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An educational mobile application for children with hearing impairment

Gulnaz Salgarayeva[1], Aigul Makhanova[2*], Fariza Lakhanova[3]

[1,2,3]*Kazakh National Women's Teacher Training University, Almaty, Kazakhstan.*

Corresponding author: Aigul Makhanova (*Email: makhanova.a@qyzpu.edu.kz*)

Abstract

The purpose of this study is to assess the effectiveness of an educational mobile application in improving algorithmic thinking and academic performance among children with hearing impairments. The research was conducted in two stages: (1) the development of the application using an inclusive design approach with game-based learning elements, and (2) an experimental implementation in the educational process. The participants were 15 sixth-grade students from a specialized school for children with hearing impairments, divided into an experimental group (n = 7) and a control group (n = 8). The experimental group used the mobile application as a supplementary tool for programming lessons, while the control group was taught using traditional methods. Pre-test and post-test assessments were conducted to evaluate changes in algorithmic thinking and academic outcomes. The results demonstrated that students in the experimental group showed significant improvement in algorithmic thinking and academic performance compared with those in the control group. The use of the mobile application increased student engagement and facilitated more effective learning. The study concludes that the developed mobile application is an effective educational tool for enhancing algorithmic thinking and improving academic outcomes among students with hearing impairments. This research highlights the potential of accessible digital technologies in supporting inclusive education. The findings can guide educators, developers, and policymakers in integrating inclusive digital resources into curricula to promote equal learning opportunities for students with special educational needs.

Keywords: Algorithmic thinking, Children with hearing impairments, Educational mobile application, Educational tool, Game-based learning.

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1. Introduction

Based on estimates from the World Health Organization (WHO), over 5% of the global population (approximately 430 million individuals, including 34 million children) experience some degree of hearing loss. By 2050, this figure is projected to rise to nearly 30% of the population, affecting individuals at varying levels of severity. The increasing prevalence of hearing impairments necessitates further research and the development of solutions to support individuals with hearing impairments around the world [1].

According to data from the Bureau of National statistics, there are 18 specialized schools for children with hearing impairments in the Republic of Kazakhstan, providing education to over 2,000 deaf and hard-of-hearing students [2]. The primary challenges faced by children with hearing impairments and deafness involve communication in daily life, establishing contact in emergency situations, and ensuring their safety [3]. Based on the research by Hashim, et al. [4] mobile applications provide new educational opportunities for children with hearing impairments, enhance their communication skills, and foster inclusion within the educational environment.

Mobile devices, such as smartphones and tablets, enable the creation of a personalized educational environment, which is particularly important for children with hearing impairments who face challenges in perceiving information through traditional teaching methods. These applications provide visual explanations and textual content, facilitating better comprehension of the material and enhancing communication skills in children with hearing impairments [5].

The mobile technology also contributes to fostering independent learning and social adaptation for children with hearing impairments. Mobile applications enable them to develop verbal skills through visual and audiovisual materials while facilitating communication with peers through interactive game [6]. Nevertheless, despite the potential of mobile applications in inclusive education, several challenges remain, including the need for personalized learning, limited availability of adapted applications in different languages, and cultural differences in technology use [7]. These issues require a careful approach to the development and implementation of mobile applications for hearing impaired children used in the educational process.

In special schools for deaf or hard of hearing children, hearing impaired students are not able to acquire the appropriate skills and knowledge at the required level, as well as to understand with peers studying in general schools [8]. This problem is caused by various circumstances. Firstly, there are few Sign Language interpreters who work in special schools, and there is a shortage of specialists in higher educational institutions that train them. Secondly, many families, due to financial costs and time requirements, cannot afford to hire a special teacher to teach their deaf child sign language [9]. According to research AlShammari, et al. [10] when the parents of a deaf child are also deaf, it is much easier for them to learn sign language, in other cases, the family needs to provide a special teacher to learn sign language or enroll the child in paid classes, and this may not be convenient for the family in terms of location, time and cost. In addition, if deaf children do not master sign language at an early age, they have difficulties in the formation of reading skills, education, communication and interaction with society [11]. As highlighted in the research by Cabanillas-Carbonell, et al. [12] the implementation of various pedagogical approaches and assistive technologies is essential for students with hearing impairments or deafness, as it facilitates equitable access to knowledge and skill acquisition comparable to that of their hearing peers. According to the research by Katsaris and Vidakis [13] determining an appropriate teaching method, particularly in the development of applications for students with hearing impairments, requires careful consideration of the vocabulary used in the learning process, as well as an assessment of the students' suitability for the chosen instructional approach.

Therefore, the integration of mobile applications for children with hearing impairments represents a significant advancement in inclusive education.

The aim of this study is to develop and evaluate a mobile application tailored to the educational and social needs of children with hearing impairments, ensuring that it supports effective learning, communication, and inclusion within the educational environment.

Guided by the aim of this study, the following research questions (RQs) were formulated:

RQ1: Does the use of an educational mobile application positively influence the development of algorithmic thinking in children with hearing impairments?

RQ2: How does the use of the mobile application affect the academic performance of children with hearing impairments compared to traditional instructional methods?

Addressing these questions will enable the determination of the pedagogical significance of integrating digital tools into the educational process of learners with special educational needs. Furthermore, the results will help evaluate the specific contribution of the developed application to enhancing the quality of knowledge acquisition. The findings may also serve as a foundation for further adaptation of digital educational content, taking into account the cognitive and communicative characteristics of children with hearing impairments.

2. Literature Review

2.1. The Role of Mobile Applications in Inclusive Education

One of the most promising approaches to supporting children with hearing impairments is the use of mobile applications that facilitate access to educational content, enhance communication skills, promote social integration, and strengthen digital literacy. In recent years, mobile technologies have emerged as a powerful educational tool and have been actively implemented to address the specific needs of children with hearing impairments.

Mobile devices provide numerous advantages in the educational process, particularly in terms of accessibility and personalized learning opportunities. Applications designed for children with hearing impairments are developed with consideration of their unique ways of perceiving information and communicating. These applications often incorporate elements such as sign language, visual cues, and textual descriptions, enabling children with hearing impairments to engage with educational content more effectively and comfortably.

Mobile applications enable the adaptation of the learning process to the individual needs of each student. This is particularly crucial for children with hearing impairments, who may encounter difficulties in perceiving information through traditional methods, such as auditory or audiovisual sources. For instance, a mobile application designed for teaching programming can incorporate adapted features, including video lessons with subtitles and sign language translation, visualizations, customizable text, and vibration feedback. Additionally, mobile applications support the development of programming skills in children with hearing impairments by integrating interactive tasks and exercises that utilize game-based elements, visual coding blocks, and social components such as competitions [14]. This facilitates the integration of children with hearing impairments into the school environment and strengthens social connections by engaging them in problem-solving activities and competitions with their peers.

In a recent study, Khasawneh [15] explored the role of educational robots in developing programming skills among elementary school students with hearing impairments, as well as the challenges teachers encounter in their implementation. The findings indicate that instructional applications contribute to the development of programming skills in students; however, their effective use requires teachers to have adequate training and experience.

2.2. Existing Applications for Children with Hearing Impairments

Currently, various domestic applications, platforms, and dictionaries have been developed to support inclusive education for children with hearing impairments. One such platform «AI-YM», serves as a valuable tool for promoting the Kazakh sign language, making it accessible not only to individuals with hearing impairments but also to hearing individuals interested in learning sign language. This platform contributes to strengthening intercultural connections and enhancing communication within society [16].

At the initiative of the National Scientific and Practical Center for the Development of Special and Inclusive Education, the «e-Ymdau» video dictionary of sign language has been developed. The name «e-Ymdau» literally translates to «electronic sign language». This video dictionary was created to standardize the use of sign language in Kazakhstan, with active contributions from experienced sign language specialists and translators who have extensive practical experience working with children and adults with hearing impairments. The key features of the video dictionary include convenience, efficiency, mobility, and accessibility. Additionally, methodological guidelines for integrating «e-Ymdau» into the educational process of special schools have been developed and are widely implemented [17].

Kazakh researchers, including Amangeldy, et al. [18] have developed an intelligent system for recognizing Kazakh sign language. The creation of an intelligent sign language learning simulator for Kazakh and other languages is a crucial initiative within the Kazakh Society of the Deaf, significantly benefiting children with hearing impairments. Such a system serves as an effective communication tool, enabling children to acquire sign language proficiency and develop essential interaction skills with the world around them.

A comparative analysis of widely used foreign mobile applications designed for individuals with hearing impairments allows us to identify several key applications, which are outlined below.

Yandex.Talk is a mobile application for hearing impaired children that allows you to turn written text into oral text into writing and vice versa [19].

Deaftawk – a collection of modern and simple digital tools that provide sign language interpreter services in different languages [20].

Spread Signs - this is the most extensive sign language dictionary in the world. Contains more than 200,000 signs necessary for communication in different languages: English, German, Russian, Spanish, Swedish, Turkish, Ukrainian, etc. [21].

Sign Language ASL Pocket Sign - mobile application for people with hearing impairments. Contains tasks and tests, games that allow you to learn the sign language in a fun way [22].

Hand Talk Translator - hearing impaired people translator. This mobile application enables individuals with hearing impairments to communicate effectively with others. By utilizing pre-designed templates, users can easily express their requests through synthesized speech, facilitating smoother interaction in various social settings [23].

An analysis of mobile applications specifically designed for children with hearing impairments, reveals that most of these applications focus on sign language learning. Unlike tutor services, such applications provide quick access to information, making them more effective for activities such as playing games, drawing, seeking information in real time, or serving as a response tool for students in the classroom [10]. However, among the reviewed applications, only one [22] integrates game-based elements to offer programming-related tasks. Given the limited availability of educational mobile applications tailored to teaching programming to children with hearing impairments, this study aims to address this gap by developing an application that enhances programming learning through interactive and engaging methods.

2.3. Technological Aspects of Mobile Application Development

The development of an educational mobile application aimed at making programming education accessible to children with hearing impairments requires a well-structured and thoughtful approach. A key aspect of this process is ensuring accessibility and inclusivity. The application should feature an intuitive interface enriched with visual elements, allowing for seamless interaction. Additionally, visual cues and controls must be easily recognizable to accommodate the specific needs of children with hearing impairments, enhancing their learning experience [24].

The integration of media elements, particularly videos, animations, and graphics, can significantly enhance the comprehension of information for young children with hearing impairments. Visual and textual components play a crucial role in ensuring that educational content is clear, accessible, and engaging, thereby facilitating better knowledge retention and understanding [25]. Applications that support sign language enable users to access interactive video lessons, in which a teacher or virtual character demonstrates gestures. This approach significantly simplifies the learning process by providing clear visual representations, enhancing comprehension, and improving retention of sign language skills [26].

For many children with hearing impairments, subtitles and textual descriptions are essential, as they enable the comprehension of information through written text, facilitating better understanding and learning [27]. Interactive games and exercises enhance the effectiveness of learning by making the educational process more engaging and dynamic. These games are designed to develop students' memory, attention, language skills, and cognitive abilities, fostering a more interactive and immersive learning experience [28].

2.4. Challenges in the Development of Mobile Applications

Despite numerous advantages, the development of mobile applications for children with hearing impairments presents certain challenges. While various applications have been designed for this demographic, the majority primarily support English and Russian sign languages. Consequently, there is a limited number of applications available for children who communicate in other languages or utilize different sign language systems [29].

Mobile applications cannot fully substitute face-to-face communication or traditional teaching methods. It is essential to recognize that mobile technologies serve primarily as a supplementary tool to fundamental educational approaches [30]. To effectively support learners with hearing impairments, applications must be highly personalized, addressing diverse individual needs. Developers should consider various factors, including the degree of hearing loss, the learner's age, and specific educational requirements [31].

Mobile applications play a significant role in inclusive education for children with hearing impairments, offering new opportunities for learning and communication. The use of educational mobile applications facilitates the integration of these children into the educational process, enhances their communication skills, and supports their social adaptation. However, the development of such applications necessitates careful consideration of multiple factors, including accessibility, personalization, and cultural diversity. In the future, the advancement of mobile technologies and their integration into educational practices will continue to be a key factor in the education and social adaptation of children with hearing impairments.

3. Research Methodology

The objective of this study is to develop mobile applications designed to teach programming to children with hearing impairments and to assess their effectiveness, technological features, and educational benefits. To achieve this goal, an experimental research methodology has been employed. The study is grounded in the principles of pedagogical inclusion, which aim to ensure equal learning opportunities for all children within the educational environment.

The research was conducted in two main stages:

1. Development of an educational mobile application designed to teach programming to children with hearing impairments.

2. Experimental evaluation to assess the effectiveness of the developed mobile application in the learning process, focusing on its technological features and educational benefits.

Among the key aspects are the personalization of the educational process, the utilization of accessible technologies, and the adaptation of educational materials, considering the specific ways in which children with hearing impairments perceive information.

3.1. Development of an Educational Mobile Application

The Agile methodology was employed in the development of a mobile educational application for students with hearing impairments. The development process following the Agile approach included the following stages: Analysis, Design, Implementation, and Testing.

3.1.1. Analysis

A survey was conducted to determine the layout, structure, and content of the educational mobile application. Participants included 15 sixth-grade students from a Special (Correctional) Boarding School for children with hearing impairments, along with their parents (15 participants) and teachers (2 participants) involved in the instructional process.

The primary objective of the Analysis stage is to facilitate students' access to programming through game-based elements within a mobile application. The responses collected from the survey were analyzed, and key user requirements were identified for the prototype and functionality of the mobile application. These requirements include:

- Ease of interface – ensuring intuitive navigation and accessibility.
- Level of use – adapting the application to the users' skills and experience.
- Compliance with task complexity – aligning tasks with students' cognitive and educational levels.
- Content of interactive messages – optimizing instructional and feedback messages for clarity and effectiveness.
- Feedback mechanisms – enabling interactive and responsive communication within the application.

3.1.2. Design

This stage involves designing the interface layouts of the future mobile application and providing a detailed description of the software requirements. The development process utilized "ActivePresenter" software, which enables the creation of adaptive and interactive projects tailored to the needs of children with hearing impairments.

The external design of the mobile application is developed to ensure ease of use for students, teachers, and parents. Particular emphasis is placed on facilitating student interaction with the application, regardless of whether the student has a hearing impairment or not. The primary goal is to make programming education accessible to all learners while fostering collaboration and inclusive learning experiences for all students.

3.1.3. Implementation

During the Implementation stage of the mobile application, interactive prototypes were developed. At this stage, program codes for buttons and basic interface elements were implemented to provide an initial demonstration of the application's functionality and user interaction. his phase aimed to ensure the proper operation of key features before finalizing the complete application.

The mobile application covers programming topics aligned with the 6th-grade computer science curriculum (see Figure 1). Upon selecting a topic, a video tutorial with subtitles relevant to the section is displayed (see Figure 2). Each topic includes three interactive exercises incorporating game-based elements (see Figures 3-5). These exercises involve constructing programs by arranging blocks, compiling algorithms, writing code, and completing game-based tasks. The system provides immediate feedback on solution accuracy through rapid animations and color changes.

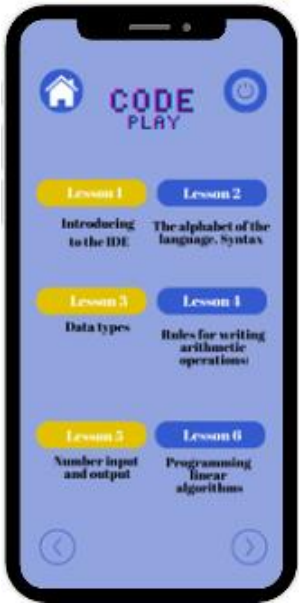

Figure 1.
Programming topics.

Figure 2.
Video tutorial with subtitles.

Figure 3.
Interactive exercises 1.

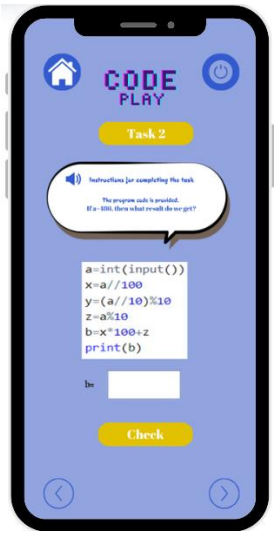

Figure 4.
Interactive exercises 2.

Figure 5.
Interactive exercises 3.

3.1.4. Testing

At this stage, the final product underwent comprehensive testing to ensure compliance with the established requirements. During the testing phase, users - including students with hearing impairments and teachers evaluated various aspects of the developed mobile application. These aspects included the structure of the sections, the clarity and relevance of the presented information, the interactivity of exercises, the functionality of assessment elements, ease of use, effectiveness in the educational process, and overall performance. The evaluation criteria for the mobile application were as follows: Excellent (5), Good (4), Satisfactory (3), and Unsatisfactory (2). The results of the evaluation are presented in Figure 6.

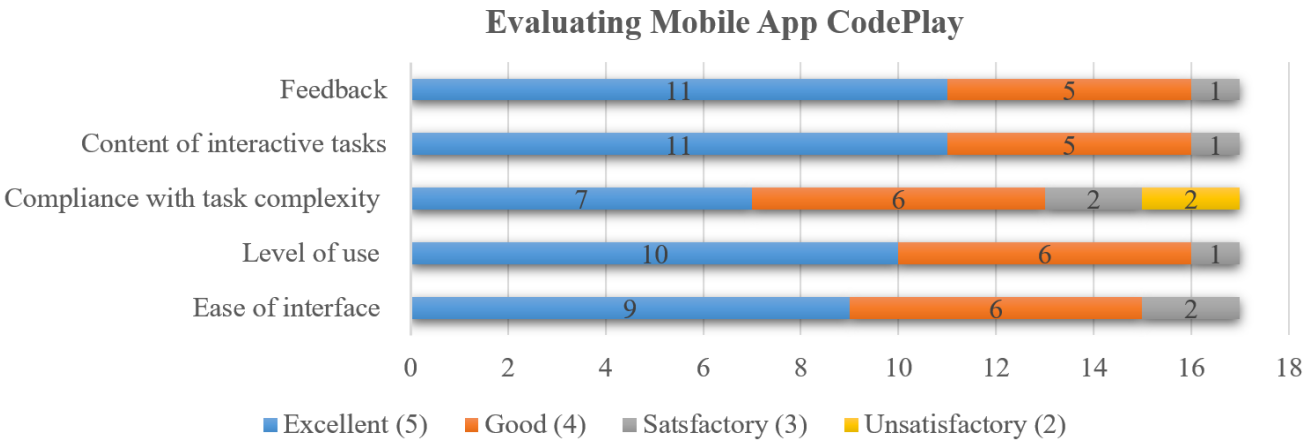

Figure 6.
Results of evaluating Mobile App.

3.2. Experiment

The objective of this stage was to evaluate the impact of the educational mobile application on the academic performance of students with hearing impairments. To achieve this, a sample of 15 deaf children (8 boys and 7 girls) aged 12–13 years from a Special (Correctional) Boarding School for children with hearing impairments was selected. Within the chosen sample, the average degree of hearing impairment was consistent across all participants.

Pretest and posttest assessments were administered to all students participating in the experiment to evaluate the impact of the educational mobile application on their academic performance. The students were divided into two groups: an experimental group (7 students) and a control group (8 students). The experimental group utilized the educational mobile application as a supplementary tool alongside their core learning materials, while the control group was taught the same content using a traditional face-to-face instructional approach. Following the experiment, a posttest was conducted for both groups to measure learning outcomes.

Informed consent was obtained from the parents of the children in the experimental group prior to their participation in the study. Subject teachers were introduced to the educational mobile application and provided with a demonstration of its functionality. The teacher guided students through the assigned tasks, offering explanations as needed. The educational mobile application was installed onto students' personal smartphones and tablets. Under the instructor's supervision, an initial one-week orientation was conducted to familiarize students with its use. During this period, the teacher assisted students in navigating the application, including accessing topics, engaging with video lessons, and completing interactive exercises.

The procedure of the study is illustrated in Figure 7.

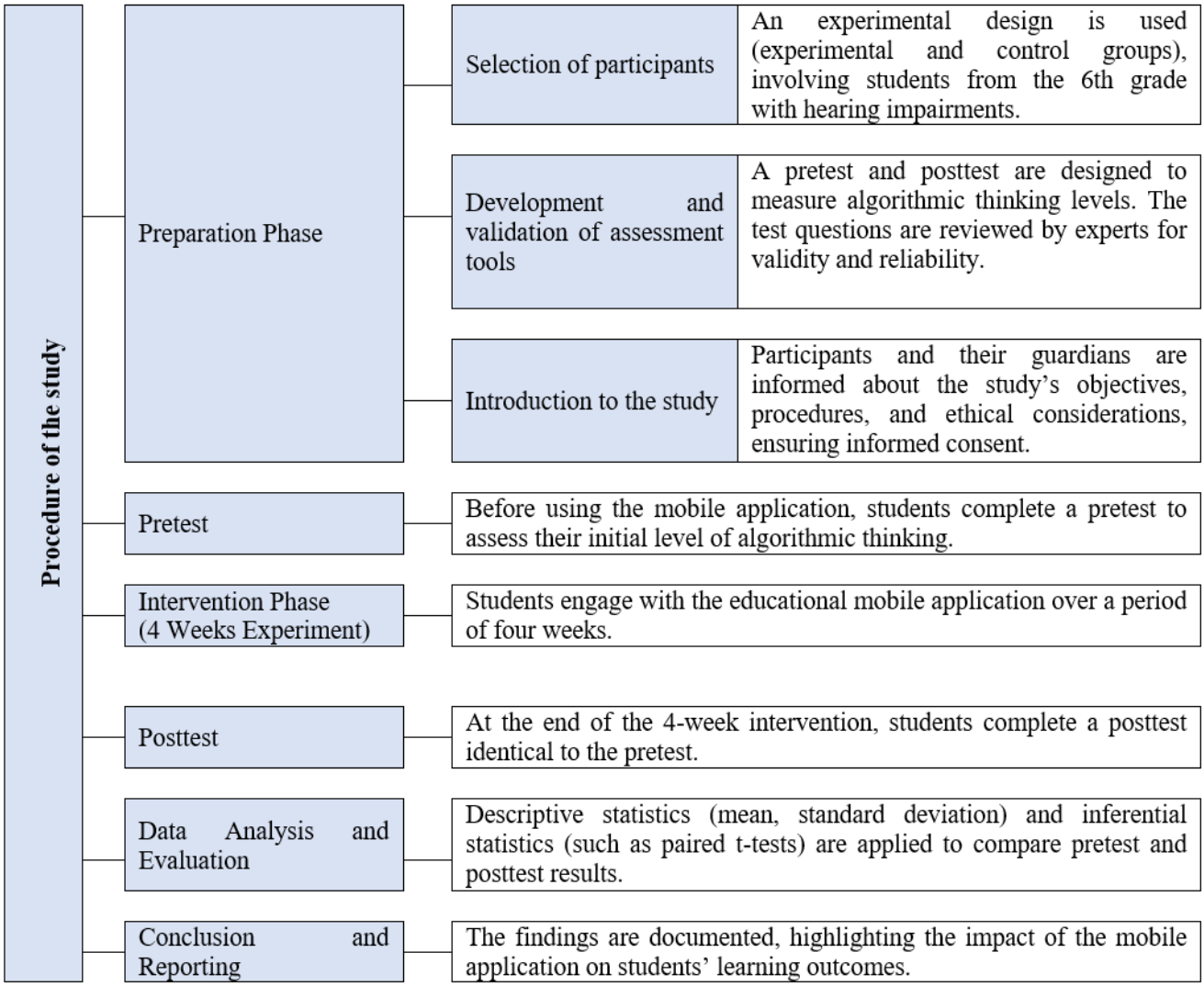

Figure 7.
Procedure of the study.

4. Results

The results obtained before the experiment are presented in Table 1, demonstrating that the predetermined knowledge indicators of both the experimental and control groups were closely aligned.

According to the post-experiment results presented in Table 2, students in the experimental group achieved significantly higher performance levels when using the educational mobile application as part of the learning process, compared to their peers in the control group.

A comparison of the average number of correct answers between the control and experimental groups across the two phases of the study (Pretest and Posttest) indicates a significant improvement in the experimental group, increasing from 3.14 to 5.29 correct answers. The control group also demonstrated a slight improvement, with scores increasing from 3.25 to 3.5 correct answers; however, this progress was less pronounced compared to the experimental group. These findings confirm the effectiveness of the educational mobile application incorporating game-based elements in enhancing student learning outcomes.

Table 1.
Mean difference in experimental and control groups pre-test.

Group	N	Mean	Standard Deviation
Control Group	8	3.2500	0.89974
Experimental Group	7	3.1429	0.88641

Table 2.
Mean difference in experimental and control groups post-test.

Group	N	Mean	Standard Deviation
Control Group	8	3.5000	0.53452
Experimental Group	7	5.2857	0.75593

Table 3.
Independent t-test of post-test.

	Statistic	df	p-value	Mean Difference	Standard Error Difference	Cohen's d Effect Size
Student's t	5.3394	13.000	0.00013431	1.7857	0.33444	2.7634

The results for the Independent t-test of the post-test are presented in Table 3. Since the p-value is less than 0.05, the difference in improvement between the experimental and control groups is statistically significant. This confirms that the use of a mobile application incorporating game-based elements has a meaningful impact on the development of algorithmic thinking in children with hearing impairments.

Additionally, the calculation of Cohen's d yielded a value of 2.76, indicating a strong effect size. This result suggests that the use of the mobile application has a substantial influence on the enhancement of algorithmic thinking skills in children.

Table 4 illustrates that the performance of students in the experimental group increased by approximately 30.7%, as they actively engaged in game-based learning compared to those following the traditional instructional approach.

Table 4.
Performance of students in the experimental group.

Group	Pretest	Posttest
Experimental Group	44.8%	75.5%

5. Discussion

Beyond quantitative outcomes, one of the most important implications of integrating mobile applications into inclusive education for children with hearing impairments lies in the enhanced accessibility of educational content. The experimental findings confirm that the integration of the mobile application into the learning process, designed to teach programming and support communication skills, significantly improves algorithmic thinking abilities in students with hearing impairments.

Mobile applications also promote independent learning, enabling students to take greater control of their educational process, thereby fostering autonomy [32]. Additionally, the incorporation of game-based elements has been shown to enhance engagement and motivation, making learning more interactive and enjoyable. This not only increases active participation but also supports the acquisition of communication skills in a playful and immersive manner [33]. Importantly, mobile applications can be tailored to meet a student's developmental level, individual characteristics, and specific needs [34] thus helping to reduce barriers commonly encountered in traditional classroom environments by children with hearing impairments.

In conclusion, the findings of this study demonstrate that mobile applications can play a vital role in enhancing both the educational and social adaptation of children with hearing impairments. Such tools not only contribute to the development of algorithmic thinking but also support broader competencies, including communication skills, independence, and active participation in the learning process. To further improve their effectiveness, however, it is crucial to account for cultural, linguistic, and individual student characteristics, while ensuring ongoing development and adaptation of mobile applications in accordance with evolving educational and technological standards.

6. Conclusion

Educational mobile applications for children with hearing impairments represent a crucial and promising tool in advancing inclusive education, as they significantly expand access to knowledge, support the development of algorithmic and communication skills, and contribute to social integration [35]. The findings of this study confirm that such applications not only facilitate academic achievement but also foster independence and confidence, thereby enhancing the overall quality of life for children with hearing loss.

At the same time, the research has revealed a number of pressing challenges that must be addressed to maximize the pedagogical and technological potential of mobile applications. Among these, the most urgent are the need for more effective personalization of learning content to match the diverse cognitive, linguistic, and social profiles of children, as well as the creation of adaptive mechanisms that account for different sign languages and cultural contexts. Another essential task is to ensure seamless integration of mobile learning tools with traditional teaching strategies, peer interaction, and teacher guidance, since these remain indispensable for the holistic development of communicative and social competencies.

Future directions for research and development include the design of more intuitive user interfaces, the use of intelligent algorithms for adaptive learning, and the incorporation of multimodal resources that combine text, visual, and sign-language-based explanations [36]. Moreover, it is necessary to investigate the long-term impact of mobile applications on academic performance, cognitive growth, and social inclusion, in order to build evidence-based strategies for sustainable implementation in diverse educational settings.

In conclusion, mobile applications demonstrate strong potential to transform inclusive education for children with hearing impairments. By advancing technological design, ensuring cultural and linguistic adaptability, and aligning digital tools with established pedagogical principles, future solutions can substantially enhance educational outcomes, promote socialization, and contribute to the full integration of children with hearing impairments into society.

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