understanding, errors, and need for support during the lesson	Allows timely methodological support before misunderstanding becomes stable

Note. Developed by the author based on Tshabalala (2023), Stylianidou (2022), Matobako (2021), Mungunda (2023), Le Hanie (2017), and Abrahamson et al. (2019).

These conditions include step-by-step explanation, scaffolding, communication access, peer interaction, flexible pace, and teacher monitoring. In such organization, students with visual and hearing impairments are not only recipients of adapted material; they become participants in problem solving, mathematical discussion, error correction, and justification of solutions.

Classroom interaction and peer support are additional methodological conditions. Pair and group work do not automatically ensure inclusion; they become inclusive only when each participant has a mathematically meaningful role. Stylianidou (2022) shows that the social and mathematical dimensions of participation in an inclusive classroom are interconnected. Therefore, each student, including the student with special educational needs, should be involved in analyzing the task condition, choosing an operation, checking a solution path, explaining reasoning, or formulating a conclusion. In this form, peer support becomes not merely social assistance but a condition for the joint construction of mathematical thought.

Lesson pace and teacher monitoring also influence the quality of inclusion. The teacher should regulate the pace of the lesson according to students' ability to perceive mathematical information, process it, and move into action. Monitoring should focus not only on whether the student has completed the task, but on how the student understands the concept, where the difficulty occurs, and what form of support is needed. This allows the teacher to prevent exclusion caused by fragmented explanation, excessive pace, or unnoticed misunderstanding.

2.2.3 Conditions for Implementing Inclusive Assessment and Feedback

The quality of inclusive mathematics teaching cannot be fully determined unless the results of students' mathematical activity are identified through assessment and supported through feedback. Assessment in inclusive mathematics teaching should not be understood only as checking answers or assigning grades. It is a pedagogical

mechanism for identifying the student's level of mathematical understanding, problem-solving strategy, type of error, and next learning step.

Inclusive assessment combines three essential requirements: the preservation of the same mathematical aim, an accessible mode of task perception and response, and diagnostic feedback for further learning. The mathematical aim of the task remains unchanged: the student should demonstrate understanding of the concept, choose an appropriate operation, justify the procedure, and interpret the result. However, the format of the task, instruction, time organization, and response form should correspond to the student's perceptual and communicative capacities. Shute et al. (2006) show that adaptive diagnostic mathematics assessment should combine accessibility with diagnostic accuracy. Therefore, assessment should reveal actual mathematical understanding without allowing the format of the task to become an additional barrier.

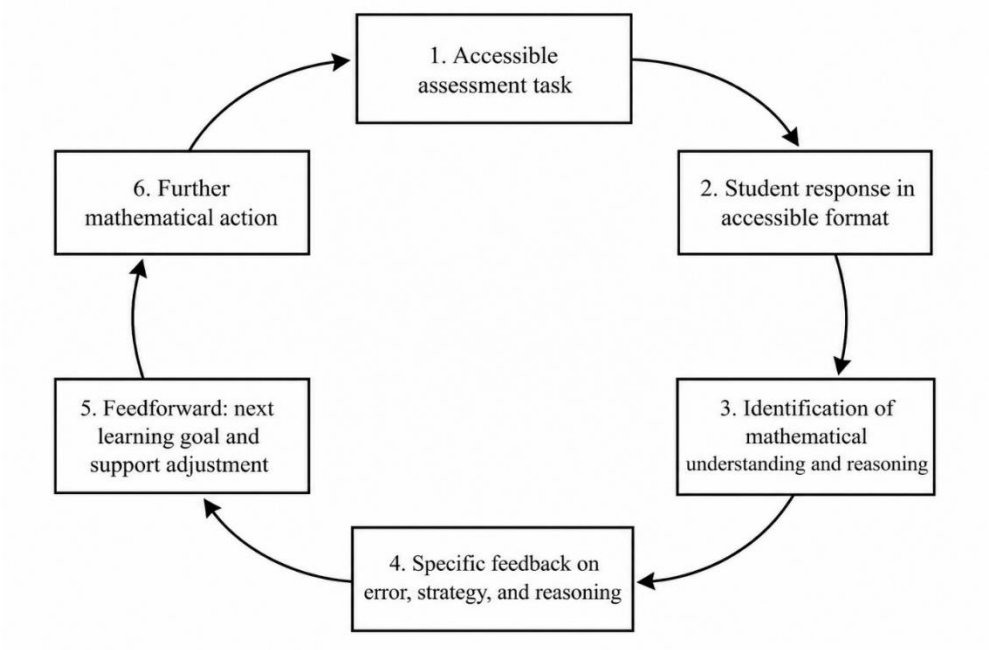
The accessibility of assessment tasks is the first condition of inclusive assessment. This condition concerns the clarity of instructions, mathematical language, symbolic notation, problem conditions, graphs, diagrams, and other task elements. Kabethi (2021) shows that the accessibility of mathematics examinations for students with hearing impairments is directly related to the clarity of task language and instructions. Marcone (2024) emphasizes the importance of precision and planned accessibility in describing mathematics tasks for students with visual impairments. If the task condition is inaccessible, assessment may measure the student's ability to perceive the task format rather than mathematical knowledge.

Assessment criteria should be subject-accurate. They should reveal understanding of mathematical concepts, identification of relationships, choice of strategy, justification of operations, and explanation of conclusions. Criteria should not evaluate whether the student has quickly perceived a visual or oral format. In a task involving a diagram, the criterion should focus on comparison of quantities and interpretation of relationships; in solving an equation, it should focus on the logic of transformations and validity of operations. When criteria are connected with mathematical content, sensory limitations do not distort the assessment result.

For students with visual impairments, assessment conditions are connected with the semantically accurate presentation of mathematical objects and the possibility to express reasoning fully. If a task includes a graph, diagram, coordinate plane, or geometric figure, the student should be able to access its mathematical meaning before producing a solution. Rottmann et al. (2020) show that a specially organized assessment interview can reveal mathematical understanding in children with visual impairments. Maćkowski et al. (2018) also show that dividing mathematical tasks into smaller steps and allowing interactive performance can support problem solving. In inclusive assessment, the response format may vary, but the mathematical content and criteria should remain stable.

The cyclical logic of inclusive assessment and feedback in mathematics learning is shown in Figure 2.2.3.1.

Figure 2. 2. 3. 1. Inclusive Assessment and Feedback Cycle in Mathematics Learning



Note. Developed by the author based on Kabethi (2021), Rottmann et al. (2020), Shute et al. (2006), Tshabalala (2023), and Matobako (2021).

For students with hearing impairments, the main condition of inclusive assessment is the clarity and stability of instructions, questions, terms, and feedback

language. The student should clearly understand what must be found, which operation is required, and how the answer should be justified. Tshabalala (2023) substantiates the role of communication access in mathematics teaching, and the same principle applies to assessment. Kabethi (2021) also shows that linguistic accessibility influences the assessment results of students with hearing impairments. Therefore, assessment questions should avoid ambiguity, use mathematical terms consistently, and provide the student with a clear opportunity to justify reasoning in a written, visual, or structured form.

In Kazakhstani mathematics education, assessment is increasingly considered not only as control but also as a means of supporting further learning. Kozhasheva and Bazhi (2024) emphasize the methodological importance of assessment and feedback in identifying students' progress in mathematics and supporting subsequent learning actions. This idea corresponds to the logic of inclusive assessment: the result of assessment should help the teacher understand what has been mastered, what remains unclear, and what kind of support should follow.

Feedback is an integral part of inclusive assessment. It should not be limited to brief judgments such as correct or incorrect. Feedback should indicate which mathematical step was performed correctly, where the error occurred, which concept requires clarification, and what action should follow. For a student with visual impairment, feedback may focus on the logic of the solution, symbolic notation, or spatial relation. For a student with hearing impairment, feedback should be linguistically clear, structured, and connected with the mathematical terms used in the task. In both cases, feedback functions as a pedagogical action aimed at developing mathematical thinking.

The quality of feedback increases when it includes a feedforward function. Feedback clarifies the current state of understanding, while feedforward directs the student toward the next learning action. If a student makes an error in solving an equation, the teacher should direct attention to the logic of isolating the unknown. If the student makes an error in interpreting a diagram, feedback should indicate how to

compare quantities and formulate a conclusion. In this way, assessment becomes part of the learning process rather than only a final control procedure.

Inclusive assessment and feedback should be based on formative and diagnostic logic. A task is given, the student responds, the teacher identifies the level of mathematical understanding, provides specific feedback, determines the next learning step, and guides the student toward further mathematical activity. This cycle allows assessment to become a condition for learning rather than a mechanism of exclusion.

The conditions for implementing inclusive assessment and feedback include accessibility of assessment tasks, preservation of mathematical requirements, subject accuracy of criteria, flexible response formats, specific feedback, and feedforward logic. Their purpose is to reveal mathematical understanding, problem-solving strategy, and reasoning rather than sensory limitations. Thus, assessment is interpreted in this study as a continuation of inclusive teaching rather than as a separate control procedure. A coherent methodological foundation for inclusive mathematics teaching in Grades 5 and 6 is formed when accessible presentation of learning material, methodological organization of the lesson, and inclusive assessment and feedback are considered as interrelated didactic conditions.

2.3 The Concept and Content Structure of Inclusive Mathematics Teaching

Building on the barriers, learning needs, and didactic conditions identified in Sections 1.1 and 1.2, this section defines inclusive mathematics teaching as a subject-methodological system and specifies the content structure of its implementation in Grades 5 and 6. Unlike Section 1.1, which focused on the current state and subject-specific barriers, and Section 1.2, which examined didactic conditions for teaching, this section determines what is structurally adapted and modeled in inclusive mathematics teaching: mathematical concepts, symbolic forms, representations, language, algorithms, cognitive demands, and forms of demonstrating content mastery.

Inclusive mathematics teaching is interpreted in the present study as a subject-methodological system that ensures students' access to mathematical content,

participation in mathematical activity, use of mathematical language and reasoning, and demonstration of learning outcomes in accessible forms. This interpretation is consistent with contemporary research in inclusive mathematics education, where inclusion is understood not only as a general educational value but also as the organization of mathematical knowledge, classroom participation, differentiated support, and equitable access to learning outcomes (Roos, 2019; Krähenmann et al., 2019; Kollosche et al., 2019). In this sense, inclusive mathematics teaching is not an external addition to mathematics methodology; it is a way of organizing the teaching and learning of mathematics so that the structure of mathematical content remains academically accurate and accessible to learners with different perceptual and communicative capacities.

Within this study, inclusive mathematics teaching is defined as a subject-methodological system that creates conditions for students with visual and hearing impairments in Grades 5 and 6 to perceive mathematical content, understand mathematical language and symbols, participate in problem-solving activity, justify solutions, and demonstrate content mastery in accessible forms. This definition includes four interrelated components: content, activity, communicative, and outcome components. The content component preserves the subject accuracy of mathematical concepts, symbols, formulas, graphs, diagrams, tables, geometric objects, and word problems. The activity component includes students' participation in problem solving, analysis, comparison, modeling, algorithmic actions, and justification. The communicative component is expressed through mathematical terminology, instructions, questioning, classroom discussion, explanation of solutions, and interpretation of mathematical statements. The outcome component is connected with the learner's ability to demonstrate understanding, reasoning, and achievement without the form of expression becoming an additional barrier.

The distinction between the didactic conditions discussed in Section 1.2 and the content structure examined in this section is essential. Section 1.2 answered the question of how inclusive mathematics teaching should be organized through

accessible presentation, lesson organization, assessment, and feedback. Section 1.3 focuses on what is structurally adapted and modeled: concepts, representations, mathematical language, algorithms, cognitive load, and forms of demonstrating content mastery. Thus, the present section does not repeat the didactic conditions but systematizes the internal structure of mathematical content and the conceptual model that connects content adaptation with inclusive teaching.

The textbook-based structure of Grades 5 and 6 mathematics content is presented in Table 2.3.1.

Table 2. 3. 1. Textbook-Based Structure of Grades 5 and 6 Mathematics Content

Content group in Grades 5 and 6	Typical textbook forms	Inclusive adaptation focus
Numbers, fractions, decimals, rational numbers	Symbolic notation, number line, part-whole models, operations	Symbolic and representational adaptation
Equations and expressions	Rules, transformations, algorithms, worked examples	Activity-algorithmic adaptation
Coordinates and geometry	Coordinate rays, coordinate planes, figures, measurement, diagrams	Representational and cognitive-load adaptation
Word problems	Text, quantities, conditions, relationships, required operations	Linguistic-semantic adaptation
Tables, diagrams, proportional relations, applied tasks	Tables, charts, comparisons, interpretation, conclusions	Representational and outcome-expression adaptation

Note. Developed by the author based on the analysis of Grades 5 and 6 mathematics textbooks by Aldamuratova et al. (2017a, 2017b, 2018a, 2018b).

To specify the content structure of inclusive mathematics teaching, the current mathematics textbooks used in Grades 5 and 6 in Kazakhstan were analyzed as curriculum-content sources. The analysis included the following textbooks: *Mathematics: Grade 5, Part 1* by Aldamuratova, Baisholanova, and Baisholanov, published by Atamura in 2017; *Mathematics: Grade 5, Part 2* by the same authors, published by Atamura in 2017; *Mathematics: Grade 6, Part 1* by Aldamuratova, Baisholanova, and Baisholanov, published by Atamura in 2018; and *Mathematics: Grade 6, Part 2* by the same authors, published by Atamura in 2018 (Aldamuratova et al., 2017a, 2017b, 2018a, 2018b). These textbooks were selected because they are designed for general education schools and are based on the updated curriculum for Grades 5 and 6 mathematics in Kazakhstan. The analysis focused on three parameters: content groups, forms of mathematical representation, and types of mathematical activity required from students.

The textbook analysis shows that Grades 5 and 6 mathematics content is not limited to a list of topics. It is organized through several interconnected forms: concepts and definitions, symbolic notation, visual and spatial representations, tables, diagrams, coordinate representations, word problems, algorithms, level-based exercises, ICT-oriented tasks, inquiry tasks, and tasks for independent reasoning. The structure of the textbooks also demonstrates that learning material is presented through preparatory tasks, topic-related questions, historical information, exercises of different levels, creative tasks, ICT tasks, and tasks for independent inquiry. This means that inclusive mathematics teaching should address not only the mathematical topic itself but also the form in which the topic is introduced, practiced, discussed, and assessed.

The Grade 5 textbooks introduce natural numbers, divisibility, place value, coordinate rays, comparison, ordinary fractions, decimal fractions, and word problems through definitions, examples, diagrams, tables, questions, and level-based tasks (Aldamuratova et al., 2017a, 2017b). The Grade 6 textbooks develop this content through rational numbers, proportions, expressions, equations, numerical equalities, transformations, coordinate-related tasks, and text-based problems requiring

algorithmic and logical reasoning (Aldamuratova et al., 2018a, 2018b). Therefore, the content structure of inclusive mathematics teaching in Grades 5 and 6 should include not only concepts and operations but also the symbolic, linguistic, visual-spatial, algorithmic, and outcome-related forms through which students work with mathematical knowledge.

The directions of inclusive adaptation of Grades 5 and 6 mathematics content are systematized in Table 2.3.2.

Table 2. 3. 2. Directions of Inclusive Adaptation of Grades 5 and 6 Mathematics Content

Adaptation direction	Textbook-based content examples	Meaning for students with visual impairments	Meaning for students with hearing impairments
Representational adaptation	Graphs, diagrams, coordinate representations, geometric figures, tables	Enables perception of mathematical relations through equivalent perceptual forms	Supports comprehension of mathematical language through stable visual-symbolic references
Linguistic-semantic adaptation	Terms, instructions, definitions, word problems, mathematical statements	Supports the connection between symbols, verbal explanation, and task meaning	Enables accurate understanding of terminology, questions, and task requirements

Table 2. 3. 2. Cont.

Adaptation direction	Textbook-based content examples	Meaning for students with visual impairments	Meaning for students with hearing impairments
Activity-algorithmic adaptation	Fraction operations, equation transformations, coordinate tasks, problem-solving steps	Supports step-by-step performance of spatial and symbolic actions	Facilitates understanding of algorithms through written and visual-symbolic sequencing
Cognitive-load adaptation	Multiple representations, tables, diagrams, text, symbols, level-based tasks	Reduces overload from simultaneous processing of visual and symbolic information	Supports processing of linguistic, visual-symbolic, and symbolic information
Outcome-expression adaptation	Solution, justification, interpretation, conclusion	Enables demonstration of mathematical thinking through accessible forms	Enables expression of reasoning through written, visual-symbolic, or structured forms

Note. Developed by the author based on the analysis of Grades 5 and 6 mathematics textbooks by Aldamuratova et al. (2017a, 2017b, 2018a, 2018b) and studies on inclusive mathematics education (Rule et al., 2011; Matobako, 2021; Tshabalala, 2023; Thomas & Van Garderen, 2015; Banerjee & Gautam, 2024).

The five directions presented in Table 2.3.2. show that content adaptation in inclusive mathematics teaching is multidimensional. It includes not only visual or technical adjustment but also linguistic, semantic, action-based, cognitive, and outcome-related structuring of mathematical content. This is especially important for

students with visual and hearing impairments because their difficulties are not connected with the absence of mathematical potential but with the way mathematical content is represented, communicated, processed, and expressed.

When inclusive mathematics teaching is considered as a subject-methodological system, the adaptation of mathematical content becomes a central issue. Content adaptation does not mean reducing the curriculum or lowering academic requirements. It means reorganizing mathematical concepts, symbolic forms, visual and spatial representations, linguistic structures, algorithmic actions, cognitive demands, and forms of demonstrating content mastery in accordance with students' perceptual and communicative capacities while preserving mathematical meaning. This understanding allows adaptation to be considered not as simplification, but as a structured transformation of the route through which the student enters the same mathematical content.

The first direction is representational adaptation. It is connected with graphs, diagrams, coordinate representations, geometric figures, models, tables, and other visual-spatial forms of mathematics. In the analyzed textbooks, these representations are not decorative elements; they carry mathematical meaning and support comparison, measurement, orientation, and interpretation. Rule et al. (2011) show that adapted materials in secondary science and mathematics lessons can increase students' access to learning content, while Matobako (2021) emphasizes that mathematical models and visual representations require special adaptation for learners with visual impairments. In the present study, representational adaptation means preserving the mathematical relationship expressed by a representation. For students with visual impairments, this requires equivalent perceptual access to relations, direction, quantity, and spatial structure. For students with hearing impairments, stable visual-symbolic references may support the comprehension of mathematical terms, relationships, and solution procedures.

The second direction is linguistic-semantic adaptation. In Grades 5 and 6 mathematics, students work with definitions, instructions, questions, word problems,

and terms that express logical and quantitative relations. Words such as greater, less, equal, ratio, part, total, difference, times as many, numerator, denominator, coefficient, and unknown determine the mathematical structure of a task. In the Grade 6 textbooks, solving equations is presented through a sequence of instructions related to collecting variable terms, collecting constant terms, combining like terms, and dividing by the coefficient (Aldamuratova et al., 2018a, 2018b). Such algorithmic language requires precise semantic understanding. Tshabalala (2023) emphasizes the importance of adapting communication and problem representation for students with hearing impairments, while Thomas and Van Garderen (2015) substantiate the need to make the linguistic demands of mathematics accessible through a Universal Design for Learning perspective. Linguistic-semantic adaptation therefore means organizing mathematical language clearly, consistently, and accurately without removing its conceptual precision.

The third direction is activity-algorithmic adaptation. Mathematical content in Grades 5 and 6 is frequently organized as a sequence of actions: reducing fractions, performing operations with rational numbers, solving equations, plotting points, reading diagrams, and modeling word problems. The analyzed textbooks present many topics through worked examples, rules, and exercises that require students to follow and explain procedures (Aldamuratova et al., 2017a, 2017b, 2018a, 2018b). Activity-algorithmic adaptation focuses on the internal action structure of mathematical content. A fraction involves identifying part-whole relations and performing operations; an equation involves transformation steps; a coordinate task involves locating position and direction; a word problem involves moving from text to mathematical model. For students with visual impairments, this direction supports staged performance of spatial and symbolic actions. For students with hearing impairments, written and visual-symbolic sequencing of the algorithm supports understanding and independent performance.

The fourth direction is cognitive-load adaptation. Grades 5 and 6 mathematics often requires students to process several sources of information at the same time: text,

symbols, diagrams, tables, questions, and solution steps. The structure of the analyzed textbooks confirms this complexity: one topic may include definitions, worked examples, visual models, level-based exercises, questions for independent inquiry, ICT tasks, and tasks requiring reasoning (Aldamuratova et al., 2017a, 2018a). Cognitive-load adaptation does not remove mathematical complexity. It regulates the amount of information, the order of presentation, the number of simultaneous representations, and the sequence of actions so that the student can focus on the key mathematical relationship. Banerjee and Gautam (2024) argue that inclusive mathematics lessons should align the presentation of information, participation in activity, and demonstration of understanding with students' cognitive capacities. In this study, cognitive-load adaptation is considered a content-structuring condition that supports meaningful processing of mathematical information.

The fifth direction is outcome-expression adaptation. This direction concerns the form in which students demonstrate mastery of mathematical content. It is not identical to assessment, which was discussed in Section 1.2.3. In the present section, outcome-expression adaptation is understood as part of the content structure because mathematical knowledge becomes complete only when the student can express a concept, operation, relationship, or conclusion. A student may demonstrate mastery by explaining a rule, justifying a transformation, interpreting a diagram, presenting a solution sequence, or formulating a mathematical conclusion. For students with visual impairments, this may require oral explanation, structured writing, tactile-supported demonstration, or other accessible forms. For students with hearing impairments, written, visual-symbolic, or step-by-step structured expression may be more effective. The central requirement is that the form of expression should preserve mathematical reasoning and content mastery.

On this basis, the structural-content model of inclusive mathematics teaching for students with visual and hearing impairments in Grades 5 and 6 is proposed. The model is authorial because it integrates the concept of inclusive mathematics teaching, the textbook-based structure of Grades 5 and 6 mathematics content, the directions of

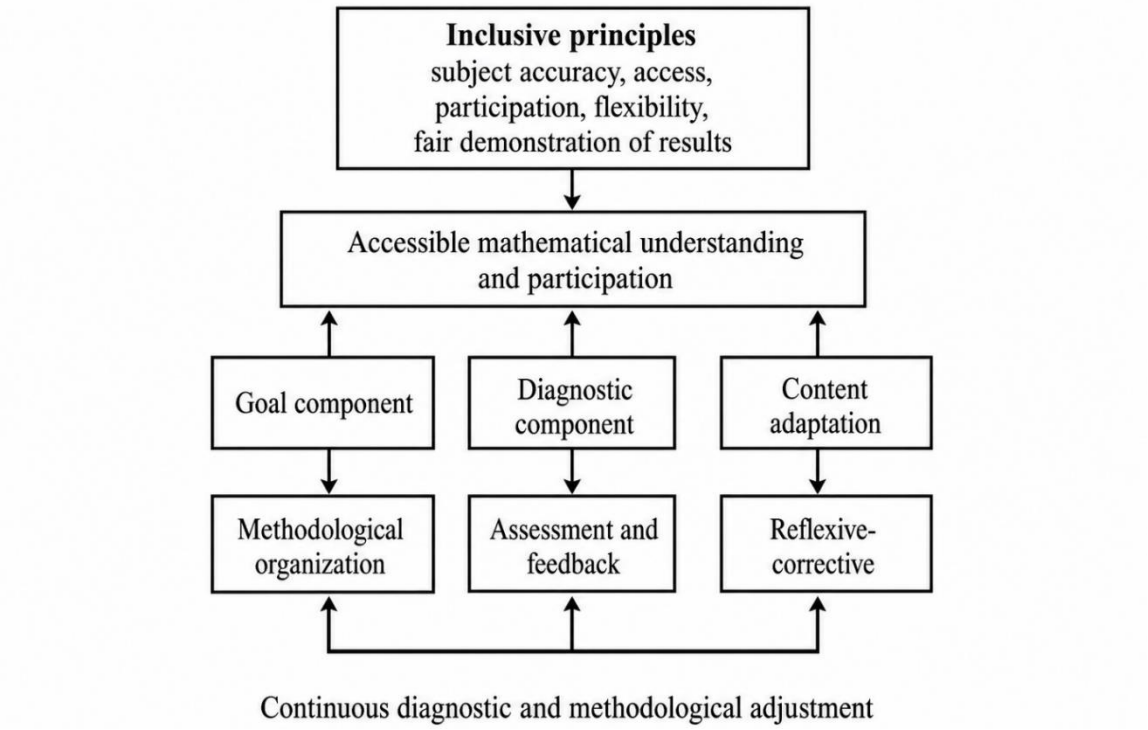
content adaptation, and the components of classroom implementation into one methodological system. Its purpose is not to replace the curriculum but to provide a structured basis for organizing access to the curriculum for students with sensory impairments.

The model is organized through an input-process-output logic. The input of the model is the Grades 5 and 6 mathematics content presented in the curriculum and textbooks: concepts, symbols, representations, language, algorithms, word problems, and expected outcomes. The process consists of five adaptation directions: representational, linguistic-semantic, activity-algorithmic, cognitive-load, and outcome-expression adaptation. These directions are implemented through four components: content, activity, communicative, and outcome components. The output of the model is an inclusive mathematics teaching methodology that allows students with visual and hearing impairments to work with the same core mathematical content through accessible routes. The reflexive-corrective component connects the output with the process by analyzing students' results, identifying difficulties, correcting content adaptation, and improving teaching decisions.

The authorial specificity of the proposed model lies in three features. First, it considers students with visual and hearing impairments within one methodological space while preserving the specificity of their perceptual and communicative needs. Second, it is grounded in the actual structure of Grades 5 and 6 mathematics content as presented in textbooks used in Kazakhstan. Third, it connects content adaptation, mathematical activity, communication, outcome expression, and reflexive correction into a single system. In this model, inclusive mathematics teaching is not viewed as a linear process in which content is simply adapted once and then delivered to the student. It is interpreted as a dynamic process in which content adaptation is clarified through student activity, communication, and demonstration of mathematical understanding.

The structural content model of inclusive mathematics teaching for students with visual and hearing impairments in Grades 5 and 6 is illustrated in Figure 2.3.1.

Figure 2. 3. 1. Structural Content Model of Inclusive Mathematics Teaching for Students With Visual and Hearing Impairments in Grades 5 and 6



Note. Developed by the author based on Krähenmann et al. (2019), Roos (2019), Stylianidou (2022), Matobako and Jita (2022), Matobako (2021), Tshabalala (2023), Rule et al. (2011), and Güven et al. (2022).

The implementation block of the model consists of four components: content, activity, communicative, and outcome components. The content component determines which mathematical concepts, symbols, representations, terms, algorithms, and tasks require adaptation. It preserves the academic accuracy of mathematics and prevents the reduction of curriculum content. The activity component determines how the adapted content becomes the basis for mathematical actions such as comparison, transformation, modeling, problem solving, and justification. The communicative component ensures that mathematical language, questions, explanations, and discussion are accessible and meaningful. The outcome component identifies how the student demonstrates content mastery through reasoning, solution procedures, interpretation, and conclusion. The

reflexive-corrective component connects these elements by allowing the teacher to revise content adaptation according to students' actual learning progress.

The model also reflects the relationship between common mathematical goals and individual routes toward these goals. Krähenmann et al. (2019) emphasize the importance of balancing differentiated learning goals with joint learning settings in inclusive mathematics teaching. In the present study, this balance is understood as follows: students with visual and hearing impairments should work with the same core mathematical content as their peers, but the route toward this content may differ in representation, language, sequence, support, and form of expression. This position is also consistent with differentiated mathematics teaching, where different routes toward common learning objectives are used to support students' individual learning possibilities (Dauletkulova, n.d.; Khumyrbek & Sydykhov, n.d.).

Inclusive mathematics teaching in Grades 5 and 6 is conceptualized as a subject-methodological system based on the preservation of mathematical content and the adaptation of routes to that content. Its content structure includes concepts, symbols, representations, mathematical language, algorithms, tasks, and outcome expression. Its adaptation directions include representational, linguistic-semantic, activity-algorithmic, cognitive-load, and outcome-expression adaptation. Its structural-content model integrates these directions with content, activity, communicative, outcome, and reflexive-corrective components. In Chapter 3, these components will be operationalized through adapted tasks, lesson fragments, assessment criteria, and experimental procedures. This model therefore provides the theoretical basis for developing methods, forms, tasks, and experimental procedures for inclusive mathematics teaching.

3. METHODOLOGY

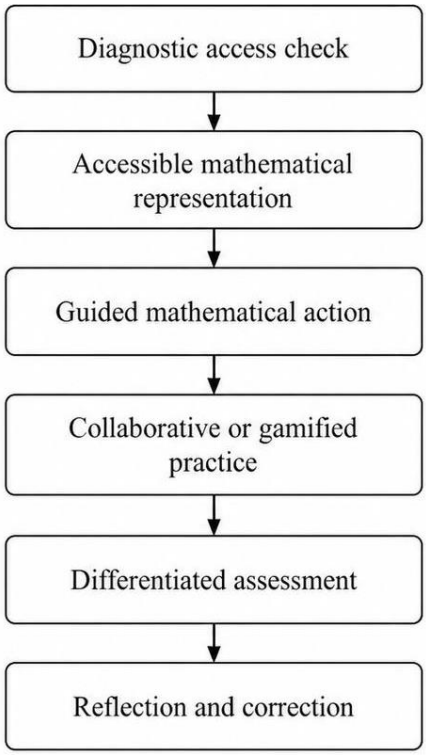
3.1 Methods and Adapted Tasks for Inclusive Mathematics Teaching of Students with Visual and Hearing Impairments

Inclusive mathematics teaching for lower secondary school students means organizing access to mathematical knowledge in a systematic way without reducing the curriculum. In Grades 5 and 6, this becomes especially relevant as students move from concrete arithmetic operations to more abstract ideas such as divisibility, fractions, common divisors and multiples, numerical equalities, linear equations, coordinate representation, and geometry. The methodological adaptation in this study is based on the Grade 5 textbook *Mathematics, Textbook for Grade 5 of General Education Schools* by Aldamuratova, Baisholanova, and Baisholanov, published by Atamura in 2017, and the Grade 6 textbook *Mathematics, Textbook for Grade 6 of General Education Schools* by Aldamuratova, Baisholanova, and Baisholanov, published by Atamura in 2018. These textbooks cover natural numbers, place value, operations, fractions, divisibility, prime and composite numbers, the greatest common divisor, the least common multiple, numerical equalities, and linear equations. The key methodological principle is that students with visual and hearing impairments study the same mathematical content through adapted forms of perception, action, communication, and assessment.

The approach developed in this study relies on the author's multisensory tactile-visual model with selected game-based elements for inclusive mathematics teaching. The model is designed for a general education school setting where students with visual and hearing impairments study together with their peers. It provides a practical structure for organizing mathematics lessons so that one learning objective is maintained for all students, while the route toward this objective is adapted according to students' sensory and communicative needs. The model consists of six connected stages: diagnostic access check, accessible representation, guided mathematical action, collaborative or game-based practice, differentiated assessment, and reflection with correction.

The author's multisensory tactile-visual gamified model of inclusive mathematics teaching is presented in Figure 3.1.1.

Figure 3. 1. 1. Author's Multisensory Tactile-Visual Gamified Model of Inclusive Mathematics Teaching



The diagnostic stage helps the teacher identify whether a student needs tactile, auditory, visual, written, enlarged, sign-supported, or combined access to the material. The representation stage changes mathematical content into accessible forms such as tactile cards, raised-line diagrams, three-dimensional models, visual algorithms, written instructions, and symbolic schemes. Guided mathematical action supports students as they perform mathematical operations step by step. Collaborative or game-based practice increases engagement through pair tasks, short classification activities, visual or tactile challenges, and practical problem-solving tasks. Differentiated assessment keeps the same mathematical expectation for every student while allowing different forms of response. Reflection and correction help the teacher decide which representation, instruction, or task format should be adjusted in the following lesson.

The model is supported by research on mathematics education for learners with sensory impairments. Klingenberg et al. (2019) emphasize that students with visual impairments can successfully learn mathematics when instruction includes tactile graphics, abacus-based work, appropriate guidance, and individual support. Miyauchi (2020) argues that inclusive education requires more than placing students in the same classroom. It also depends on teacher readiness, accessible tools, and systematic support. These findings should not be applied mechanically. Tactile or visual materials become effective only when they are connected with mathematical language, symbolic notation, and problem-solving logic. The mathematics teacher, therefore, becomes not only a source of explanation but also a designer of an accessible mathematical environment.

For students with visual impairments, the main methods include tactile modelling, auditory explanation, raised-line diagrams, abacus-supported calculation, three-dimensional modelling, enlarged print, and hands-on exploration. These methods are necessary because many Grade 5 and Grade 6 topics are usually taught through visual means, including number tables, fraction diagrams, coordinate grids, geometric figures, and written equation transformations. Hayes and Proulx (2024) note that mathematics and science often become inaccessible for students with visual impairments when concepts are presented mainly through visual representations. When teaching natural numbers and place value, the student may work with tactile place value cards or enlarged number cards. When learning fractions, the student may use tactile fraction circles, strips, or divided objects. In geometry, three-dimensional figures and raised-line drawings help the student move from sensory experience to abstract mathematical reasoning.

For students with hearing impairments, the leading methods include visually structured instruction, written algorithms, sign-supported explanation, demonstration, repetition, visual modelling, and peer-supported learning. The main barrier is often not the mathematical concept itself, but the oral and language-heavy way in which mathematical explanation is delivered. Tshabalala (2023) found that language plays a

central role in the difficulties teachers face when teaching mathematics to deaf and hard-of-hearing learners, while demonstration, repetition, and peer tutoring support understanding. When teaching divisibility, the teacher should present the rule not only orally but also through a visual algorithm and a classification table. When teaching equations, each transformation should be written as a numbered step so that the learner can follow the logic of the mathematical action.

The practical application of the proposed methods to Grade 5 and Grade 6 mathematics content is shown in Table 3.1.1.

Table 3. 1. 1. Adaptation of Grade 5 and Grade 6 Mathematics Topics for Students with Visual and Hearing Impairments

Textbook content	Adaptation for students with visual impairments	Adaptation for students with hearing impairments	Expected learning outcome
Natural numbers and place value	Tactile number cards, place value blocks, oral explanation	Visual place value chart, written examples	Identifies digit value according to position
Divisibility by 2, 5, 10, 3, and 9	Tactile number cards, guided analysis of final digit and digit sum	Visual algorithm, classification table	Applies divisibility rules to natural numbers
Prime and composite numbers	Tactile counters, grouping of divisors	Visual divisor table, step-by-step classification	Distinguishes prime and composite numbers

Table 3. 1. 1. Cont.

Textbook content	Adaptation for students with visual impairments	Adaptation for students with hearing impairments	Expected learning outcome
Greatest common divisor and least common multiple	Tactile step cards, abacus-supported calculation	Numbered written algorithm, visual marking of common elements	Finds GCD and LCM and applies them to tasks
Fractions and part of a number	Tactile fraction circles, strips, divided objects	Fraction bars, labelled diagrams, written rules	Understands part-whole relations and compares fractions
Numerical equalities	Tactile balance model, left and right equation zones	Symbolic scheme, if a equals b, then a plus c equals b plus c	Explains properties of numerical equalities
Linear equations	Tactile equation cards, guided inverse operations	Written solving algorithm, numbered transformations	Solves simple linear equations step by step
Geometry and coordinate representation	3D figures, raised line diagrams, tactile coordinate grid	Labelled diagrams, enlarged coordinate grid, visual arrows	Recognizes geometric properties and locates points
Word problems	Oral decomposition, tactile scheme of known and unknown values	Written condition table, arrows, short visual statements	Translates a word problem into a mathematical operation

The topic of divisibility shows how the methodology works in practice. In lower secondary mathematics, students study divisibility by 2, 5, 10, 3, and 9. During an inclusive lesson, the teacher introduces one learning objective for all students, which is to determine whether a natural number is divisible according to a given rule. A student with visual impairment may work with tactile number cards or enlarged printed numbers, while the teacher guides the student to identify the final digit or calculate the digit sum. A student with hearing impairment may receive the same rule through a visual algorithm, written instruction, and a classification table. The lesson may continue with a number sorting task in which students classify numbers into divisible and non-divisible groups. The mathematical content remains the same, while access to it differs according to learner needs.

Prime and composite numbers, greatest common divisor, and least common multiple require a more procedural form of adaptation. These topics are conceptually demanding because students must understand internal numerical relationships rather than isolated facts. For students with visual impairments, divisors can be represented through tactile counters or number cards, which allow them to group and compare possible divisors physically. For students with hearing impairments, the teacher can present the procedure through a written table that shows the number, its divisors, and its classification. When finding the greatest common divisor or least common multiple, the teacher divides the work into clear steps. Students identify the numbers, find divisors or multiples, mark common elements, choose the required value, and apply it to the problem. Procedural clarity turns an abstract numerical relationship into a visible or tactile sequence of actions.

Fractions require careful coordination of conceptual, tactile, and visual representation. In the Grade 5 textbook, topics related to fractions and finding a part of a number are introduced through concrete examples and model-based reasoning. Students with visual impairments may learn fractions through tactile fraction circles, fraction strips, divided objects, and length models. Students with hearing impairments benefit from fraction bars, labelled diagrams, and written rules. When comparing one

half and one third, a student with visual impairment may compare tactile parts by size, while a student with hearing impairment may analyse a labelled visual diagram. The teacher must connect both forms to the same mathematical idea: the value of a fraction depends on the size of the equal parts into which the whole is divided. Without this connection, tactile and visual materials may remain illustrative without leading to genuine mathematical understanding.

Numerical equalities and linear equations should be taught through the balance model and step-by-step transformation. In the Grade 6 textbook, students first study the properties of numerical equalities and then move to linear equations. For students with visual impairments, equality can be represented by two tactile zones that correspond to the left and right sides of the equation. For students with hearing impairments, the same idea can be expressed through a written symbolic rule, for example, if a equals b, then a plus c equals b plus c. When solving equations, the teacher should use a stable algorithm. Students identify the unknown, determine the operation, apply the inverse operation, and check the result. This approach supports procedural fluency and conceptual understanding because students learn not only how to transform an equation but also why the transformation preserves equality.

Geometry and coordinate representation require careful sensory adaptation because these topics are often presented through board drawings and visual diagrams. For students with visual impairments, geometric figures should be introduced through three-dimensional models, tactile diagrams, and guided exploration of sides, angles, surfaces, and spatial relations. For students with hearing impairments, labelled diagrams, written definitions, and visual property tables are more effective. A coordinate plane may be presented as a raised-line grid for students with visual impairments and as an enlarged visual grid with arrows for students with hearing impairments. This allows students to build spatial understanding through accessible representations rather than through visual observation alone.

Word problems also require specific methodological adaptation because they combine mathematical language, logical reasoning, and the selection of an appropriate

operation. Students with visual impairments may need oral decomposition of the problem condition and a tactile or verbal scheme of known and unknown values. Students with hearing impairments may need a written condition table, short visual statements, arrows showing the relationship between quantities, and clearly separated steps. In both cases, the teacher should help the student identify what is known, what should be found, which operation is needed, and how the answer should be interpreted. This approach prevents the word problem from becoming only a language barrier and turns it into a structured mathematical task.

Selected game-based elements may be used as motivational and formative tools. Kliziene et al. (2024) found that gamification improved mathematics achievement among pupils with hearing impairment, especially in numbers, calculations, geometry, and measurement. However, game-based tasks should reinforce mathematical reasoning rather than replace it. After studying divisibility, students may complete a number classification game. After studying fractions, they may identify the greater fraction using tactile or visual models. After studying equations, they may complete a step-by-step equation route. For students with visual impairments, such tasks may include tactile cards, tokens, verbal prompts, and tactile progress indicators. For students with hearing impairments, they may include visual cards, written instructions, and visible scoring criteria.

Additional preparatory support may be used for topics that require more time for perception, such as fractions, equations, geometry, and coordinate representation. Such support may include audio explanation, enlarged worksheets, tactile previews, or short written guides. However, these materials should be used only when they directly support the lesson objective and are accessible to the learner. Preparatory materials should not replace classroom instruction; they should help the student enter the lesson with clearer initial understanding and readiness for guided practice.

Classroom organization should include whole-class instruction, pair work, small-group activity, individual guidance, and formative assessment. Whole-class instruction introduces the common learning objective, while pair and group work support

communication and peer explanation. Rule et al. (2011) showed that adaptive materials designed for students with visual impairments may benefit the whole class because tactile and hands-on resources make abstract STEM content more concrete. Inclusive materials should not isolate students with impairments. Manipulatives, models, visual tables, and structured worksheets should be available to all learners whenever possible, while individual adaptations are provided according to specific needs.

Assessment in inclusive mathematics teaching must differ in form while remaining equivalent in intellectual expectation. The learning objective stays the same for all students, but the response format may vary. A student with visual impairment may answer orally, through tactile models, abacus work, enlarged worksheets, or adapted written tasks. A student with hearing impairment may answer through written solutions, diagrams, visual schemes, or step-by-step algorithms. The assessment focuses on mathematical understanding rather than the sensory channel. It evaluates accuracy of reasoning, ability to apply a method, independence in performing steps, and transfer of knowledge to a new task. This principle helps avoid lowering academic expectations and prevents students from being assessed through inaccessible formats. In the experimental part of the study, this principle was reflected in the use of parallel pre-test and post-test tasks, which assessed the same mathematical skills while allowing accessible formats of perception and response for students with visual and hearing impairments.

The proposed methods and adapted tasks apply to the main content areas of Grade 5 and Grade 6 mathematics, not only to isolated topics. Natural numbers and divisibility are taught through tactile cards, visual classification, and algorithms. Prime and composite numbers are taught through grouping and divisor analysis. Greatest common divisor and least common multiple are taught through procedural modelling. Fractions are taught through tactile and visual part-whole models. Numerical equalities and equations are taught through balance models and stepwise transformations. Geometry and coordinates are taught through three-dimensional, tactile, and visual representations. Word problems are taught through decomposition tables and

accessible schemes. The pedagogical value of the proposed approach lies in preserving the integrity of mathematical content while expanding the ways in which students with visual and hearing impairments can access, understand, practise, and demonstrate mathematical knowledge.

The methods and adapted tasks described in this section form the methodological basis for the pedagogical experiment presented in the following section. In the experimental work, these methods were applied in a general education school setting with Grade 5 and Grade 6 students with sensory impairments. The effectiveness of the proposed methodology was evaluated through pre-test and post-test comparison, observation of accessibility and engagement, and analysis of students' performance on adapted mathematics tasks.

3.2 Organization of the Pedagogical Experiment in a General Education School

The pedagogical experiment was organized at KSU Secondary School No. 15 to examine how the inclusive mathematics teaching methodology described in Section 3.1 could be implemented in the real conditions of a general education school. The previous section presented the methodological basis of adapted mathematics teaching through tactile, visual, written, oral, step-by-step, and practical forms of learning. The purpose of the present section is to show how these methods were transformed into an experimental procedure focused on students' individual learning progress. In this regard, the experiment was designed as a small-scale case-based pedagogical experiment based on pre-test and post-test comparison, observation of accessibility and engagement, and analysis of students' performance on adapted mathematics tasks.

The choice of a general education school as the experimental base was methodologically significant. In specialized educational settings, students with sensory impairments may already have prior experience with adapted materials, tactile resources, enlarged formats, visual support, or other forms of special pedagogical assistance. In such conditions, it may be difficult to distinguish the effect of the proposed methodology from the influence of the already adapted educational

environment. A general education school, by contrast, provides an opportunity to examine how adapted mathematics teaching functions in a common classroom context, where students with special educational needs study the same curriculum as their peers and where mathematical content is often presented through standard oral, visual, symbolic, and written forms. This context corresponds to the practical problem identified in the introduction: students with visual and hearing impairments may formally participate in mathematics lessons, but their real access to mathematical content depends on whether the teacher can adapt the route of perception, explanation, practice, and assessment without reducing the academic level of the task.

The participants of the pedagogical experiment are described in Table 3.2.1.

Table 3. 2. 1. Participants of the Pedagogical Experiment

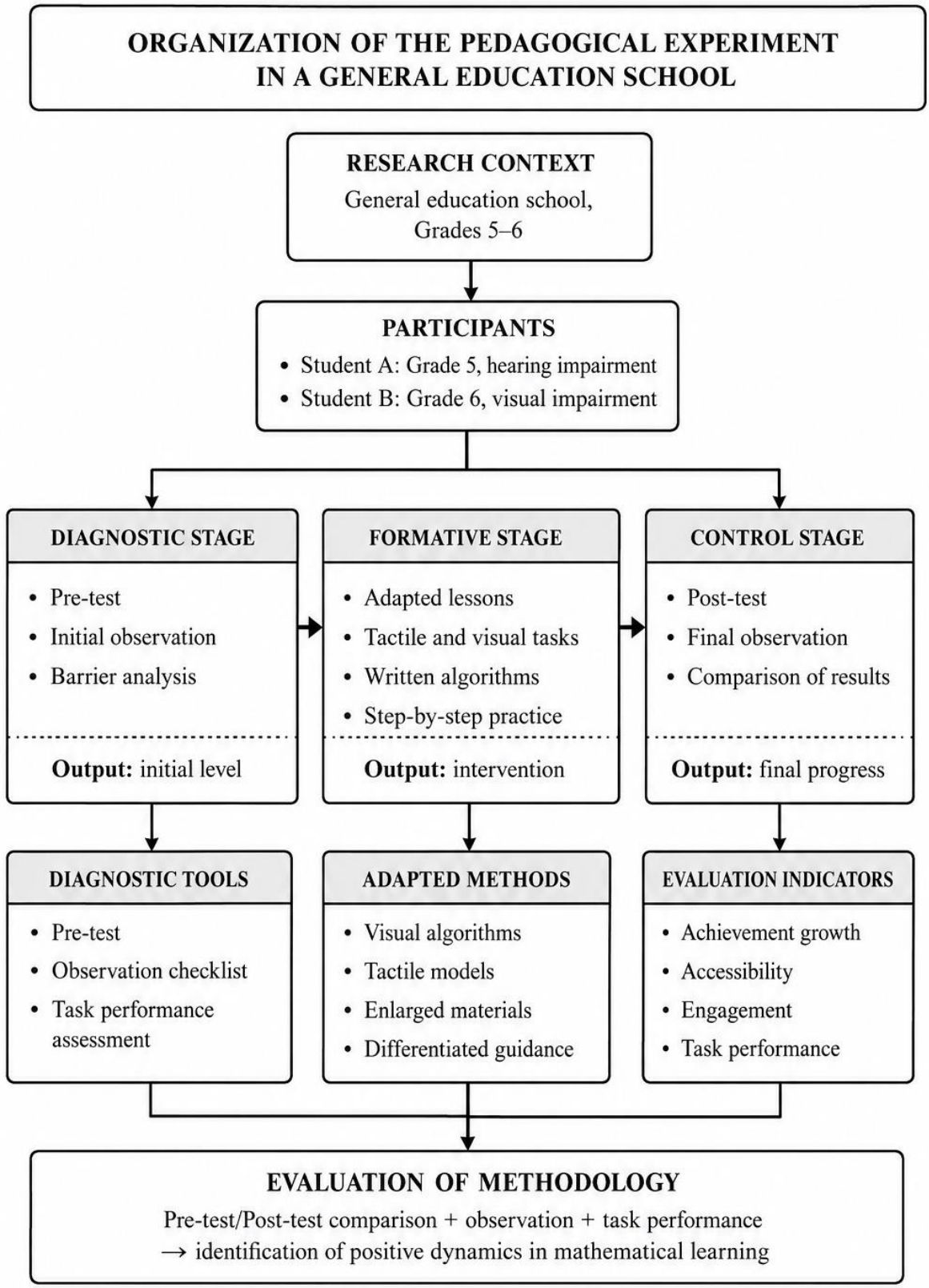
Participant	Grade	Type of special educational need	Main learning barriers in mathematics	Adaptation focus
Student A	Grade 5	Hearing impairment	Oral explanation, mathematical terminology, rapid classroom communication, insufficient written support	Written instructions, visual algorithms, classification tables, step-by-step tasks
Student B	Grade 6	Visual impairment	Board writing, diagrams, small notation, geometric and coordinate representations	Enlarged materials, oral description, tactile models, raised-line elements, practical tasks

The participants of the experiment were two lower secondary students studying at KSU Secondary School No. 15. Student A was a Grade 5 student with hearing impairment, and Student B was a Grade 6 student with visual impairment. The students were selected because Grades 5 and 6 mathematics includes topics that may create different sensory and communicative barriers, such as symbolic notation, oral explanation, diagrams, geometric representations, linear equations, coordinate models, and word problems. The selected cases made it possible to analyse how one methodological system could be applied to two different types of educational needs while preserving the same principle: mathematical content should not be simplified, but the forms of access, practice, and response should be adapted.

The organization of the experiment followed a coherent methodological sequence in which diagnosis, intervention, and evaluation were connected into one cycle. At the diagnostic stage, students completed pre-test tasks, and their initial accessibility needs were observed. At the formative stage, adapted mathematics tasks were implemented during a series of lesson fragments related to selected Grade 5 and Grade 6 topics. At the control stage, students completed parallel post-test tasks, and their final performance was compared with their initial results. The general logic of the experimental procedure is presented in Figure 3.2.1.

Since the number of students with visual and hearing impairments in one general education school is limited, the study did not use a large experimental and control group design. Instead, it applied a small-scale case-based pedagogical experiment focused on individual progress. This design was appropriate for the purpose of the study because the effectiveness of inclusive mathematics teaching in such conditions can be examined through careful analysis of changes in students' access to mathematical content, task performance, engagement, and ability to demonstrate understanding after the intervention. Each student's initial and final results were compared through pre-test and post-test tasks. This made it possible to identify positive dynamics associated with the use of adapted teaching methods rather than to claim broad statistical generalization.

Figure 3. 2. 1. Organization of the Pedagogical Experiment in a General Education School



The diagnostic stage was aimed at identifying students' initial level of mathematical achievement and determining which forms of mathematical content created the greatest barriers for each student. The formative stage involved the use of adapted teaching methods, including visual algorithms, written instructions, tactile or enlarged materials, oral description, guided mathematical action, and accessible response formats. The control stage was used to determine whether students' mathematical performance and accessibility indicators changed after the intervention. The structure of the experiment is summarized in Table 3.2.2.

Table 3. 2. 2. Stages of the Pedagogical Experiment

Stage	Purpose	Main activities	Diagnostic tools
Diagnostic stage	To identify the initial level of mathematical achievement and accessibility needs	Pre-test, initial observation, analysis of sensory and communicative barriers	Pre-test, observation checklist
Formative stage	To implement adapted mathematics teaching methods	Adapted lesson fragments, tactile and visual materials, written algorithms, guided practice, accessible response formats	Lesson tasks, observation notes
Control stage	To evaluate changes after the intervention	Post-test, final observation, comparison of task performance	Post-test, observation checklist

The content of the intervention was selected according to the Grade 5 and Grade 6 mathematics curriculum and the methodological focus of the dissertation. For Student A, who had hearing impairment, the main emphasis was placed on written instructions, visual algorithms, classification tables, labelled examples, and step-by-step completion of tasks. These adaptations were especially relevant for topics that required the

understanding of mathematical terminology, rules, and verbal instructions. For Student B, who had visual impairment, the main emphasis was placed on enlarged materials, oral description, tactile or practical models, and gradual explanation of solution steps. These adaptations were necessary for topics involving symbolic notation, spatial representation, diagrams, geometric properties, and written transformations. The intervention therefore preserved the mathematical objective while adapting the route through which each student accessed and demonstrated the content.

The pre-test and post-test were the main diagnostic tools for measuring individual learning progress. Their purpose was not to compare the students with each other or with their classmates, but to identify the development of each student's mathematical understanding before and after the use of adapted teaching methods. The tasks covered the main content areas of lower secondary mathematics: natural numbers and divisibility; prime and composite numbers, greatest common divisor and least common multiple; fractions and part of a number; numerical equalities and linear equations; geometry, coordinates, and word problems. These content blocks were selected because they require symbolic reasoning, mathematical language, visual or spatial representation, and step-by-step problem solving.

The intervention focus and adapted tasks used during the experiment are presented in Table 3.2.3.

Table 3. 2. 3. Intervention Focus and Adapted Tasks Used During the Experiment

Participant	Topic	Adapted task format	Methodological support	Expected outcome
Student A	Divisibility	Visual algorithm and classification table	Written instruction, step-by-step rule application	Applies divisibility rules

Table 3. 2. 3. Cont.

Participant	Topic	Adapted task format	Methodological support	Expected outcome
Student A	Fractions	Labelled fraction bars and written comparison rule	Visual representation, written explanation of comparison	Compares simple fractions
Student A	Word problems	Written condition table and arrows showing relationships	Short written statements, identification of known and unknown values	Selects the correct operation
Student B	Linear equations	Enlarged equation cards and tactile balance idea	Oral step-by-step explanation, guided inverse operation	Solves simple linear equations
Student B	Geometry	Enlarged or tactile geometric model	Guided description of sides, angles, and properties	Recognizes geometric properties
Student B	Coordinate representation	Enlarged or tactile coordinate grid	Oral orientation, step-by-step location of points	Identifies coordinates and spatial relations

Special attention was given to the validity of the diagnostic tasks. The content validity of the pre-test and post-test was ensured by their correspondence to the Grade 5 and Grade 6 mathematics curriculum and textbook topics. Both tests had the same structure and assessed the same mathematical skills, while the post-test used different

numerical values, changed task conditions, and parallel examples. This reduced the possibility of memorization and allowed the researcher to identify actual changes in mathematical understanding. In addition, the tasks were reviewed in terms of accessibility: instructions for the student with hearing impairment were presented in clear written form, while tasks for the student with visual impairment could be provided through enlarged materials, oral clarification, or tactile support when necessary. The scoring criteria were kept stable across the pre-test and post-test so that the same mathematical skills were assessed before and after the intervention.

The validity of the pre-test and post-test tasks is summarized in Table 3.2.4.

Table 3. 2. 4. Validity of Pre-test and Post-test Tasks

Content block	Pre-test example	Parallel post-test example	Assessed skill
Divisibility	Determine whether 648 is divisible by 9	Determine whether 729 is divisible by 9	Application of a divisibility rule
Fractions	Compare 1/2 and 1/3	Compare 2/5 and 3/5	Comparing fractions
Linear equations	Solve x + 5 = 12	Solve x + 7 = 15	Finding the unknown
Geometry	Name one property of a rectangle	Name one property of a square	Recognizing geometric properties
Word problems	A student had 45 tenge and spent 15 tenge. Find the remaining amount	A student had 60 tenge and spent 25 tenge. Find the remaining amount	Translating a word problem into a mathematical operation

The validity of the diagnostic procedure was strengthened not only by the parallel structure of the tasks, but also by the alignment between the intervention and the assessment. The skills developed during the formative stage were the same skills assessed in the post-test. For example, divisibility tasks practised through visual algorithms and classification tables were later checked through parallel divisibility

problems. Equation-solving tasks practised through enlarged or tactile equation cards were later assessed through a parallel equation requiring the same operation. This alignment made the assessment methodologically consistent: the pre-test identified initial difficulties, the intervention addressed those difficulties through adapted teaching, and the post-test examined whether positive dynamics appeared after the intervention.

Data collection was organized through several complementary sources. The first source was the comparison of pre-test and post-test scores, which showed changes in mathematical achievement. The second source was observation of accessibility and engagement during the lessons. Observation focused on whether the student could access the learning material, understand the task requirement, participate in guided practice, use adapted materials, complete the task with appropriate support, and demonstrate understanding in an accessible response format. The third source was analysis of students' task performance during the formative stage. This made it possible to identify not only whether the answer was correct, but also how the student approached the task, where difficulties appeared, and which type of adaptation supported understanding most effectively.

The analysis of the obtained data was descriptive and interpretive. Since the experiment was conducted with two individual cases, the purpose was not to apply large-scale statistical procedures, but to describe and explain individual learning progress in a methodologically accurate way. The pre-test and post-test results were compared for each student separately. The analysis focused on the number of correctly completed tasks, the types of errors before and after the intervention, the level of independence in task completion, and the ability to use adapted materials or instructions meaningfully. Observation data were used to interpret the quantitative changes and to explain whether the improvement was associated with better access to mathematical content, clearer understanding of instructions, more active participation, or more appropriate response formats.

Ethical requirements were observed during the experimental work. The students' names were replaced with codes, and the collected data were used only for research purposes. The tasks were presented in accessible formats according to students' sensory and communicative needs. The assessment was organized in a supportive environment without pressure, and the aim was to identify individual learning progress rather than compare students with their classmates. This ethical position was especially important because the study involved students with special educational needs and required careful attention to emotional comfort, confidentiality, and respect for students' dignity.

Thus, the pedagogical experiment was organized as a structured small-scale case-based study in which adapted mathematics teaching methods were applied to students with sensory impairments in a general education school. The organization of the experiment made it possible to evaluate students' initial and final mathematical achievement, observe accessibility and engagement, and prepare the basis for analysing the effectiveness of the proposed methodology. The results of the pre-test and post-test comparison are presented in the following section.

4. ANALYSIS AND RESULTS

4.1 Analysis of Pre-test and Post-test Results and Evaluation of the Methodology

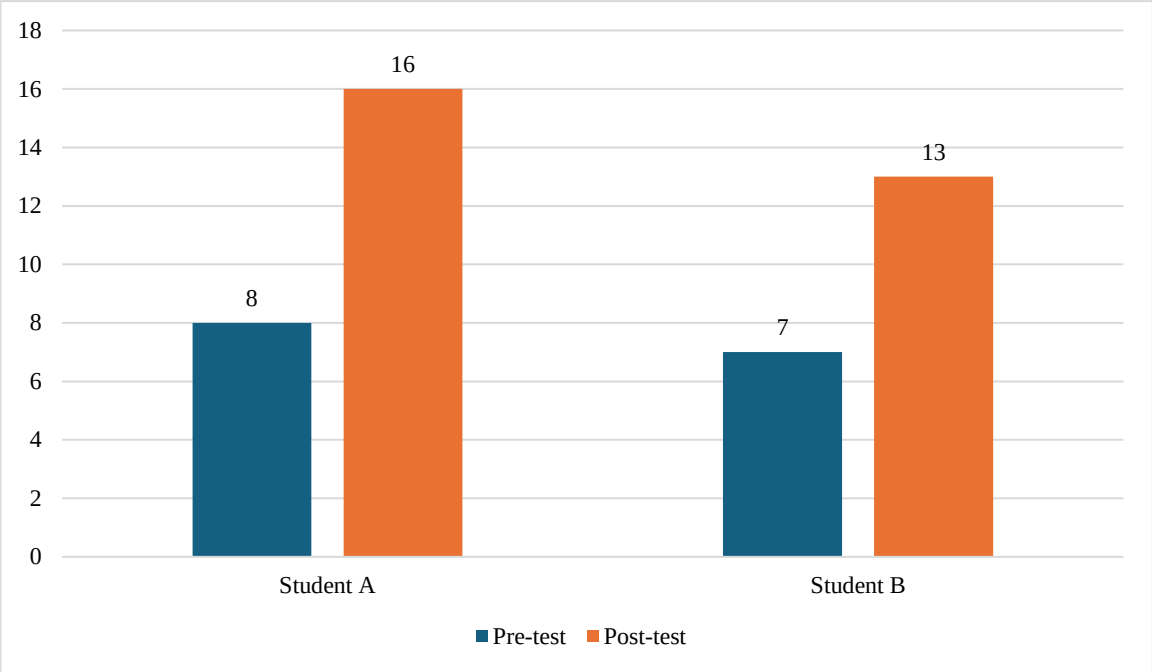
The analysis of the experimental results was conducted in accordance with the methodological logic of the small-scale case-based pedagogical experiment described in Section 3.2. Since the experimental work involved two lower secondary students with sensory impairments in a general education school, the interpretation of the results was based on individual learning progress rather than on group-level statistical comparison. The main analytical focus was placed on the comparison of pre-test and post-test results, the dynamics of accessibility and engagement, the quality of students' task performance, and the reduction of errors related to inaccessible forms of mathematical presentation. Therefore, this section evaluates not only whether the students' scores changed after the intervention, but also how the adapted teaching methods influenced their ability to understand, process, and demonstrate mathematical knowledge.

The results of the pre-test and post-test are presented in Table 4.1.1. and Figure 4.1.1.

Table 4.1. 1. Pre-test and Post-test Results of the Participants

Participant	Type of special educational need	Pre-test score	Post-test score	Gain	Interpretation
Student A	Hearing impairment	8/20	16/20	+8	Positive individual progress
Student B	Visual impairment	7/20	13/20	+6	Positive individual progress

Figure 4. 1. 1. Comparison of Pre-test and Post-test Results of the Participants



The diagnostic test consisted of 20 tasks, and each correct answer was assessed with one point. Thus, the maximum score was 20 points. The tasks covered the same content areas before and after the intervention: divisibility, fractions, numerical equalities and linear equations, geometry, coordinate representation, and word problems. The post-test preserved the structure and level of difficulty of the pre-test, but it included parallel tasks with changed numerical values and slightly modified conditions. This structure made it possible to compare students' initial and final performance without relying on direct repetition of the same items.

The comparison of pre-test and post-test results showed positive individual dynamics in both cases. Student A improved from 8 points to 16 points out of 20, which indicates an 8-point gain after the use of adapted instruction. Student B improved from 7 points to 13 points out of 20, showing a 6-point gain. These results should not be interpreted as a comparison between the two students, because their sensory needs, grade levels, and learning barriers were different. Rather, each student's post-test result was compared with their own pre-test result. This approach corresponds to the case-based design of the study and allows the researcher to identify positive dynamics associated with the implementation of adapted mathematics teaching methods.

The results by selected mathematics content blocks are shown in Table 4.1.2.

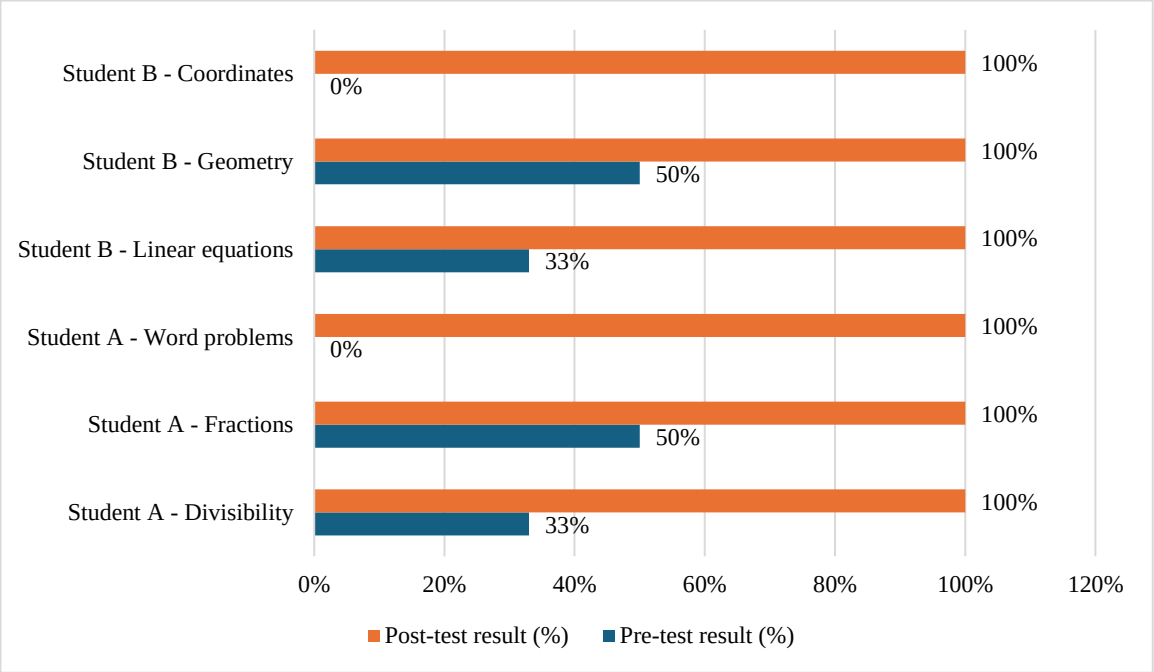
Table 4.1. 2. Results by Selected Mathematics Content Blocks

Participant	Content block	Pre-test result	Post-test result	Observed change
Student A	Divisibility	1/3	3/3	Better use of visual algorithm
Student A	Fractions	1/2	2/2	Improved comparison of fractions
Student A	Word problems	0/2	2/2	Better understanding of written condition
Student B	Linear equations	1/3	3/3	More accurate step-by-step solution
Student B	Geometry	1/2	2/2	Better recognition of properties
Student B	Coordinates	0/2	2/2	Improved spatial orientation

The content-block analysis shows that the strongest improvements were observed in those areas where the adapted methods directly addressed the students' main learning barriers. Student A demonstrated progress in divisibility, fractions, and word problems. In the pre-test, the student completed only one task correctly in divisibility and one task correctly in fractions, while the word problem task was not completed successfully. In the post-test, the student reached the maximum result in all three selected blocks. This indicates that visual algorithms, written rules, and structured condition tables helped the student understand the task requirements more clearly and apply mathematical rules more consistently.

The pre-test and post-test dynamics by selected mathematics content blocks are illustrated in Figure 4.1.2.

Figure 4. 1. 2. Pre-test and Post-test Dynamics by Selected Mathematics Content Blocks



Student B also demonstrated positive progress in the selected content blocks. In the pre-test, the student completed one task correctly in linear equations and one task correctly in geometry, while coordinate-related tasks created considerable difficulty. In the post-test, the student reached the maximum result in linear equations, geometry, and coordinates. This improvement may be associated with the use of enlarged materials, oral step-by-step explanation, tactile or practical representations, and guided orientation in spatial tasks. These results support the methodological assumption that students with visual impairments can work with the same mathematical content when symbolic, spatial, and visual information is presented through accessible routes.

The analysis of Student A's performance should be understood in relation to the communicative barriers identified at the diagnostic stage. The main difficulty for this student was not the mathematical operation itself, but the oral and language-heavy form in which mathematical tasks were usually presented. When instructions were given only orally or when the explanation depended on rapid classroom communication, the student needed additional clarification and sometimes missed important elements of the task. During the intervention, written instructions, visual algorithms, classification

tables, and step-by-step rules were used to make the mathematical content more stable and accessible. As a result, the student was able to follow the logic of divisibility rules more consistently, compare simple fractions with clearer visual support, and identify relevant information in word problems more accurately. These changes indicate that access to mathematical language and task conditions is a central factor in the learning progress of students with hearing impairment.

The case of Student B revealed a different methodological pattern. At the diagnostic stage, the main barriers were connected with visual access to mathematical notation, diagrams, geometric figures, coordinate representation, and board-based explanation. Small notation and visually dense task formats limited the student's ability to perceive the full mathematical structure of the problem. During the formative stage, enlarged materials, oral description, tactile or practical models, and guided step-by-step explanation were used. These adaptations helped the student follow the structure of a linear equation, identify the unknown, apply the inverse operation, and check the result. In geometry and coordinate-related tasks, enlarged or tactile representations supported the recognition of spatial relations and properties of figures. Therefore, the observed progress in Student B's performance may be associated with the replacement of inaccessible visual forms by accessible enlarged, oral, tactile, and practical forms of representation.

In addition to test scores, the dynamics of accessibility and engagement were analysed through observation. This was important because the effectiveness of inclusive mathematics teaching cannot be evaluated only by the number of correct answers. A student may have the potential to understand mathematical content but may not demonstrate it if the task format, instruction, or response mode is inaccessible. Observation therefore focused on whether the students understood task instructions, used adapted materials, participated in guided practice, completed tasks with greater independence, and demonstrated mathematical reasoning through accessible response formats. The observation indicators were assessed using a three-level scale: 0 points

indicated that the indicator was not observed, 1 point indicated that it was partially observed, and 2 points indicated that it was clearly observed.

The dynamics of accessibility and engagement during the intervention are presented in Table 4.1.3.

Table 4.1. 3. Accessibility and Engagement Dynamics

Indicator	Student A before intervention	Student A after intervention	Student B before intervention	Student B after intervention
Understanding of task instructions	½	2/2	1/2	2/2
Use of adapted materials	½	2/2	1/2	2/2
Participation in guided practice	½	2/2	1/2	2/2
Independent task completion	0/2	1/2	0/2	1/2
Accessible response format	½	2/2	1/2	2/2
Total	4/10	9/10	4/10	9/10

The observation results provide an important qualitative explanation of the test dynamics. In the case of Student A, written instructions and visual algorithms reduced dependence on repeated oral explanation and allowed the student to participate more confidently in guided mathematical practice. In the case of Student B, enlarged materials, oral clarification, and tactile or practical models made mathematical information more accessible and supported more independent completion of tasks. In both cases, accessibility and engagement increased from 4 points to 9 points out of 10. This does not mean that the students became fully independent in all learning situations; however, it shows that the adapted learning environment created more favourable

conditions for understanding instructions, using support materials, participating in guided practice, and demonstrating mathematical reasoning.

A separate aspect of the analysis concerned error dynamics. The purpose of this analysis was to determine whether the types of errors changed after the intervention. At the pre-test stage, some errors were related to mathematical misunderstanding, while others were caused by inaccessible task presentation, unclear instructions, or difficulty in perceiving visual or oral information. After the intervention, the number of accessibility-related errors decreased because the adapted methodology was directed precisely at removing such barriers.

Table 4.1. 4. Error Dynamics Before and After the Intervention

Participant	Frequent errors in pre-test	Support used during intervention	Errors reduced in post-test
Student A	Misunderstanding oral instructions; incomplete application of rules	Written instructions; visual algorithms; classification tables	Fewer instruction-related errors; more consistent rule application
Student A	Difficulty identifying key information in word problems	Written condition table; separation of known and unknown values	Better selection of mathematical operation
Student B	Difficulty reading small notation and following board-based transformations	Enlarged materials; oral step-by-step explanation	Fewer notation-related and sequence-related errors
Student B	Difficulty interpreting geometric and coordinate representations	Oral description; tactile or enlarged models	Better recognition of spatial relations and figure properties

The analysis of error dynamics is presented in Table 4.1.4.

The reduction of errors after the intervention is methodologically significant because it shows that some initial difficulties were not caused by the mathematical content itself, but by the form in which the content was presented. In the case of Student A, written and visual support helped reduce errors connected with oral instruction and unclear task conditions. In the case of Student B, enlarged and tactile support helped reduce errors connected with visual perception of notation, diagrams, and spatial models. This finding corresponds to the central theoretical position of the dissertation: inclusive mathematics teaching should not simplify mathematical content, but should provide accessible routes through which students can perceive, practise, and demonstrate the same mathematical ideas.

The evaluation of the methodology should therefore be based on the integration of several types of evidence. The pre-test and post-test comparison shows the change in mathematical achievement. The content-block analysis explains in which areas the changes occurred. The observation of accessibility and engagement reveals whether students became more active and independent in the learning process. The error analysis shows whether the intervention reduced barriers connected with inaccessible instruction, notation, diagrams, or task conditions. Taken together, these indicators allow the methodology to be evaluated not as a set of isolated techniques, but as a coherent system that connects diagnosis, adaptation, guided practice, and assessment.

At the same time, the interpretation of the results requires methodological caution. Since the study involved two individual cases in one general education school, the findings cannot be generalized statistically to all students with visual and hearing impairments. The study did not aim to prove a universal effect through large-scale quantitative procedures. Its purpose was to examine the practical feasibility and potential usefulness of the proposed methodology in real classroom conditions. From this perspective, the results are valuable because they show how adapted mathematics teaching can support access, engagement, and individual learning progress when students with sensory impairments study the same mathematical content as their peers.

The analysis also indicates that the effectiveness of inclusive mathematics teaching depends on the consistency between diagnosis, adaptation, practice, and assessment. The pre-test identified the initial level of achievement and the main accessibility barriers. The formative stage addressed these barriers through adapted tasks and accessible instruction. The post-test made it possible to compare final performance with initial results. This sequence created a coherent methodological cycle in which assessment was not separated from instruction, but was used as a means of identifying progress and improving pedagogical decisions. Therefore, the proposed methodology may be considered practically applicable for general education schools where students with visual or hearing impairments require adapted routes to the same mathematical learning objectives.

Thus, the analysis of the experimental results supports the main assumption of the study: mathematical content for students with visual and hearing impairments should not be simplified; rather, it should be presented through accessible tactile, visual, written, oral, step-by-step, and practical forms. The positive dynamics identified through pre-test and post-test comparison, accessibility observation, engagement indicators, and error analysis provide evidence of the potential effectiveness of the proposed methodology. These findings form the basis for the general conclusions and practical recommendations of the dissertation.

5. DISCUSSION AND CONCLUSION

The aim of the dissertation was to develop and justify a methodology for inclusive mathematics teaching for Grade 5 and Grade 6 students with visual and hearing impairments in a general education school setting. The conducted research showed that this aim was achieved through theoretical analysis, methodological modelling, development of adapted mathematics tasks, organization of a small-scale case-based pedagogical experiment, and analysis of students' individual learning progress through pre-test and post-test comparison. The central conclusion of the study is that inclusive mathematics teaching should not be understood as the simplification of curriculum content. Rather, it should be organized as a systematic didactic process in which the same mathematical objective is preserved, while the forms of perception, representation, communication, guided practice, assessment, and response are adapted to learners' sensory and communicative needs.

The theoretical part of the dissertation showed that the transition from primary to lower secondary mathematics creates new difficulties for students with visual and hearing impairments. In Grades 5 and 6, students work with divisibility, fractions, prime and composite numbers, greatest common divisor, least common multiple, numerical equalities, linear equations, geometry, coordinate representation, and word problems. These topics require not only calculation skills, but also symbolic reasoning, spatial imagination, mathematical language, interpretation of diagrams, understanding of written models, and the ability to follow multi-step procedures. For students with visual impairments, the main barriers are connected with board writing, small symbolic notation, diagrams, coordinate grids, geometric representations, and visually presented models. For students with hearing impairments, the main barriers are connected with oral explanations, rapid classroom communication, mathematical terminology, and insufficient written or visual support. This analysis made it possible to identify the methodological conditions necessary for accessible mathematics teaching in lower secondary school.

The scientific novelty of the dissertation lies in the development of a practically oriented methodology for inclusive mathematics teaching for Grade 5 and Grade 6 students with visual and hearing impairments in a general education school. The proposed methodology is based on a multisensory tactile-visual model with selected game-based elements. This model includes diagnostic access checking, accessible mathematical representation, guided mathematical action, collaborative or game-based practice, differentiated assessment, and reflection with correction. Its main methodological value is that it allows the teacher to organize one common mathematical objective through different access routes. For students with visual impairments, these routes include enlarged materials, oral description, tactile models, raised-line elements, practical manipulation, and step-by-step explanation. For students with hearing impairments, they include written instructions, visual algorithms, classification tables, labelled diagrams, structured examples, and accessible response formats.

The practical significance of the dissertation is reflected in the diagnostic and methodological materials developed for the study. These include adapted mathematics tasks, pre-test and post-test materials, an accessibility and engagement observation checklist, examples of tactile and visual support, written algorithms, classification tables, and structured task formats for selected Grade 5 and Grade 6 mathematics topics. The proposed materials can be used by mathematics teachers working in general education schools where students with special educational needs study together with their peers. They are especially relevant for teaching divisibility, fractions, linear equations, geometry, coordinate representation, and word problems, because these topics often require symbolic, visual, spatial, linguistic, and procedural forms of mathematical thinking.

The experimental part of the dissertation was organized at KSU Secondary School No. 15 named after K. Azerbayev with the participation of two lower secondary students with sensory impairments. Student A was a Grade 5 student with hearing impairment, and Student B was a Grade 6 student with visual impairment. The

experiment was designed as a small-scale case-based pedagogical study focused on individual learning progress. The effectiveness of the proposed methodology was evaluated through pre-test and post-test comparison, observation of accessibility and engagement, analysis of task performance, and identification of error dynamics before and after the intervention. This design was appropriate for the purpose of the study because the research did not aim to make broad statistical generalizations, but to examine how adapted mathematics teaching functions in real classroom conditions.

The results of the experimental work showed positive individual dynamics in both cases. Student A improved from 8 points to 16 points out of 20, which indicates an 8-point gain after the use of written instructions, visual algorithms, classification tables, and step-by-step task formats. Student B improved from 7 points to 13 points out of 20, showing a 6-point gain after the use of enlarged materials, oral description, tactile or practical models, and guided explanation of solution steps. The content-block analysis also showed positive changes. Student A demonstrated improvement in divisibility, fractions, and word problems, while Student B demonstrated improvement in linear equations, geometry, and coordinate representation. These results indicate that adapted instruction supported students' access to mathematical content and helped them demonstrate mathematical understanding more successfully.

The observation results supported the pre-test and post-test findings. Accessibility and engagement indicators increased from 4 points to 9 points out of 10 for both students. This shows that after the intervention the students understood task instructions more clearly, used adapted materials more actively, participated more confidently in guided practice, completed tasks with greater independence, and demonstrated their answers through more accessible response formats. The analysis of errors also confirmed that several initial difficulties were not caused by the mathematical content itself, but by the form in which the content was presented. For Student A, written and visual support reduced instruction-related errors and improved the use of mathematical rules. For Student B, enlarged and tactile support reduced notation-related and spatial-representation errors.

The findings of the dissertation confirm that effective inclusive mathematics teaching requires the integration of content accuracy and accessibility. Adaptation should not lower the mathematical level of the task. Instead, it should change the way students access, process, practise, and demonstrate mathematical knowledge. In this sense, the proposed methodology contributes to the development of inclusive mathematics education by showing how abstract mathematical content can be made accessible to students with visual and hearing impairments without weakening the academic integrity of the curriculum. The results support the main assumption of the study: if mathematical content is presented through tactile, visual, written, oral, step-by-step, and practical forms, students with sensory impairments can demonstrate improved access to learning materials, greater engagement, and positive progress in mathematical achievement.

The study also has certain limitations. The experimental work was conducted in one general education school and involved two individual cases. Therefore, the findings cannot be generalized statistically to all students with visual and hearing impairments. The results may also be influenced by students' individual sensory characteristics, previous mathematical experience, communication skills, level of independence, and familiarity with adapted materials. These limitations do not reduce the practical value of the study, but they show that further research is needed. Future studies may test the proposed methodology in other general education schools, with larger numbers of students, different age groups, and additional mathematical topics. It would also be useful to examine the long-term influence of adapted mathematics teaching on students' mathematical independence, confidence, and ability to transfer knowledge to new tasks.

The results of the dissertation allow several practical recommendations to be made. Mathematics teachers should begin inclusive lesson planning with the analysis of barriers within the mathematical topic itself. When teaching students with visual impairments, teachers should provide enlarged materials, oral descriptions, tactile models, practical demonstrations, and step-by-step explanations. When teaching

students with hearing impairments, teachers should use written instructions, visual algorithms, labelled diagrams, classification tables, and clearly structured task formats. Assessment should preserve the same mathematical objective while allowing accessible forms of perception and response. Schools should also support teachers by providing adapted materials, assistive tools, and methodological guidance for organizing inclusive mathematics lessons.

Thus, the dissertation demonstrates that inclusive mathematics teaching in Grades 5 and 6 becomes more effective when mathematical content is not simplified, but presented through accessible and methodologically structured forms. The proposed methodology may serve as a practical basis for improving mathematics teaching in general education schools where students with visual and hearing impairments study together with their peers. It provides a way to connect curriculum requirements, adapted instruction, accessible assessment, and students' individual learning progress into one coherent methodological system.

6.LIMITATIONS

The present study has several limitations. First, the pedagogical experiment was conducted in one general education school and involved only two individual cases: one Grade 5 student with hearing impairment and one Grade 6 student with visual impairment. Therefore, the findings cannot be generalized statistically to all Grade 5–6 students with visual and hearing impairments.

Second, the study was based on a small-scale case-based pedagogical experiment rather than a large experimental and control group design. For this reason, the results should be interpreted as evidence of positive individual learning progress and practical feasibility of the proposed methodology, not as proof of a universal effect.

Third, the results may have been influenced by the students' individual characteristics, including their previous mathematical knowledge, communication skills, level of independence, sensory needs, and familiarity with adapted learning materials. These factors may affect how students respond to tactile, visual, written, oral, step-by-step, and practical forms of instruction.

Fourth, the intervention focused only on selected Grade 5 and Grade 6 mathematics topics, such as divisibility, fractions, linear equations, geometry, coordinate representation, and word problems. Therefore, further research is needed to test the proposed methodology with a larger number of students, in different schools, across longer periods of time, and on a wider range of mathematics topics.

These limitations do not reduce the practical value of the study. Rather, they show the need for further research and confirm that the proposed methodology should be viewed as a practically useful model that can be improved, expanded, and tested in broader educational contexts.

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LIST OF APPENDICES

Appendix A. Pre-test and Post-test Mathematics Achievement Tasks for Grade 5–6 Students

Purpose of the diagnostic tasks: These tasks are designed to assess the mathematical achievement of Grade 5–6 students with visual and hearing impairments before and after the implementation of the inclusive mathematics teaching methodology. The pre-test identifies students' initial level of mathematical achievement, while the post-test measures individual progress after the use of adapted teaching methods.

Target group: Grade 5–6 students with visual and hearing impairments studying in a general education school.

Test format: Pre-test and parallel post-test.

Total number of tasks: 20 tasks in each test.

Maximum score: 20 points.

Time: 40 minutes.

Scoring procedure: Each correct answer is awarded 1 point. An incorrect or missing answer is awarded 0 points. The same scoring procedure is used for both the pre-test and the post-test.

Adaptation notes: For students with visual impairments, the test may be provided in enlarged print, audio-supported format, or with tactile materials where necessary. Diagrams, geometric figures, coordinate grids, and written notation may be enlarged or explained orally. For students with hearing impairments, all instructions should be provided in clear written form and may be supported by visual explanation, labelled examples, or sign-supported clarification if necessary. The mathematical content and scoring criteria must remain the same for all students.

Pre-test

Student code: _____

Type of impairment: Visual impairment / Hearing impairment

Grade: 5 / 6

Test type: Pre-test / Post-test

Date: _____

Natural Numbers and Divisibility

1. Write the place value of the digit 7 in the number 47,582.

2. Which of the following numbers is divisible by 5?

A. 124

B. 235

C. 318

D. 421

3. Determine whether 648 is divisible by 9. Show the rule you used.

4. Write one number that is divisible by both 2 and 10.

Prime and Composite Numbers, GCD and LCM

5. Is 17 a prime or composite number? Explain briefly.

6. Write all divisors of 12.

7. Find the greatest common divisor of 18 and 24.

8. Find the least common multiple of 4 and 6.

Fractions and Part of a Number

9. Which fraction is greater: 1/2 or 1/3?

10. Find 1/4 of 20.

11. Compare the fractions: 3/5 and 4/5. Write the greater fraction.

12. A ribbon is 30 cm long. 1/3 of the ribbon was cut. How many centimetres were cut?

Numerical Equalities and Linear Equations

13. Complete the equality: 8 + 6 = ___ + 7.

14. If a = b, which expression is also correct?

A. a + 3 = b + 3

B. a + 3 = b – 3

C. a − 3 = b + 3

D. a × 3 = b + 2

15. Solve the equation: x + 5 = 12.

16. Solve the equation: 3x = 18.

Geometry, Coordinates, and Word Problems

17. How many sides does a rectangle have?

18. Name one property of a square.

19. On a coordinate plane, point A has coordinates (2, 3). What is the first coordinate called?

20. A student had 45 tenge. He bought a pencil for 15 tenge. How much money did he have left?

Post-test

Student code: _____

Type of impairment: Visual impairment / Hearing impairment

Grade: 5 / 6

Date: _____

Test type: Post-test

Natural Numbers and Divisibility

1. Write the place value of the digit 6 in the number 36,419.
2. Which of the following numbers is divisible by 5?

A. 132

B. 260

C. 417

D. 584

3. Determine whether 729 is divisible by 9. Show the rule you used.
4. Write one number that is divisible by both 5 and 10.

Prime and Composite Numbers, GCD and LCM

5. Is 19 a prime or composite number? Explain briefly.
6. Write all divisors of 18.
7. Find the greatest common divisor of 20 and 30.
8. Find the least common multiple of 3 and 8.

Fractions and Part of a Number

9. Which fraction is greater: 2/5 or 3/5?

10. Find 1/5 of 25.

11. Compare the fractions: 2/7 and 5/7. Write the greater fraction.

12. A rope is 40 cm long. 1/4 of the rope was cut. How many centimetres were cut?

Numerical Equalities and Linear Equations

13. Complete the equality: 9 + 5 = ___ + 6

14. If m = n, which expression is also correct?

A. m + 4 = n + 4

B. m + 4 = n – 4

C. m − 4 = n + 4

D. m × 4 = n + 3

15. Solve the equation: x + 7 = 15

16. Solve the equation: 4x = 24

Geometry, Coordinates, and Word Problems

17. How many sides does a triangle have?

18. Name one property of a rectangle.

19. On a coordinate plane, point B has coordinates (4, 2). What is the second coordinate called?

20. A student had 60 tenge. He bought a notebook for 25 tenge. How much money did he have left?

Scoring Interpretation

Score	Level of mathematical achievement
0–7	Low level
8–14	Medium level
15–20	High level

Appendix B. Accessibility and Engagement Observation Checklist

Purpose of the checklist: This checklist is designed to observe the accessibility of mathematics lessons and the engagement of Grade 5–6 students with visual and hearing impairments during the implementation of the inclusive mathematics teaching methodology. The checklist helps to identify whether the student can understand task instructions, use adapted materials, participate in guided mathematical practice, complete tasks with increasing independence, and demonstrate mathematical understanding through accessible response formats.

Target group: Grade 5–6 students with visual and hearing impairments studying in a general education school.

Observer: Researcher / Mathematics teacher / Mentor teacher

Observation format: Before and after the intervention.

Observation scale: 0 = Not observed; 1 = Partially observed; 2 = Clearly observed.

Maximum score: 10 points.

General Information

Student code: _____

Grade: 5 / 6

Type of impairment: Visual impairment / Hearing impairment

Lesson topic: _____

Observation stage: Before intervention / After intervention

Date: _____

Observer: _____

Observation Checklist

No.	Observation indicator	0	1	2	Comments
1	The student understands the task instructions before starting the activity	☐	☐	☐	
2	The student uses adapted learning materials during the lesson	☐	☐	☐	
3	The student participates in guided mathematical practice	☐	☐	☐	
4	The student completes the mathematical task with increasing independence	☐	☐	☐	
5	The student demonstrates mathematical understanding through an accessible response format	☐	☐	☐	

Total score: _____ / 10

Scoring Interpretation

Total score	Level of accessibility and engagement	Interpretation
0–3	Low level	The student has limited access to task instructions, adapted materials, guided practice, or response formats. Significant support is required.
4–7	Medium level	The student has partial access to the lesson content and participates with support. Some adapted materials are effective, but further correction is needed.
8–10	High level	The student understands instructions, uses adapted materials actively, participates in guided practice, and demonstrates understanding through accessible response formats.

Description of Observation Indicators

1. Understanding of task instructions

This indicator shows whether the student understands what should be done before starting the task. For a student with hearing impairment, this may depend on written instructions, visual explanation, labelled examples, or sign-supported clarification. For a student with visual impairment, this may depend on oral explanation, enlarged text, tactile support, or step-by-step verbal clarification.

2. Use of adapted learning materials

This indicator shows whether the student actually uses the adapted materials provided during the lesson. Adapted materials may include enlarged worksheets, tactile models, raised-line elements, visual algorithms, written rules, classification tables, oral descriptions, or practical manipulatives.

3. Participation in guided mathematical practice

This indicator shows whether the student participates in teacher-guided or supported mathematical activity. Participation may include answering questions, following solution steps, using a model, applying a rule, comparing quantities, solving equations, identifying geometric properties, or working through a word problem.

4. Independent task completion

This indicator shows whether the student can complete mathematical tasks with reduced dependence on teacher support. Full independence is not required; the focus is on whether the student shows progress in applying the method, using adapted materials, and completing steps more confidently.

5. Accessible response format

This indicator shows whether the student can demonstrate mathematical understanding through a response format that corresponds to their sensory and communicative needs. The response may be oral, written, tactile, visual, practical, step-by-step, or supported by adapted materials.

Observation Summary Sheet

Indicator	Before intervention	After intervention	Observed change
Understanding of task instructions	____ /2	____ /2	_____
Use of adapted materials	____ /2	____ /2	_____
Participation in guided practice	____ /2	____ /2	_____
Independent task completion	____ /2	____ /2	_____
Accessible response format	____ /2	____ /2	_____
Total	**____ /10**	**____ /10**	_____

Adaptation Notes for Students with Visual Impairments

When observing a student with visual impairment, the observer should pay attention to whether the student can access mathematical information that is usually presented visually. Special attention should be given to the use of enlarged print, oral description, tactile models, raised-line diagrams, three-dimensional figures, enlarged or tactile coordinate grids, and step-by-step verbal explanation. The observer should also note whether the student can follow symbolic notation, identify spatial relations, and demonstrate mathematical reasoning without being limited by inaccessible visual formats.

Adaptation Notes for Students with Hearing Impairments

When observing a student with hearing impairment, the observer should pay attention to whether the student can access mathematical explanations, instructions, and classroom communication. Special attention should be given to written instructions, visual algorithms, labelled diagrams, classification tables, structured examples, clear

board organization, sign-supported clarification when necessary, and opportunities to respond in written or visual form.

The observer should also note whether the student can understand mathematical terminology, follow the logic of the task, and participate in guided practice without being limited by oral-only explanation.

Observer's Notes

Main accessibility strengths observed during the lesson:

Main difficulties observed during the lesson:

Adapted materials or support used during the lesson:

Recommended correction for the next lesson:

Notes for Data Analysis

The checklist results should be used together with pre-test and post-test scores in order to interpret students' individual learning progress. If the student's accessibility and engagement score increases after the intervention, this may indicate that the adapted teaching methods supported the student's participation in mathematical learning. The observation results should not be interpreted separately from task performance. They

should be used to explain how adapted materials, clear instructions, guided practice, and accessible response formats contributed to the student's mathematical achievement.

Appendix C. Expert Review Form for Validating Pre-test and Post-test Tasks

Purpose of the expert review: This expert review form is designed to evaluate the validity, accessibility, and methodological quality of the pre-test and post-test mathematics achievement tasks developed for Grade 5–6 students with visual and hearing impairments. The review is intended to confirm whether the diagnostic tasks correspond to the Grade 5–6 mathematics curriculum, assess the intended mathematical skills, preserve the same level of difficulty in the pre-test and post-test, and provide accessible task formats for students with sensory impairments.

Target diagnostic materials: Pre-test and post-test mathematics achievement tasks for Grade 5–6 students.

Target group of the diagnostic tasks: Grade 5–6 students with visual and hearing impairments studying in a general education school.

Expert reviewers: Mathematics education specialists, inclusive education specialists, mathematics teachers, or specialists with experience in teaching students with special educational needs.

Review scale: 2 = Fully meets the criterion; 1 = Partially meets the criterion; 0 = Does not meet the criterion.

Maximum score: 20 points.

General Information

Expert code: _____

Expert's field of specialization: _____

Position: _____

Institution: _____

Date of review: _____

Expert Review Criteria

No.	Review criterion	0	1	2	Expert comment
1	The tasks correspond to the Grade 5–6 mathematics curriculum	☐	☐	☐	
2	The tasks correspond to the selected textbook topics and lower secondary mathematics content	☐	☐	☐	
3	The tasks assess the intended mathematical skills clearly	☐	☐	☐	
4	The tasks cover the main content blocks of the diagnostic test: divisibility, fractions, equations, geometry, coordinates, and word problems	☐	☐	☐	
5	The pre-test and post-test have a parallel structure	☐	☐	☐	
6	The post-test tasks are equivalent to the pre-test tasks in level of difficulty	☐	☐	☐	
7	The post-test uses different numbers and task conditions while measuring the same mathematical skills	☐	☐	☐	
8	The wording of the tasks is clear, age-appropriate, and understandable for Grade 5–6 students	☐	☐	☐	
9	The tasks are accessible for students with hearing impairments when written instructions and visual support are provided	☐	☐	☐	
10	The tasks are accessible for students with visual impairments when enlarged, oral, tactile, or practical support is provided	☐	☐	☐	

Total score: _____ / 20

Interpretation of Expert Review Results

Total score	Validity level	Interpretation
0–7	Low validity	The diagnostic tasks require substantial revision. Several tasks may not correspond to the curriculum, intended skills, accessibility requirements, or parallel test structure.
8–14	Medium validity	The diagnostic tasks are generally appropriate, but several criteria require clarification or improvement before use in the experiment.
15–20	High validity	The diagnostic tasks are valid, curriculum-based, accessible, and methodologically appropriate for assessing Grade 5–6 students with visual and hearing impairments.

Content Validity Evaluation

The expert is asked to evaluate whether the diagnostic tasks adequately represent the mathematical content selected for the study. The tasks should reflect essential Grade 5–6 mathematics topics and should not assess skills that are outside the intended curriculum level.

Content block	**Included in the test**	**Appropriate for Grade 5–6**	**Comment**
Natural numbers and divisibility	☐ Yes / ☐ No	☐ Yes / ☐ No	
Prime and composite numbers, GCD and LCM	☐ Yes / ☐ No	☐ Yes / ☐ No	
Fractions and part of a number	☐ Yes / ☐ No	☐ Yes / ☐ No	
Numerical equalities and linear equations	☐ Yes / ☐ No	☐ Yes / ☐ No	

Geometry, coordinates, and word problems	☐ Yes / ☐ No	☐ Yes / ☐ No

Parallel Structure Evaluation

The expert is asked to evaluate whether the post-test is equivalent to the pre-test in structure, content focus, and difficulty level. The post-test should not repeat the same tasks mechanically, but it should assess the same mathematical skills through parallel examples.

Aspect of parallel structure	Yes	Partly	No	Comment
The pre-test and post-test contain the same number of tasks	☐	☐	☐	
The pre-test and post-test cover the same content blocks	☐	☐	☐	
The post-test tasks assess the same mathematical skills as the pre-test tasks	☐	☐	☐	
The numerical values and task conditions are changed appropriately	☐	☐	☐	
The difficulty level of the post-test is comparable to the pre-test	☐	☐	☐	

Accessibility Evaluation

The expert is asked to evaluate whether the diagnostic tasks can be adapted for students with visual and hearing impairments without changing the mathematical objective. Accessibility should support perception and response, but it should not simplify the mathematical content or provide the answer.

Accessibility criterion	Yes	Partly	No	Comment
The instructions can be provided in clear written form for students with hearing impairments	☐	☐	☐	
The tasks can be supported by visual algorithms, tables, or labelled examples when necessary	☐	☐	☐	
The tasks can be enlarged or read aloud for students with visual impairments	☐	☐	☐	
Diagrams, geometric figures, or coordinate tasks can be supported by tactile, enlarged, or oral explanation	☐	☐	☐	
The adaptation does not reduce the mathematical objective of the task	☐	☐	☐	

Scoring Criteria Evaluation

The expert is asked to determine whether the scoring system is clear and appropriate for comparing pre-test and post-test results.

Scoring criterion	Yes	Partly	No	Comment
Each task has a clear expected answer	☐	☐	☐	
The 1-point scoring system is appropriate for the diagnostic purpose	☐	☐	☐	
The same scoring criteria can be applied to both pre-test and post-test tasks	☐	☐	☐	
The scoring system allows individual progress to be compared before and after the intervention	☐	☐	☐	
The scoring procedure is understandable for the researcher and teacher	☐	☐	☐	

Expert's General Conclusion

Please provide an overall conclusion about the quality and applicability of the pre-test and post-test tasks.

Strengths of the diagnostic tasks:

Aspects requiring improvement:

Recommended corrections:

Final Expert Recommendation

Please select one option:

☐ The diagnostic tasks are recommended for use without revision.

☐ The diagnostic tasks are recommended for use after minor revision.

☐ The diagnostic tasks require major revision before use.

☐ The diagnostic tasks are not recommended for use in their current form.

Expert's full name: _____

Signature: _____

Date: _____

Appendix D. Inclusive Lesson Plan Evaluation Sheet

Purpose of the adapted tasks: The adapted mathematics tasks were used during the formative stage of the pedagogical experiment in order to support Grade 5 and Grade 6 students with sensory impairments in accessing mathematical content without reducing the academic level of the curriculum. The tasks were designed according to the inclusive mathematics teaching methodology described in the dissertation and were connected with the same mathematical skills assessed in the pre-test and post-test. The main purpose of these tasks was to provide accessible routes for understanding, practising, and demonstrating mathematical knowledge through visual, written, oral, enlarged, tactile, step-by-step, and practical forms.

Target group: Grade 5–6 students with visual and hearing impairments studying in a general education school.

Participants: Student A – Grade 5 student with hearing impairment. Student B – Grade 6 student with visual impairment.

General adaptation principle: The mathematical objective of each task was preserved. Adaptation was made only in the form of task presentation, instruction, support material, learning action, and response format. The tasks were not simplified in content; rather, they were made more accessible according to students' sensory and communicative needs.

Task 1. Divisibility Rules

Adapted Task for Student A with Hearing Impairment

Topic: Divisibility by 2, 5, 10, 3, and 9.

Grade: 5.

Learning objective: The student applies divisibility rules to determine whether a number is divisible by 2, 5, 10, 3, or 9.

Adaptation focus: Written instruction, visual algorithm, classification table, step-by-step rule application.

Adapted materials: Written rule card, visual algorithm, number classification table, coloured markers or signs "Yes" and "No".

Written rule card for the student:

A number is divisible by **2** if the last digit is even: 0, 2, 4, 6, 8.

A number is divisible by **5** if the last digit is 0 or 5.

A number is divisible by **10** if the last digit is 0.

A number is divisible by **3** if the sum of its digits is divisible by 3.

A number is divisible by **9** if the sum of its digits is divisible by 9.

Visual algorithm:

1. Look at the number.
2. Check the last digit.
3. If needed, add the digits.
4. Choose the correct divisibility rule.
5. Write “Yes” or “No”.
6. Explain the rule shortly.

Student task: Complete the table.

Number	Divisible by 2	Divisible by 5	Divisible by 10	Divisible by 3	Divisible by 9
120					
135					
248					
360					
729					

Teacher support: The teacher presents the rule in written form and points to the relevant part of the visual algorithm. Oral explanation is supported by written examples. The student is encouraged to follow the same sequence for each number.

Assessment criterion: The student correctly applies divisibility rules and explains the choice using a written or visual rule.

Task 2. Fraction Comparison

Adapted Task for Student A with Hearing Impairment

Topic: Comparing simple fractions.

Grade: 5.

Learning objective: The student compares fractions with the same or different denominators using visual representation and written rules.

Adaptation focus: Labelled fraction bars, written comparison rule, visual support.

Adapted materials: Labelled fraction bars, written comparison rule, worksheet with fraction pairs.

Written rule card for the student: When two fractions have the **same denominator**, compare the numerators.

The fraction with the greater numerator is greater.

Example: 3/5 and 4/5

The denominators are the same.

4 is greater than 3.

Therefore, 4/5 is greater than 3/5.

When two fractions have **different denominators**, use a model or compare the size of equal parts.

Student task: Compare the fractions. Write the greater fraction.

No.	Fraction pair	Greater fraction
1	1/2 and 1/3	
2	3/5 and 4/5	
3	2/7 and 5/7	
4	2/4 and 3/4	

Teacher support: The teacher uses labelled fraction bars and written explanation. The student is guided to look at the numerator and denominator separately. If the student does not understand the oral explanation, the teacher points to the written rule and model.

Assessment criterion: The student identifies the greater fraction and justifies the answer using the writen rule or labelled visual model.

Task 3. Word Problem with Written Condition Table

Adapted Task for Student A with Hearing Impairment

Topic: Word problems involving subtraction.

Grade: 5.

Learning objective: The student identifies known and unknown information in a word problem and selects the correct arithmetic operation.

Adaptation focus: Written condition table, short statements, arrows showing relationships, step-by-step solution.

Adapted materials: Written problem card, condition table, operation selection card.

Student task: A student had **60 tenge**. He bought a notebook for **25 tenge**. How much money did he have left? Complete the table.

What is known?	What should be found?	Operation	Solution

Step-by-step instruction:

1. Read the problem.
2. Find how much money the student had.
3. Find how much money he spent.
4. Choose the operation.
5. Write the solution.
6. Write the answer.

Answer: The student had **35 tenge** left.

Teacher support: The teacher gives the task in written form and checks whether the student understands the meaning of “had”, “spent”, and “left”. The teacher may underline key information and use arrows to show the relationship between the quantities.

Assessment criterion: The student correctly identifies known and unknown information, selects subtraction, and writes the correct answer.

Task 4. Linear Equation

Adapted Task for Student B with Visual Impairment

Topic: Solving simple linear equations.

Grade: 6.

Learning objective: The student solves a simple linear equation using inverse operation and checks the result.

Adaptation focus: Enlarged equation card, oral step-by-step explanation, tactile balance idea, guided solution.

Adapted materials: Enlarged equation cards, tactile left-side and right-side zones, step cards, oral instruction.

Student task: Solve the equation: **x + 6 = 14**

Step-by-step solution card:

1. Identify the unknown: **x**.
2. Identify the operation: **+ 6**.
3. Use the inverse operation: **14 − 6**.
4. Find the value of x.
5. Check the answer.

Expected solution: x + 6 = 14

x = 14 – 6

x = 8

Check: 8 + 6 = 14

Answer: x = 8.

Additional practice equations:

1. x + 7 = 15
2. x − 4 = 9
3. 3x = 18
4. 4x = 24

Expected answers:

1. x = 8

2. x = 13
3. x = 6
4. x = 6

Teacher support: The teacher reads the equation aloud, provides the equation in enlarged print, and uses tactile zones to represent the left and right sides of the equality. The student is guided through each step verbally.

Assessment criterion: The student solves the equation step by step, applies the inverse operation correctly, and checks the result.

Task 5. Geometry: Properties of Figures

Adapted Task for Student B with Visual Impairment

Topic: Geometric figures and their properties.

Grade: 6.

Learning objective: The student recognizes geometric figures and names their basic properties.

Adaptation focus: Enlarged figures, tactile models, oral description, guided exploration.

Adapted materials: Enlarged drawings of rectangle, square, and triangle; tactile models or cardboard figures; oral description card.

Teacher's oral description example:

A rectangle has four sides.

Opposite sides are equal.

All angles are right angles.

A square has four equal sides.

All angles are right angles.

A triangle has three sides and three angles.

Student task: Complete the table.

Figure	Number of sides	One property
Rectangle		
Square		
Triangle		

Practical task: The student touches or examines the tactile model and identifies the number of sides. Then the student states one property of the figure orally or in written form.

Teacher support: The teacher guides the student's exploration of the figure by asking questions: "How many sides can you identify?", "Are the sides equal?", "What can you say about the angles?" The teacher avoids giving the answer directly and instead supports the student in identifying the property.

Assessment criterion: The student correctly identifies the figure, names the number of sides, and states one appropriate property.

Task 6. Coordinate Representation

Adapted Task for Student B with Visual Impairment

Topic: Coordinate plane and coordinates of points.

Grade: 6.

Learning objective: The student identifies the first and second coordinates of a point and locates simple points on a coordinate grid.

Adaptation focus: Enlarged coordinate grid, tactile coordinate grid, oral orientation, step-by-step location of points.

Adapted materials: Enlarged coordinate grid, tactile grid or raised-line grid, point markers, oral instruction card.

Instruction card:

A point on the coordinate plane is written as **(x, y)**.

The first coordinate is **x**.

The second coordinate is **y**.

To locate a point, first move along the x-axis, then move along the y-axis.

Student task 1: Point A has coordinates **(2, 3)**. Answer the questions:

1. What is the first coordinate?
2. What is the second coordinate?
3. Which coordinate shows movement along the x-axis?
4. Which coordinate shows movement along the y-axis?

Expected answers:

1. The first coordinate is 2.
2. The second coordinate is 3.
3. The first coordinate shows movement along the x-axis.
4. The second coordinate shows movement along the y-axis.

Student task 2:

Locate the following points on an enlarged or tactile coordinate grid: A (2, 3); B (4, 2); C (1, 5).

Teacher support: The teacher gives oral orientation and guides the student step by step: first locate the x-coordinate, then locate the y-coordinate. If a tactile grid is used, the student places a marker on the correct point.

Assessment criterion: The student identifies x- and y-coordinates correctly and locates points on the grid with appropriate support.

Summary of Adapted Tasks Used During the Intervention

Participant	Topic	Adapted task format	Methodological support	Expected outcome
Student A	Divisibility	Visual algorithm and classification table	Written instruction, step-by-step rule application	Applies divisibility rules
Student A	Fractions	Labelled fraction bars and written rule	Visual representation, written comparison rule	Compares simple fractions
Student A	Word problems	Written condition table	Identification of known and unknown values	Selects the correct operation
Student B	Linear equations	Enlarged equation cards and tactile balance idea	Oral step-by-step explanation	Solves simple linear equations
Student B	Geometry	Enlarged or tactile geometric models	Guided description of sides and properties	Recognizes geometric properties
Student B	Coordinates	Enlarged or tactile coordinate grid	Oral orientation and point markers	Identifies and locates coordinates

Notes on the Use of Adapted Tasks

The adapted tasks were used during the formative stage of the experiment after the pre-test and before the post-test. They were selected according to the main barriers identified during the diagnostic stage. For the student with hearing impairment, the main emphasis was placed on written and visual support because oral-only explanation

may create difficulties in understanding task conditions and mathematical terminology. For the student with visual impairment, the main emphasis was placed on enlarged, tactile, oral, and practical support because symbolic notation, diagrams, and spatial representations may be difficult to access visually.

The same mathematical objectives were preserved for both students. The adaptations were used to support access to mathematical content, not to simplify the task. The teacher provided support through explanation, modelling, guided practice, and accessible materials, while the student was encouraged to complete the task independently whenever possible.

Appendix E. Sample Inclusive Short-Term Lesson Plan

Subject: Mathematics

Grade: 5

Lesson topic: Divisibility by 2, 5, 10, 3, and 9

Lesson duration: 40 minutes

Type of lesson: Introduction and practice lesson

Target class: General education classroom including students with visual and hearing impairments

Learning Objectives

By the end of the lesson, students will be able to:

1. identify whether a natural number is divisible by 2, 5, 10, 3, or 9;
2. apply divisibility rules to given numbers;
3. classify numbers according to divisibility rules;
4. explain the rule used in an oral, written, visual, or tactile form.

Inclusive Aim of the Lesson

The lesson aims to teach divisibility rules without simplifying the mathematical content. Students with visual impairments are supported through enlarged materials, oral explanation, tactile number cards, and step-by-step guidance. Students with hearing impairments are supported through written instructions, visual algorithms, classification tables, and labelled examples.

Assessment Criteria

Criterion	Descriptor
Applies divisibility rules	Determines whether a number is divisible by 2, 5, 10, 3, or 9.
Explains the rule	Shows or explains the rule in an accessible form.
Classifies numbers	Places numbers into correct divisibility groups.
Demonstrates understanding	Gives an answer orally, in writing, visually, or through tactile materials.

Key Terms: Divisible, divisibility rule, natural number, digit, sum of digits, even number, final digit, multiple.

Materials

For the whole class: number cards, divisibility rule table, classification chart, worksheet.

For students with visual impairments: enlarged number cards, enlarged worksheet, tactile number cards if available, oral explanation, additional time.

For students with hearing impairments: written instructions, visual algorithm, labelled examples, classification table, written rule cards.

Lesson Procedure

Stage and time	Teacher's activity	Students' activity	Inclusive adaptation	Assessment
Beginning 5 min	Introduces the topic and learning objectives. Gives simple examples of divisibility.	Listen, observe, read the objective, answer questions.	Hearing impairment: objective is written on the board. Visual impairment: objective and examples are read aloud.	Oral or written responses.
Explanation 10 min	Explains divisibility rules by 2, 5, 10, 3, and 9 step by step.	Follow the explanation and complete examples.	Hearing impairment: written algorithm and visual examples. Visual impairment: oral explanation and enlarged/tactile number cards.	Checking questions.
Guided practice 10 min	Gives numbers and asks students to identify which rule applies. Example: 648 is divisible by 9 because 6 + 4 + 8 = 18.	Apply the rules with teacher support.	Hearing impairment: written steps. Visual impairment: numbers are read aloud and explained step by step.	Correct rule application.

Pair/group activity 7 min	Gives number cards and asks students to classify them.	Sort numbers into correct groups.	Hearing impairment: classification table. Visual impairment: enlarged/tactile cards and oral support.	Observation of participation and accuracy.
Independent task 5 min	Gives 3–4 short tasks.	Complete tasks independently or with minimal support.	Students may answer orally, in writing, visually, or through tactile materials.	Individual task checking.
Reflection 3 min	Asks what rule was easy or difficult. Summarizes the lesson.	Reflect on learning.	Hearing impairment: written reflection. Visual impairment: oral response.	Reflection answers.

Differentiation

Students who need support receive one rule at a time, smaller numbers, step-by-step prompts, and peer support. Students who complete tasks quickly identify numbers divisible by more than one rule and explain why a number is not divisible by a given number.

Homework

Write three numbers divisible by 2. Write three numbers divisible by 5. Determine whether 378 is divisible by 9. Show the rule used. Write one number divisible by both 5 and 10.

For students with visual impairments, homework may be provided in enlarged print or explained orally. For students with hearing impairments, homework instructions should be written clearly and supported by one example.

Teacher Reflection

Reflection question	Teacher's note
Did students achieve the learning objective?	
Which rule was easiest for students?	
Which rule caused difficulty?	
Were the adapted materials effective?	

What should be improved in the next lesson?