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DIGITAL INCLUSIVE EDUCATION FOR VISUALLY IMPAIRED STUDENTS IN UZBEKISTAN: INTEGRATION OF BRAILLE AND VOICE TECHNOLOGIES IN TEACHING INFORMATICS

Annotation

Developing digital inclusive education for visually impaired students in Uzbekistan is a significant issue. The article analyzes barriers in their education and proposes solutions through the integration of Braille and voice technologies.

Key words: inclusive education, visually impaired students, Braille, voice technologies, informatics education, digital adaptation, educational resources in Uzbek, screen reader programs, Braille displays, innovative educational technologies.

ЦИФРОВОЕ ИНКЛЮЗИВНОЕ ОБРАЗОВАНИЕ ДЛЯ УЧАЩИХСЯ С НАРУШЕНИЯМИ ЗРЕНИЯ В УЗБЕКИСТАНЕ: ИНТЕГРАЦИЯ ШРИФТА БРАЙЛЯ И ГОЛОСОВЫХ ТЕХНОЛОГИЙ В ОБУЧЕНИИ ИНФОРМАТИКЕ

Аннотация

Цифровое инклюзивное образование для учащихся с нарушениями зрения в Узбекистане является важной проблемой. Статья анализирует барьеры в обучении таких учащихся и предлагает решения путем интеграции шрифта Брайля и голосовых технологий.

Ключевые слова: инклюзивное образование, учащиеся с нарушениями зрения, шрифт Брайля, голосовые технологии, обучение информатике, цифровая адаптация, образовательные ресурсы на узбекском языке, программы экранного чтения, дисплеи Брайля, инновационные образовательные технологии.

O‘ZBEKISTONDA KO‘RISH QOBILIYATI CHEKLANGAN O‘QUVCHILAR UCHUN RAQAMLI INKLYUZIV TA’LIM: INFORMATIKA FANINI O‘RGATISHDA BRAYL VA OVOZLI TEXNOLOGIYALARNING INTEGRATSIYASI

Annotatsiya

O‘zbekistonda ko‘rish qobiliyati cheklangan o‘quvchilar uchun informatika fanini o‘qitishda raqamli inklyuziv ta’limni rivojlantirish muhim muammo hisoblanadi. Maqola ushbu o‘quvchilarning ta’limdagi to‘siqlarini tahlil qilib, Brayl yozuvi va ovozli texnologiyalarni integratsiya qilish orqali yechimlar taklif etadi.

Kalit so‘zlari: inklyuziv ta’lim, ko‘rish qobiliyati cheklangan o‘quvchilar, brayl yozuvi, ovozli texnologiyalar, informatika ta’limi, raqamli moslashtirish, o‘zbek tilida ta’lim resurslari, ekran o‘quvchi dasturlar, brayl displeylari, innovatsion ta’lim texnologiyalari.

Introduction. Uzbekistan’s “Raqamli O‘zbekiston – 2030” strategy prioritizes digital literacy, highlighting the need for inclusive education systems for visually impaired students [14]. By 2025, there will be more than 36 million people living in Uzbekistan, and 2.7% of them - or 1.03 million people - will have a disability, including visual impairments [3]. Despite 26.74 million internet users (75% of the population) in 2023 [10], visually impaired students face barriers due to limited accessible infrastructure and trained educators. In order to enable fair access, assistive technologies such as refreshable Braille displays and audio tools (such as text-to-speech software and NVDA screen readers) are necessary for informatics, which is essential for promoting computational thinking.Globally, 85% of visually impaired students using such tools demonstrate improved performance in STEM subjects. In Uzbekistan, 205 digital technology training centers trained 144,000 learners in 2022, yet only 3% of programs targeted visually impaired students [5]. This study examines the integration of Braille and audio technologies in informatics education, predicting that with sustained investment, 40% of visually impaired students could access inclusive education by 2030 [2].

Literature Review. The integration of assistive technologies, such as Braille displays and audio systems, has transformed inclusive education globally, though their application in Uzbekistan’s informatics curriculum remains limited. A systematic review of 71 studies from 2013 to 2023 shows that multimodal interfaces combining tactile and audio feedback enhance student engagement by 68% [12]. Specifically, 85% of visually impaired students using tools like NVDA or refreshable Braille displays achieve better outcomes in computational subjects [6]. However, only 12% of these studies address low- and middle-income countries, indicating a research gap for Uzbekistan [7]. In Uzbekistan, the “Raqamli O‘zbekiston – 2030” initiative trained 144,000 learners in 2022, but only 3% of programs incorporated assistive technologies for visually impaired students [5]. Key challenges include the high cost of Braille displays ($2,000–$3,000) [11], limited digital infrastructure (only 15% of schools have accessible tools) [8], and inadequate teacher training, with 79% of educators in low-resource settings lacking relevant skills [15]. Research by Horna-Saldaña and Canaleta (2024) demonstrates that 3D-printed Braille tools improve comprehension by 62% [1], while audio-haptic pedagogies enhance understanding in 73% of cases [6].

Predictive models suggest that with targeted investments, 45% of Uzbekistan's schools could adopt assistive technologies by 2030, potentially benefiting 50,000 visually impaired students [10].

Research Methodology. This study adopts a mixed-methods design, combining quantitative measures (academic performance, technology usage) and qualitative insights (user experiences, pedagogical challenges) to evaluate the efficacy of Braille and audio technologies in informatics education. 150 visually impaired adolescents (ages 12 to 18) from 10 schools in Toshkent, Samarqand, and Buxoro were chosen by stratified random sampling with a 95% 2.confidence level, 5% margin of error, and Cochran's formula as part of a quasi-experimental pre- and post-test design [8]. Additionally, 30 informatics teachers and 20 special education staff were purposively sampled to provide implementation insights [8]. Data were collected through:

Quantitative: 5-point Likert-scale usability surveys, device usage records (frequency, duration, and error rates), and standardized informatics tests modified for accessibility (Cronbach's alpha > 0.80).

Qualitative: Semi-structured interviews with 15 students, 10 teachers, and 5 staff; three focus groups (6–8 participants each); and non-participant observations in 10 classes.

A 12-week intervention piloted a curriculum integrating Braille displays and audio tools (e.g., NVDA), with teachers receiving 20 hours of training aligned with UNESCO's inclusive education guidelines. Descriptive statistics, paired t-tests, ANOVA, logistic regression (goal AUC ≥ 0.75), and NVivo thematic analysis were used in the data analysis [9]. The Uzbekistan Pedagogical Sciences Research Institute's ethical approval guaranteed data confidentiality and informed consent (in Braille or audio forms). The short intervention length and the urban-centric sample are limitations; longitudinal rural studies are planned.

Results and Analysis. Quantitative Results: The informatics test scores before and after the intervention improved significantly, with the average score before the intervention being 62.4 (SD = 12.3) and the average score after the intervention being 78.6 (SD = 10.8; t(149) = 14.72, p < 0.001, Cohen's d = 1.39 [9]. Between Toshkent, Samarqand, and Buxoro, no discernible regional variations were found (F(2, 147) = 1.23, p = 0.297) [9]. Students completed 82% of tasks (SD = 9%) and made 12% of errors (SD = 5%) using audio tools for 32% of tasks and Braille displays for 68% of tasks (SD = 15%). [11]. Technology use and academic success were found to be moderately positively correlated by a Pearson correlation (r = 0.47, p < 0.01) [9]. With Cronbach's alpha values of 0.83 and 0.87, respectively, surveys assessed the usability of audio tools at 3.9 (SD = 0.8) and Braille displays at 4.1 (SD = 0.7), indicating good reliability [9]. With an AUC of 0.79, logistic regression revealed that teacher training hours (β = 0.48, p < 0.05) and previous technology exposure (β = 0.62, p < 0.05) were predictors of effective adoption.

Qualitative Results: Four major themes emerged from the thematic analysis of focus groups, interviews, and observations.

Accessibility: 80% of students reported that Braille displays were "intuitive" after training, even though 30% reported delays in audio tool processing [1, 6].

Pedagogical Adaptation: Multimodal education was successfully implemented in 70% of observed classes, despite 40% of teachers citing a lack of preparation as a barrier [15].

Student Engagement: Compared to 65% (SD = 10%) in traditional settings, the use of assistive technology increased engagement to 88% (SD = 7%) [12].

Implementation Barriers: 60% of teachers reported high device costs, and 20% of rural sessions had connectivity issues [10, 11].

Increased accessibility and involvement were linked to academic advances, according to triangulation [9]. Predictive modeling indicates that by 2028, school adoption may rise by 30% in urban areas while lagging by 15% to 20% in rural areas, where 40% of schools are impacted by connectivity constraints [2, 10].

Table 1: Summary of Quantitative Results

Metric	Pre-Intervention	Post-Intervention	Statistical Significance
Test Score (M ± SD)	62.4 ± 12.3	78.6 ± 10.8	t(149) = 14.72, p < 0.001
Braille Usage (%)	-	68 ± 15	-
Audio Usage (%)	-	32 ± 10	-
Task Completion (%)	-	82 ± 9	-
Error Rate (%)	-	12 ± 5	-

Conclusion and Recommendations. This study demonstrates that for visually impaired students in informatics education, using Braille and audio technology greatly improves student involvement (M = 88%, SD = 7%) and academic performance (t(149) = 14.72, p < 0.001, Cohen's d = 1.39). These results are in line with the "Raqamli O'zbekiston – 2030" plan and worldwide patterns, where the use of assistive technology has increased by 20% a year in poor countries [2]. However, 40% of rural schools lack proper infrastructure, and scalability is limited by high device costs and regional connectivity constraints. The following suggestions are put forth in order to address these issues:

Infrastructure Investment: Using a projected 15% annual budget growth, increase funds to provide assistive technologies to 50% of rural schools by 2030.

Teacher Training: To increase technology use by 10–15%, mandate 40-hour training programs (β = 0.48, p < 0.05).

Cost Subsidies: By introducing subsidies, gadget costs can be lowered by 20% to 30%, which might lead to a 25% increase in urban usage by 2028.

Localized Content: Since only 30% of the available materials are in Uzbek, create audio and Braille resources in that language.

Longitudinal Research: To increase coverage by 20% by 2030, carry out two to three-year studies that include remote schools.

AI Integration: To cut error rates (now 12%, SD = 5%) by 5–10%, test AI-powered screen readers [13].

By 2030, Uzbekistan might meet international standards by increasing inclusive digital education access for visually impaired pupils by 50% through focused interventions.

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