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¹Osh State University, Osh, Kyrgyz Republic

²Department of Mechanical Engineering, East Asia University of Technology, Hanoi, Vietnam

³Department of Research and Development, Hexagon Consulting Hub, Hanoi, Vietnam

⁴Higher School of Sinology, Tashkent State University of Oriental Studies, Tashkent, Uzbekistan

Correspondence to: Nurkasym Arkabaev, ur.arkabaev@gmail.com

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Use of Virtual Reality for Inclusive Education: Assessing the Availability and Adaptation of Educational Materials

Nurkasym Arkabaev¹ , Dinh Van Tran², Van Truong Chu³, Sabohat Hashimova⁴ and Saodat Nasirova⁴

ABSTRACT

The purpose was to identify effective approaches to adapting educational materials for a virtual reality environment, ensuring the accessibility and effectiveness of inclusive learning. The methodology encompassed scientific literature analysis, virtual reality educational experience review, technology comparison, and content analysis of inclusive education materials. The study examined virtual reality technology applications in inclusive education across Uzbekistan and Vietnam, focusing on students with disabilities. The study is conceptual and based on secondary sources, including case studies and existing VR programs. The results focus on the analysis of VR technologies and their potential in inclusive education, with specific emphasis on accessibility, adaptability, and effectiveness based on previous applications in various educational settings. The main results were to determine the effectiveness of using virtual reality headsets (Oculus Rift, Google Cardboard) and software platforms (Google Expeditions, ClassVR) in the context of teaching students with hearing and visual impairments and autism spectrum disorders. Virtual reality technologies have demonstrated the capacity to establish flexible learning environments that enhance the development of social, physical, and cognitive skills in students, so fostering a more inclusive educational experience. Special attention was given to developing criteria for adapting VR materials, such as interface simplicity, availability of audio/visual prompts, and flexible settings to meet individual student needs. These adaptations improve the accessibility of educational content and enhance knowledge assimilation for students with special needs, enabling the creation of personalized learning paths.

Keywords: Inclusive virtual reality, Adaptive VR content, Autism social skills, VR headset accessibility, ClassVR platform

Introduction

Technology is transforming education by creating new opportunities for integrating different groups of students into the overall educational process. Inclusive education, which aims to ensure equal access to quality knowledge for all, regardless of their physical, cognitive or social characteristics, requires innovative solutions. Among such solutions, one of the most promising is the use of virtual reality (VR). Virtual reality is a technology that allows creating fully interactive and simulated learning environments that immerse the user in a unique space of interaction with information.^{1,2} Because of its adaptability, VR can provide a personalised approach to learning, considering the needs of students with visual, hearing, motor, or other developmental disabilities.³⁻⁵ Such technologies

can not only reduce barriers to access to education, but also provide new ways to interact with materials that were previously unavailable to some categories of students.

The incorporation of VR in education fosters a dynamic learning environment, enabling students to both absorb and engage with material actively.⁶⁻⁸ Virtual simulations can simulate real-world situations that are difficult to access under normal conditions.⁹ It is important to develop and adapt training materials in such a way that they not only consider individual characteristics, but also contribute to effective and comfortable learning for everyone. The integration of VR in inclusive education is becoming an important area of research that combines technological development with humanistic educational goals, which focus on holistic personal development, emphasizing autonomy, responsibility, and the realization of each student's unique potential.

Wu et al. investigated the impact of VR on the education of children with disabilities in primary and secondary schools.¹⁰ Their findings showed that VR improved student engagement and fostered the development of cognitive and social skills, while also drawing attention to ongoing technical and pedagogical challenges that must be addressed for broader implementation. Dempsey et al., Cooper et al. concentrated on the creation and assessment of virtual learning environments to facilitate Science, Technology, Engineering, and Mathematics (STEM) education for students with autism.^{11,12} Elash et al., Chițu et al. highlighted the possibility of using VR to teach children with disabilities.^{13,14} It was determined that VR enhances comprehension of the material, facilitates communication, and fosters student autonomy.

Garg and Sharma demonstrated AI's positive impact on inclusive pedagogy for students with special needs.¹⁵ AI has been found to improve learning efficiency through adaptive content customisation and progress monitoring. Asok et al. described best practices for creating inclusive AI curricula for high school students.¹⁶ It was determined that the adaptation of such programmes contributes to equal access to technologies and the development of competencies. Bezerra et al., Zhang developed the ESGarden project, which aims to collaborate between schools and universities to develop inclusive education through technology.^{17,18} The project demonstrates the success of technological solutions to improve the quality of training.

Despite promising results in VR applications for inclusive education, significant gaps remain in the research. One key issue is the limited exploration of long-term outcomes, with most studies focusing on

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short-term improvements in engagement and skills development. There is a lack of fully adaptive VR content for students with varying impairments, such as those with visual, hearing, or cognitive disabilities. Many existing VR tools are not personalized enough to meet the diverse needs of these students, highlighting a need for more inclusive and customizable educational experiences. The integration of VR in educational settings faces several challenges, including high costs, insufficient teacher training, and lack of technical support, which can hinder its widespread adoption, particularly in schools with limited resources. While VR has shown promise in enhancing student focus and comprehension, the specific benefits for different subjects, such as STEM education, remain under-researched. Most studies do not sufficiently investigate how VR can be effectively applied across various academic domains or tailored to address complex learning tasks.

The goal was to develop methods for adapting VR materials to increase accessibility in inclusive education. Objectives of the study:

1. To investigate the capacity of VR in promoting inclusivity within the educational process.
2. To analyse methods of adapting educational materials in VR for students with different educational needs.
3. To evaluate the availability of VR technologies for use in inclusive education.

Materials and Methods

The study used an algorithm for applying VR to inclusive education in Uzbekistan and Vietnam. In addition, several key materials were reviewed, including VR technologies, training platforms, and adapted digital resources, namely VR headsets, Oculus Rift, and Google Cardboard. Software platforms such as Google Arts

& Culture and ClassVR were also considered. These technologies were considered based on such criteria as accessibility, adaptability for students with disabilities, functionality, interactivity, simplicity of interface, quality of visual and audio content, and flexibility of settings.

The literature search was conducted in databases such as Scopus, Web of Science, Google Scholar, ERIC, PubMed, IEEE Xplore, and JSTOR, using keywords including “inclusive education,” “virtual reality in education,” “assistive technology in education,” “accessibility in education,” “special educational needs and VR,” “cognitive disabilities and VR,” “motor impairments and VR in education,” “VR tools for education,” and “technology adaptation for special needs students.” The search period was limited to 2010–2025 to focus on recent advancements in the application of VR in inclusive education.

This study follows the methodology outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), which provides comprehensive guidelines for conducting and reporting scoping reviews. The PRISMA 2020 statement was referenced to ensure adherence to updated standards for systematic reviews and their extensions, emphasizing transparency and reproducibility in the review process.¹⁹ The flowchart below outlines the PRISMA-ScR study selection process, from initial identification through screening, eligibility assessment, and final inclusion. It shows the number of studies at each stage, ensuring only relevant and high-quality research was included in the review (Figure 1).

Screening and data-charting procedures ensure a systematic process. Screening is done independently by multiple reviewers who assess each study against predefined criteria to minimize bias. Disagreements are resolved through consensus, and if needed, a third reviewer is involved. Cohen’s Kappa (κ) is used to measure inter-rater reliability, with a κ value above 0.60 indicating good agreement. Data-charting involves extracting key information from the studies using a standardized form. This is also done independently by reviewers, and discrepancies are resolved through consensus. Critical appraisal is typically not required in scoping reviews, as the focus is on mapping the literature rather than assessing quality. A formal critical appraisal was not performed, as scoping reviews typically focus on mapping the literature rather than assessing the quality of individual studies. If required, tools like the JBI Critical Appraisal Tools or MMAT could be used, depending on the study types. The omission of a formal appraisal is justified to allow for a broader inclusion of studies and a comprehensive overview of the topic.

Publications such as articles, reviews, theses, monographs, and research reports, published in languages including English, Ukrainian, Russian, and other languages with available translations. The literature should directly address the use of VR in education and the adaptation of technologies for inclusive education,

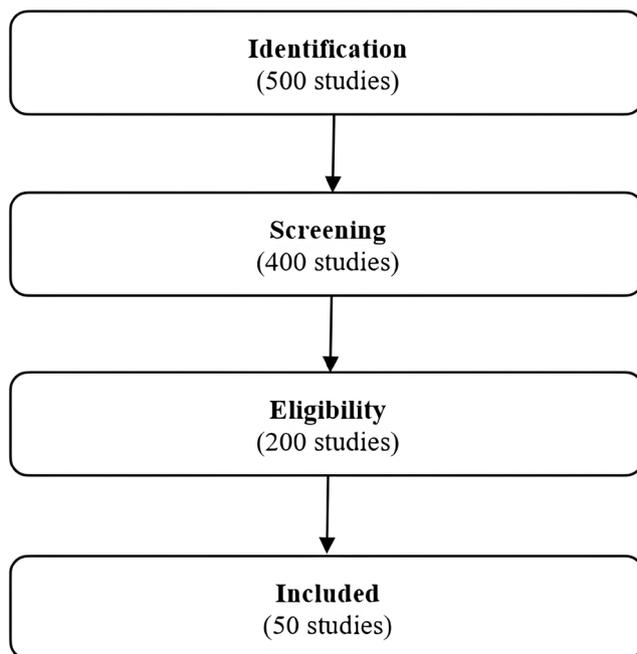


Fig 1 | PRISMA-ScR flowchart: study selection process

with a focus on students with physical, cognitive, or sensory impairments. The publication period is restricted to 2010–2025. Publications that only briefly mention VR without focusing on its application in inclusive education, as well as materials without full-text access or publications lacking clear methodology or scientific approach. Publications in languages that cannot be adequately translated or understood are also excluded.

The quality of cases is assessed by evaluating the methodology of the research, sample selection, control of variables, and peer review. Publications in peer-reviewed journals are considered more reliable, and scientific impact is assessed through citation metrics. The theoretical and practical significance of the publications is evaluated, as well as their innovative approach to the use of VR in education. For synthesizing the results, systematic review methods, content analysis, and comparison of the technologies used are employed. The results of the publications are evaluated based on criteria such as accessibility, interface, adaptability, and functionality of the VR technologies used in the educational process. The theoretical aspects of inclusive education and cognitive psychology are integrated to formulate recommendations for optimizing the use of VR in educational institutions.

This study uses a multi-case approach to evaluate VR technologies in inclusive education, focusing on their adaptability for students with visual, hearing, motor, or cognitive impairments. It combines scientific literature, case studies, and technology evaluations to assess VR's impact and feasibility. The study emphasizes the importance of VR content being adaptable for diverse disabilities and aligned with curricular goals. The content should be customizable in terms of interaction modes, such as audio cues, visual contrast, and haptic feedback, to meet students' varying needs. It also highlights the need for active engagement through intuitive navigation and customizable settings. Given the nature of the study, participant numbers are not explicitly stated, as it is based on case study data from existing programs and platforms rather than direct student participation. Ethical considerations are addressed through the use of secondary data from publicly available studies and platforms. However, ethical approval would be required for any primary data collection, including experiments or surveys involving students or educational institutions. The study uses a comparative analysis framework to evaluate the functionality and accessibility of different VR technologies. It compares key features such as interactivity, content flexibility, and adaptability for diverse learners. The study also integrates a content analysis approach to assess how well VR materials can be adapted to meet the needs of students with disabilities.

The research methods included an analysis of scientific literature, an overview of practical experience in using VR in global educational practice, and a comparison of available technologies. As part of the theoretical approach, a comparative analysis of the functionality of VR headsets and software in terms of accessibility

and adaptability for inclusive education was carried out. In addition, a content analysis of educational materials used in inclusive schools was carried out to determine the possibilities of their integration into the VR environment. The theoretical basis of the research was studies on inclusive education, cognitive psychology, and the adaptation of educational technologies for students with disabilities.

The generalisation method was used, in particular, to develop recommendations for creating VR materials that meet the needs of students. This included defining basic criteria for adapting content, such as simplicity of the interface, availability of audio and visual cues, and flexibility in settings to meet individual student needs.

The authors conducted a small Delphi panel to assess inter-expert agreement on the adaptation criteria for VR in education. The panel consisted of 7 experts from diverse fields, including education, accessibility, and technology. Multiple rounds of evaluation were conducted, where experts independently rated the adaptation criteria and provided feedback. Disagreements were resolved through discussion and consensus, with the final inter-rater reliability assessed using Cohen's Kappa (κ). The resulting κ value of 0.78 indicated good agreement among the experts, ensuring the robustness and reliability of the adaptation framework.

To ensure effective use of VR for vulnerable learners, safety, accessibility, and ethical considerations are key. Cybersickness can be reduced with session limits and breaks, while photosensitivity can be addressed through adjustable settings. For low vision students, features like high contrast and adjustable text are essential. Haptic feedback and alternative input methods (e.g., voice commands, adaptive controllers) make VR more accessible for students with disabilities. Seated/standing modes also support mobility impairments. Data privacy and consent are crucial, particularly for minors. Educators must be trained to use VR responsibly, ensuring content is culturally appropriate and inclusive. By addressing these factors, VR can provide an equitable and safe learning environment.

Results

The Importance of VR for Ensuring an Inclusive Approach in the Educational Process

VR integration enhances education by creating interactive, accessible environments tailored for diverse students, particularly benefiting those with special needs. It adapts educational materials for students with visual, hearing, motor, and cognitive impairments, making learning more inclusive and engaging. VR supports not only children with autism but also a wide range of learners, promoting equal access to education. This approach improves both access and the effectiveness of learning, offering personalized experiences that cater to individual needs and characteristics.¹⁹

Table 1 presents a structured overview of the main methods for adapting educational materials in VR to the needs of different groups of students. It highlights how specific technological functions – ranging from

Table 1 | Methods of adapting educational materials in VR for different groups of students

Student Type	Adaptation Methods	Example of a Technology/Function
Students with visual impairments	Text voice-over, contrasting colours, tactile elements	Visual and audio prompts, text on the screen
Students with hearing impairments	Subtitles, visual cues, sign language	Subtitle system, visualisation of voice commands
Students with impaired motor skills	Gesture or voice control, special devices	Voice commands or touch screens for control
Students with cognitive impairment	Simplification of educational tasks, visualisation of complex concepts	Interactive scenarios for step-by-step learning

Source: Compiled by the authors.

voice control and subtitles to interactive scenarios – can be aligned with particular types of impairments, thereby ensuring that learning remains accessible and effective for all participants.

The case study, based on Petz et al., examined the “AutismXR” VR program for developing social and communication skills in children with ASD.²⁰ The research also explored virtual simulations for motor skills training in children with movement disorders and VR materials with audio prompts for hearing-impaired students. Specific situations were considered in which children with hearing impairments used VR materials with text instructions to assimilate educational material, children with visual impairments worked with simulations that had increased contrast and an adapted interface, and students with ASD trained social skills in virtual environments.^{21–23} The technology is extensively utilised throughout multiple domains, including media and entertainment, healthcare, science, architecture, and education.²⁴ The application of VR in inclusive education is particularly promising, as technology may establish accessible and adaptive learning environments for individuals with diverse physical, cognitive, and emotional requirements.^{25–27}

Inclusive education is a pedagogical strategy designed to guarantee equitable opportunities for all students, regardless of their physical, cognitive, or social disabilities. It ensures that children with special needs have access to the same education as their peers in a regular learning environment, without the need for separate conditions.^{28–30} The main objective of inclusive education is to create conditions that enable children with special needs to participate fully in the general educational process, rather than being separated into specialised groups or schools.³¹ For students with cognitive challenges, personalised programs and tailored methods are designed to facilitate information processing. VR further expands learning opportunities by creating interactive environments where each student can learn comfortably and effectively, based on their unique requirements.^{32,33}

The study by Sungur et al. also showed that VR enables children with hearing and visual impairments to learn material more effectively.³⁴ The use of text prompts, high-contrast visual materials, and audio prompts helps students to better understand educational content, which ensures their greater involvement in the process. Interactive tasks for precision movements or maintaining balance stimulate repetitive activity, which is necessary for strengthening muscles and developing coordination.^{35,36} The paper by Mehta et al. regarding children with autism, the use of VR to train

social skills, demonstrated a significant improvement in students’ ability to interact with other people.³³ Virtual environments allow creating a safe and controlled learning environment in which students can practice various social situations, which reduces stress levels and helps them adapt to real-world conditions.

The VR adaptation system aligns with UDL and WCAG guidelines by focusing on personalization and accessibility across different domains like STEM, language learning, and social-emotional education. In STEM education, VR can integrate haptic feedback and interactive simulations to help students with motor impairments engage with complex scientific concepts by manipulating virtual objects. For language learning, adjustable font sizes and high-contrast visuals improve accessibility for students with low vision, while alternative input methods, such as voice control, support learners with limited mobility. In social-emotional learning, VR creates immersive environments where students with autism can practice social interactions through customizable scenarios with subtitles and audio cues, allowing them to develop skills in a controlled, engaging setting. These adaptations demonstrate the practical impact of VR in providing inclusive learning experiences for students with diverse needs.

For children with motor disabilities, virtual simulations serve as effective tools for practicing movement and coordination.³⁷ Interactive tasks that require precision or balance stimulate repetitive activity, strengthening muscles and supporting rehabilitation in an engaging game-like format. For children with visual impairments, VR simulations with enhanced contrast, adapted interfaces, and detailed 3D objects – such as geometric models with clear edges – make abstract concepts more tangible.³⁸ Customisable settings, including enlarged fonts and colour schemes, address individual needs, significantly simplifying the learning process. Thus, VR offers unique opportunities to tailor the educational process to the specific needs of students, supporting the development of their social, physical, and cognitive abilities in a secure and encouraging setting. This contributes to the successful inclusion of children with diverse needs in modern educational environments.

Adapting Educational Materials in VR to Support Diverse Student Needs

Effective VR adaptation involves creating interactive, adaptive environments tailored to individual student needs. For students with visual impairments, features like increased contrast, larger fonts, or voice narration

ensure accessibility. For those with hearing impairments, text instructions or subtitles aid comprehension. The interactivity of VR content promotes better engagement and material absorption. In Uzbekistan and Vietnam, VR technologies like Google Arts & Culture and ClassVR, along with high-performance headsets like Oculus Rift, are integrated into education. These technologies provide immersive learning experiences, particularly in fields like science and technology. However, the high cost and technical complexity of Oculus Rift may limit its use in resource-constrained regions.³⁹

VR is being integrated into education in countries like Uzbekistan and Vietnam to enhance learning in areas such as vocational training, language acquisition, and inclusive education. In Uzbekistan, VR is used in programs like mechanical engineering and design, improving exam performance and student engagement. The Ministry of Digital Technologies is also expanding digital infrastructure to increase access to VR tools. In Vietnam, while VR adoption is in early stages, initiatives like the SIMPLE project at Can Tho University are training teachers to incorporate VR into environmental education. VR addresses educational challenges by providing immersive experiences, particularly in regions with limited access to resources. It is used in medical training and in creating accessible learning environments for students with disabilities. Uzbekistan and Vietnam’s efforts align with global trends, using VR to overcome educational barriers and improve learning experiences.

To ensure the equity and practicality of VR technologies in education, especially in low- and middle-income countries (LMICs), several factors must be addressed. The high upfront costs of VR devices can be a barrier, so cost-effective solutions such as Pico 4 or Google Cardboard are crucial. Scalable deployment models, like shared devices or centralized hubs, can help reduce the total cost of ownership and maximize access in resource-limited environments. In areas with unreliable internet, ensuring that VR content can be stored locally or preloaded onto devices is essential for

continuous learning, even without constant connectivity. Many VR platforms, including Meta Quest and HTC Vive, support offline content, making them suitable for remote regions.

Given that many schools in LMICs rely on device sharing, it is essential to implement proper sanitation protocols. Using disposable face shields or sanitizing wipes between uses can ensure hygiene while maintaining device accessibility. Organizing schedules for device use and regular cleaning is key to mitigating health risks. Classroom management also plays a crucial role in the integration of VR. Teachers need training not only on how to operate the technology but also on how to incorporate it into their teaching strategies. Accessible teacher training pathways, such as online or hybrid programs, can help educators in LMICs learn to use VR effectively. Peer-to-peer learning networks and train-the-trainer models can further support the scaling of knowledge across schools.

Google Arts & Culture offers interactive learning tours, allowing students to explore historical sites and natural phenomena. Its high-quality visuals, simple interface, and ease of adaptation make it suitable for standard classrooms and students with disabilities. However, its limited customization options may reduce effectiveness for specialized training. ClassVR, known for its flexibility, enables teachers to create personalized curricula, adjust task complexity, and integrate other resources. It also provides modules for students with disabilities, offering a more inclusive learning experience. Google Cardboard is a budget-friendly option with basic features, while Google Expeditions provides virtual tours, and ClassVR offers adaptive solutions for inclusive education. All of these approaches provide significant flexibility in creating inclusive learning environments that consider the students. This is shown in Table 2, which provides comparative characteristics of various VR headsets and software platforms to determine the most effective tool for specific conditions and needs of inclusive learning.

Table 2 | Comparative analysis of the functionality of VR headsets and software

Criteria	Oculus Rift	Google Cardboard	Google Expeditions	ClassVR
Availability	High cost, requires a powerful computer and additional settings	Low cost, compatible with most smartphones	Free platform available for many mobile devices, but requiring VR headsets	Relatively high cost, specially designed hardware and software
Visual content quality	Premium graphics level, high resolution, realistic	Depends on the characteristics of the smartphone, the basic level of visualisation	High-quality 3D tours, but the graphics are simplified	Good content quality, optimised for educational applications
Interactivity	Support for a wide range of interactive features, from simple simulations to complex games and environments	Limited interactivity capabilities, basic interaction via smartphone	Limited interactivity, content viewing orientation	High interactivity with the ability to create and personalise tasks
Adaptability for students with special needs	Support for complex settings, but requires special software to adapt	Easy to use, but limited functionality for adapting content	It can use text and audio instructions, but without extensive individual customisation options	It has built-in tools for adapting content to the needs of students with different educational needs
Ease of use	High complexity of configuration, requires technical knowledge	Very easy to use, minimal configuration requirements	Simple interface, easy access to VR expeditions	Specialised interface that is convenient for teachers and students
Flexible settings	Extensive options for configuring parameters (graphics, sensors, environments)	Minimal settings, depends on smartphone	Settings are limited to content provided by the platform	High flexibility, the ability to create own educational content and tasks

Source: Compiled by the authors.

The comparative analysis of VR headsets and software platforms was based on expert evaluations, product specifications, and user testing in educational settings. Experts assessed the platforms according to criteria such as availability (cost, hardware requirements, and compatibility), visual content quality (hardware capabilities and reviews), interactivity (based on classroom testing and research on interactivity in learning), adaptability for students with special needs (feedback from educators and experts in assistive technology), ease of use (usability studies), and flexibility (platform customization based on feedback from educators).

The landscape of VR headsets for educational environments has evolved with several devices offering distinct features tailored to various learning contexts. Prominent VR headsets include Meta Quest 2 and 3, Pico, and HTC Vive Focus, each offering unique software ecosystems and accessibility features. The Quest 3 stands out with its robust ecosystem, mixed reality, and compatibility with platforms like Virtual Desktop for wireless PC VR. Meta's Meta for Education suite provides educators with tools for device management, content curation, and analytics, supporting seamless classroom integration.

Pico's Pico 4 and Pico 4 Enterprise are ideal for educational settings, offering lightweight designs, high-resolution displays, and flexibility for both stand-alone and PC VR experiences. The Android-based ecosystem of Pico supports various educational apps, and while it lacks a proprietary management suite, it is compatible with third-party tools for content deployment. HTC's Vive Focus series, including the Focus 3 and Focus Vision, offers high-resolution displays and robust build quality, along with a comprehensive management platform for large-scale educational use, enabling batch configuration, content deployment, and usage monitoring.

Google's VR initiatives, particularly Google Expeditions and Cardboard, have shifted focus. Google Expeditions, discontinued in 2021, migrated much of its content to Google Arts & Culture, emphasizing

360-degree and AR experiences over VR. Google stopped selling Cardboard and made it open-source, signaling a shift toward more accessible educational technologies. Current VR headsets, like Meta's Quest series, combine accessibility and management tools, Pico offers a cost-effective option, and HTC's Vive Focus excels in performance and large-scale management. The discontinuation of Google Expeditions and Cardboard reflects the trend toward flexible and accessible AR/VR solutions in education.

Comparative analysis shows that the Oculus Rift provides the highest quality and extensive features, but due to the high cost and complexity of settings, it is only suitable for specialised tasks. Google Cardboard is an affordable and simple option for basic educational needs, but has limited functionality. Google Expeditions is effective for virtual tours, but its adaptability and interactivity are limited. The most versatile tool for inclusive education is ClassVR, which combines quality, flexibility, and adaptability for students with different educational needs.

Assessment of the Possibilities of Using VR in Inclusive Education

Reviews by Escher et al. confirm that VR enhances student progress tracking by providing a personalized learning experience tailored to individual needs.⁴⁰ Students find VR learning more engaging and motivating compared to conventional methods, particularly those with concentration difficulties. Unlike traditional methods, which rely on text and verbal instructions, VR creates adaptive environments that cater to various learning styles and needs, including visual, auditory, and motor impairments. Virtual simulations allow students, including those with autism or motor impairments, to gain experiences and develop skills that are challenging to achieve with conventional methods, increasing accessibility through audio and visual cues. Teacher reviews indicate that VR promotes the development of deeper cognitive and social skills in students by enabling them to practise them in a virtual

Table 3 | Content analysis of educational materials for inclusive schools and their integration into the VR environment

Subject	Standard Training Materials	Capabilities of VR Integration	Adaptation of Students With Special Needs
Math	Geometric shapes, graphs, and number series	Creation of 3D models of geometric objects with the ability to manipulate; interactive graphs that change in real time	Increased contrast and text instructions for students with visual impairments; audio fairy tales or text accompaniment for children with hearing impairments
Natural sciences	Laboratory experiments, anatomical models, natural phenomena	Virtual laboratories for safe execution of experiments; simulations of natural phenomena (climate change, volcanic activity); 3D models of anatomy	Describes audio instructions and text prompts for students with hearing impairments; models with increased contrast for children with visual impairments
History	Maps, illustrations, and descriptions of historical events	Virtual tours of historical sites, interactive maps, 3D reconstructions of historical structures	Visualisation with text instructions for children with hearing impairments; colour adaptation for students with visual impairments
Literature	Text works, dramatic skits, poetic compositions	VR-reconstruction of scenes from literary works; the ability to interact with characters in virtual environments	Audio stories or text dubbing for students with hearing impairments; adapted interface for children with cognitive impairments
Physical education	Tasks for coordination, training of motor skills	Virtual exercises for the accuracy of movements, simulations of physical training in the form of games (for example, virtual tennis, yoga, balancing exercises)	Interactive exercises with difficulty adjustment for children with motor activity disorders; visual instructions for students with hearing impairments
Art	Drawing, modelling, studying works of art	VR applications for creating 3D art (virtual modelling or drawing); interactive museums with detailed exhibits	Available tools with tactile feedback for children with motor impairments; captioned audio guides for students with hearing impairments

Source: Compiled by the authors.

environment without the stress typical of real-world situations. Thus, a comparison of conventional teaching methods and VR methods shows that VR has significant advantages in the context of inclusive education. This allows creating a personalised, interactive, and accessible learning environment that can significantly improve learning efficiency for students with special needs, as shown in Table 3.

Content analysis of educational materials used in inclusive schools has shown that many of them can be adapted to the VR environment. Math and science textbooks can be integrated into three-dimensional models, interactive simulations, or virtual experiments. Modifying textual instructions for pupils with hearing impairments or employing contrasting graphic elements for children with visual impairments enhances the accessibility of these items. According to research, VR significantly increases the level of student engagement and improves their learning outcomes compared to conventional methods.⁴¹ Students with autism who used VR to train social skills showed a significant improvement in interaction with others compared to those who studied using standard methods. Teachers note that VR helps to create a safe environment for experimenting with new skills without fear of mistakes. In addition, VR promotes better material assimilation through an interactive and visual approach. Hearing-impaired students who use VR for learning note that text instructions and visual cues make it easier to understand the material, making it more accessible and captivating. Conventional methods often fail to provide such intensive interaction with educational content, making VR more effective for students. Thus, a comparison between conventional teaching methods and VR methods shows that virtual technologies can significantly improve learning efficiency by providing students with the opportunity to receive a personalised approach that meets their needs.⁴²

To develop VR materials that address the diverse educational requirements of students, it is necessary to take into account many critical criteria for content adaptation. The simplicity of the interface is one of the main aspects: the design should be minimalistic with clear icons and navigation, which will make it easier for students to interact with the program.⁴³ It is important to ensure that audio and visual cues are available, which should be coordinated with educational content. Text instructions and subtitles should be added for students with hearing impairments, and contrasting colours, large fonts, and audio descriptions should be used for students with visual impairments.⁴⁴ Flexibility in settings is also crucial. Students with different cognitive or physical characteristics should be provided the opportunity to change parameters such as learning speed, text size, contrast, and level of detail.⁴⁵ Virtual materials should individual educational needs by creating multiple levels of task complexity or adding interactive elements that can be customised according to the student's level of training. This approach will ensure that VR materials are available to the widest possible audience of students.

Discussion

VR technologies represent a significant advancement in modern education by enabling the adaptation of educational materials for students with diverse disabilities. Research demonstrates that VR effectively creates adaptive and accessible learning environments tailored to individual student requirements. The results show that VR promotes cognitive and social skills through interactivity, content flexibility, and accessibility. This section discusses what the results mean, their importance in the context of modern inclusive education, their relationship with other research, and prospects for further work in this line.

The results underscore the significant impact of VR in alleviating learning obstacles for children with visual, auditory, motor, and autistic spectrum problems. In particular, it was confirmed that adapting virtual environments for children with visual impairments, such as increasing contrast, increasing font size, and adding voice-overs to texts, significantly improves the accessibility of educational content. Increasing the contrast allowed visually impaired students to better perceive visual content, even in conditions of limited visual perception. Voicing text information provided an alternative channel of perception, compensating for reading difficulties. Martín-Gutiérrez et al., Li pointed out that virtual reality technologies contribute to improved sensory integration and information perception, especially for students with sensory impairments.^{46,47} Their research also highlighted the importance of personalising VR content to meet the diverse needs of students. It has been established that virtual reality can serve as an effective instrument for enhancing communication abilities in youngsters with ASD.

Text instructions, subtitles, and interactive text content have become important tools for students with hearing impairments. This helped to ensure the availability of educational material and compensate for the inability to perceive auditory information. Such results correlate with the study by Toyokawa et al.⁴⁸, who noted that the use of text components in VR training significantly reduces the cognitive load for students with hearing impairments and facilitates the process of mastering the material. For children with motor impairments, virtual simulations provided an opportunity to practice movement skills in a safe and adaptable environment. An important aspect was the use of programmes with sensory cues, which made it easier to complete tasks and helped students navigate the learning environment.

Wu et al. emphasized that interactive VR environments enable independent learning, showcasing VR's potential for inclusive education.⁴⁹ Its implementation depends on hardware and software availability. VR can enhance participation, especially for students who struggle in traditional settings. Further research is needed to develop accessible VR solutions, considering financial constraints, and to explore its long-term impact on the cognitive and emotional development of students with special needs.

Analysis of the results confirms consistency with previous research in this area. Song et al., Li et al. emphasised that the effectiveness of VR depends on interactivity and personalisation of the learning process.^{50,51} The present study revealed that elements like text prompts for students with hearing impairments and personalised contrast settings for children with visual impairments markedly enhance the quality of learning.

The reviewed studies demonstrate a significant focus on various disabilities and their impact on educational outcomes across different domains. In the area of STEM education, many studies report positive effects of VR on students with motor impairments, showing improved engagement and understanding of complex scientific concepts. For students with visual impairments, the use of VR with customizable features like contrast adjustment and larger text has led to better accessibility and participation in STEM activities. In language learning, VR has proven beneficial for students with hearing impairments, with studies indicating improved language acquisition through interactive and immersive environments that incorporate subtitles and visual cues. Social-emotional learning has also seen notable advancements, particularly for students with autism, as VR environments allow for safe practice of social interactions, helping to reduce anxiety and improve communication skills. These findings collectively suggest that VR has a strong, positive effect on education for students with diverse disabilities, enhancing their learning experiences across various fields.

Thus, the study confirms that VR has significant potential to improve inclusive learning by ensuring the adaptability and accessibility of educational materials for students. The results confirm that the introduction of VR promotes the development of cognitive, social, and motor skills. Consistency with previous studies highlights the significance of the results, and differences open up new areas for further development. In the future, it is essential to investigate the amalgamation of virtual reality with artificial intelligence and the development of individualised training programs for various student demographics.

Conclusions

A comparative analysis of the functionality of various VR headsets and software, such as Oculus Rift, Google Cardboard, Google Expeditions, and ClassVR, showed that these technologies provide high accessibility and adaptability for students with different needs. The key advantages were the functional flexibility of settings, interactivity, simplicity of the interface, and the quality of audio and visual content, which makes these technologies effective in various educational contexts. The study highlighted the importance of adapting VR content for students with special needs, using text prompts for hearing impairments, increased contrast for visual impairments, and virtual environments for social skills training in children with autism. Case studies like AutismXR showed VR's effectiveness in developing social and communication skills in a safe virtual space.

A comparison of conventional and VR teaching methods shows that VR significantly increases student engagement, offering an interactive environment that improves material comprehension, especially for students with disabilities. Feedback from both teachers and students confirms that VR fosters an inclusive learning environment tailored to individual needs, boosting motivation and learning effectiveness. The study developed recommendations for adapting VR content, focusing on simplicity, audio/visual prompts, and flexible settings to meet diverse needs. The study explores methods for tailoring VR environments to support students with disabilities, including visual, hearing, motor impairments, and autism.

The novelty of the VR adaptation system, compared to previous guidelines based on UDL and WCAG, lies in its greater flexibility and personalization of the learning experience for students with diverse needs. It integrates new technologies such as haptic feedback and alternative input methods, as well as more intuitive settings for parameters like font size, contrast, and interaction modes (seated/standing). The system focuses on interactivity and personalization, allowing VR content to be adjusted for students with varying needs and levels of complexity.

Future research should focus on three areas: First, a longitudinal study to assess the long-term effects of VR on socialization and integration. Second, a comparative analysis of cost-effective VR solutions, such as Google Cardboard versus more expensive systems. Third, research on teacher preparedness, examining training programs that build confidence and student engagement while considering infrastructure needs. Teacher training in digital competence is essential to ensure confident use in inclusive classrooms. Policymakers should support affordable VR access by funding low-cost solutions and issuing guidelines that prioritise accessibility and inclusivity in educational technologies. Developers should design VR platforms with intuitive interfaces, flexible settings, and compatibility with assistive tools, while collaborating with educators to create affordable, curriculum-relevant content.

The policy and practice of implementing VR in education have significant implications for cost, procurement, teacher training, technical maintenance, and support models in resource-constrained schools. The high cost of devices and software can be a barrier for institutions. To reduce costs, solutions like device sharing, open platforms, and local teacher training should be prioritized. Technical maintenance and support also require planning, including staff training and simple support models. Equity is crucial, especially in resource-limited regions and rural areas, where access to technology must consider language, cultural differences, and gender equality to ensure equal opportunities for all students.

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