Paper ID #45288

Bridging Educational Equity Gaps: A Systematic Review of AI-Driven and New Technologies for Students Living with Disabilities in STEM Education

Kevin Zhongyang Shao, University of Washington

Zhongyang (Kevin) Shao is currently a first-year Ph.D. student in Electrical and Computer Engineering (ECE) at the University of Washington, Seattle (UW). His research focuses on human-computer interaction and STEM education, particularly in developing user-centered, inclusive, and responsible AI technologies to enhance the accessibility and personalize learning for post-secondary STEM students. His current work harnesses AI and NLP to design accessible educational tools for underrepresented college STEM students. He holds his Bachelor's and Master's degree in ECE from The Ohio State University and UW, respectively.

Dr. Denise Wilson, University of Washington

Denise Wilson is a professor of electrical and computer engineering at the University of Washington, Seattle. Her research interests in engineering education focus on the role of self-efficacy, belonging, and other non-cognitive aspects on the student experience. Her research interests and publication record are split among workforce, engineering education, and sensors research. She is committed to supporting progress toward gender parity in engineering and enabling equitable conditions for all engineers in the workforce and as well as for engineering students throughout all phases of their education.

Eric Kyeong-Min Cho, University of Washington

Kyeong-Min (Eric) Cho is a third-year undergraduate student at the University of Washington, Seattle. He is pursuing his Bachelor's degree in Electrical and Computer Engineering with a focus on embedded systems. His research interests include human-computer interaction, engineering education, and robotics applications.

Sophia Tang, University of Washington

Sophia Tang is an undergraduate student pursuing a degree in Human-Centered Design and Engineering (HCDE) at the University of Washington. Her areas of interest include in Human-Computer Interaction, User-Centered Design, Inclusive Design, and Accessibility.

Hanlin Ma, University of Washington

Hanlin Ma is currently a junior undergraduate student in the Department of Electrical and Computer Engineering at the University of Washington, Seattle. His research interests include neural engineering and computers, embedded systems, and human-computer interaction.

Prof. Sep Makhsous, University of Washington

Sep Makhsous is an Assistant Teaching Professor in the Department of Electrical and Computer Engineering at the University of Washington and the Director of the ARC Lab (Autonomy, Robotics, and Collaboration). His work focuses on engineering education, with an emphasis on hands-on, interactive learning methods that bridge the gap between theory and practice. Sep's research explores inclusive robotics education, developing culturally-aware human-robot interfaces and tools to support students with disabilities, ensuring accessibility and equity in STEM fields.

In addition to his educational research, Sep collaborates with NASA, JCATI, and the Air Force on motor controller development for hybrid-electric aviation and integrates these industry-driven challenges into his teaching. He brings experience from the NSF I-Corps program and successful startup ventures, helping students connect classroom learning to real-world applications.

Through the ARC Lab, Sep focuses on advancing robotics education, fostering an inclusive approach to technology development, and preparing students to engage with emerging challenges in robotics and autonomy.

Bridging Educational Equity Gaps: A Systematic Review of AI-Driven and New Technologies for Students Living with Disabilities in STEM Education

Abstract

The underrepresentation of Students Living with Disabilities (SLWD) in engineering highlights a critical educational diversity gap, necessitating fundamental changes within engineering education to attract, support, and retain these students. Current research underscores the effectiveness of personalized learning strategies, which consistently lead to improved learning outcomes and increased student engagement for SLWD populations. However, the layered complexities of race, ethnicity, gender, socio-economic status, and cultural backgrounds, which intersect with disabilities, make it essential to adopt a comprehensive solution that not only addresses accessibility but also embraces the full spectrum of student diversity to truly close the equity gap. Artificial intelligence (AI) holds transformative potential in bridging these gaps by augmenting learning accessibility and providing personalized support. This study conducted a systematic literature review of thirteen articles to explore existing AI-driven and new technologies in STEM education for SLWD. The review identified several benefits of AI-driven and new technologies for SLWD, including enhanced engagement, accessibility, personalized learning, progress tracking, skill development, deeper understanding, and increased confidence. However, existing tools for SLWD also reveal significant challenges, including accessibility and technological limitations, customization constraints, practical and applicability barriers, and educational inefficacy. This review analyzed proposed solutions to these challenges in technological advancements, user-centric design, and methods for evaluation and validation. The insights from this review will inform a proposed participatory design study aimed to amplify the marginalized voices of SLWD by addressing their specific academic and intersectional needs. This approach will take a step towards an equitable learning environment, setting a new paradigm in personalized, diverse, and inclusive engineering education through AI technology.

1. Introduction

The pursuit of educational equity for students living with disabilities (SLWD) has been a transformative journey, marked by a series of legal and policy milestones that reflect an evolving understanding of what equity should look like in learning environments. Initially, the concept of educational equity in the United States emerged from the need to provide accessible education to a diverse population amid industrialization and increased immigration [1], [2]. However, this early notion of equity often overlooked the needs of marginalized groups, including the poor, SLWD, indigenous peoples, and African Americans. The Civil Rights Movement, particularly through the landmark Brown v. Board of Education decision, along with subsequent analyses like the Coleman Study [3] and Jencks's work [4], fundamentally reshaped the definition of equity in education. This shift moved the focus from mere access and uniformity of resources to a more nuanced understanding of factors beyond the school's control, such as family background and other societal and economic influences.

Equity, interpreted as equality of opportunity, and the need for customizable educational solutions for SLWD were significantly advanced by early 21st-century legislative reforms. The 1997 reauthorization of the Individuals with Disabilities Education Act (IDEA), drawing on Silverstein's work, was crucial in reinforcing the individualized paradigm. It established Free Appropriate Public Education (FAPE) and Individualized Education Programs (IEPs), fostering a cooperative, inclusive, and student-focused educational model. Compliance with the Least Restrictive Environment (LRE) principle and the adoption of standards-based IEPs guaranteed that SLWD had equitable chances to achieve academic benchmarks, a commitment further solidified by the 2001 ESEA amendments and the 2004 reauthorization of IDEA [5].

Building on the transformed landscape of educational equity for SLWD, it is necessary to consider the compounded impact of intersecting factors like race, ethnicity, gender, socio-economic status, and cultural backgrounds. Tailoring educational policy and practice to these intersections, as Artiles [6] suggests, is not only beneficial but necessary. The challenges faced by SLWD extend beyond traditional barriers of resource access; they are also shaped by broader societal and cultural influences that impact their educational journey. McLaughlin [5] argues that the notion of equity itself must be fluid and capable of adapting to the evolving needs of a diverse student population. Furthermore, the advocacy for a disability-affirmative framework by Brinkman et al. [7] and the emphasis on individual rights by Dean et al. [8] underscores the need for a flexible, individualized educational model. The dynamic nature of educational equity calls for a customizable approach that fully recognizes the influence of intersecting factors on the accessibility of educational resources, opportunities, accommodations, and support systems.

In recent years, the pursuit of educational equity has increasingly intersected with advancements in technology, particularly artificial intelligence (AI). Just as earlier legal and policy reforms sought to address the systemic barriers faced by marginalized groups, technological innovations are opening new pathways to equitable education. A pivotal moment in AI research occurred in March 2016, when AlphaGo defeated the world chess champion, capturing global attention and sparking global interest across numerous fields. In education, AI-driven tools have similarly ushered in a new era, with tools like ChatGPT. Introduced in November 2022, ChatGPT has been transforming how the field educates and assesses students [9]. Customizable AI-driven learning technologies have demonstrated sufficient adaptability to meet a range of pedagogical needs for SLWD. These tools engage the SLWD through natural language, via text or audio, assisting with tasks such as error detection in assignments, crafting individualized teaching materials and lesson plans, providing instantaneous feedback, personal tutoring, and administrative support, as well as facilitating language learning and conversational practice [9], [10], [11], [12]. Research by Daniel et al. [13] and Chung et al. [14], among others, highlights how the customization of chatbots enhances user engagement and delivers tailored services across various domains, from retail to healthcare. As these technologies evolve, their potential in educational settings becomes increasingly evident, offering students and educators alike tools that are responsive and reflective of individual learning needs and styles.

Although various reviews have been conducted to explore AI in education for SLWD or to examine STEM education for SLWD [15], [16], [17], [18], [19], few have focused specifically on the intersection of these two areas: AI-driven and new learning technologies for SLWD that are specifically designed to support learning in STEM education. This paper aims to address this gap by providing a more comprehensive review of existing AI-driven educational tools designed for SLWD in STEM education. This goal led to the following research questions (RQ):

- RQ1: What types of AI and new technologies have been developed for STEM education for students living with disabilities (SLWD)?
- RQ2: What are the benefits and limitations of existing tools developed for STEM education for SLWD?
- RQ3: What does the literature propose for the future of AI and new technologies geared toward STEM SLWD individuals?

2. Related Work

Barua et al. [16] conducted a systematic literature review on how AI technologies have been applied to support students with neurodevelopmental disorders (NDDs) such as ADHD, dyslexia, and autism spectrum. Their review highlights the effectiveness of various AI-assisted tools in enhancing educational outcomes by improving social interactions and personalized learning. It also discusses the limitations of existing AI tools, emphasizing the need for future developments to focus on personalization to cater to individual learning needs more effectively while taking privacy and ethical considerations into account.

Rather than focusing purely on NDDs, Bhatti et al. [17] analyzed diverse applications of AI technologies aimed at assisting students with not only dyslexia and dyscalculia but also a wider spectrum of learning disabilities. Similar to the review by Barua et al., this study also examined literature involving facial expressions and eye-tracking analysis to monitor students' engagement. The authors highlight the potential of AI to provide personalized learning experiences but note that current research and development predominantly focus on diagnostic tools rather than on interventions that actively support and enhance learning experiences for SWLDs.

In a broader context, Salas-Pilco et al. [18] conducted a broader systematic literature exploring the impact of AI and new technologies on inclusive education for underrepresented and minority students at the sociocultural level. The review identifies the advantages of using AI and new technologies, such as improving student performance, encouraging student interest in STEM, and enhancing student engagement. It also proposes solutions to address pedagogical, technological, and sociocultural challenges, offering guidance for instructors, practitioners, and policymakers to better support inclusiveness and diversity in education.

At an even higher level of abstraction, Komalawardhana and Panjaburee [19] examined the trends and advancements in personalized learning technology in science education between 2010 and 2022. Their study highlights the growing emphasis on personalized learning technologies to enhance student engagement and performance in science education, particularly in recent years. However, the authors also point out the lack of iterative evaluation, appropriate instructional design, and transparent research methodology, which are crucial for the effective implementation and long-term success of personalized learning technologies in science education.

While researchers have conducted reviews on AI in education for SWLD and the general student body, the literature lacks a systematic review of AI-driven and new technologies specifically for SLWD in STEM education. This review fills the gap by exploring the current AI-driven and new technologies used in STEM education for SLWD, clearly identifying limitations and opportunities for future research.

3. Methods

This systematic literature review was conducted following the guidelines presented in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and followed the steps outlined in Figure 1 [20]. The purpose of the review is to analyze the recent studies on the use of AI-driven and new technologies to support SLWD in STEM education. The search was performed across four databases: IEEE Xplore, ACM Digital Library, ERIC, and Springer Link. Search terms were formulated along three dimensions: AI-related technologies, STEM education, and SLWD. To ensure comprehensive coverage, the search was executed with the following Boolean search string using the wildcard (*) to maximize keyword variation and broaden the search results:

- ("Artificial intelligence" OR "AI" OR "machine learning" OR "ML" OR "Natural Language Processing" OR "NLP" OR "Large Language Models" OR "LLMs" OR “virtual reality” OR “augmented reality”)
- AND ("disab*" OR "impair*" OR "disorder*" OR "Dyslexia" OR "ADHD" OR "ADHS")
- AND ("*engineer*" OR "science" OR "STEM" OR "physics" OR "chemistry" OR "mathematics" OR "biology")
- AND ("education*")
- AND ("student*" OR "learn*")

The initial search using the specified query returned 8,388 articles from all four databases. Prior to retrieving all search records from each database, automation filtering tools were used within each database to exclude records that were not inside the specified year range (2017-2024), not peer-reviewed, or not in the format of a journal or conference paper. Subsequently, all remaining search records were retrieved, and 100 duplicates were removed using a Python-based helper code. After these steps, 3,431 articles remained for further screening. The titles and abstracts of these articles were then screened against the inclusion and exclusion criteria for this review (Table 1), resulting in 30 articles being retrieved for full-text review. Upon assessing the full text for eligibility, 17 articles were found to not fully meet the inclusion and exclusion criteria (e.g. literature review papers, articles outside of STEM fields, articles not focused on SLWD). Thirteen articles remained for consideration in this review.

Table 1. Inclusion and Exclusion Criteria.

Inclusion Criteria	• Publications focused on AI-driven and new technologies that are specifically designed to support SLWD in STEM education. • Publications in the form of a peer-reviewed journal or conference article. • Publications that are empirical and original research articles. • Publications that are in English. • Publications that are dated between 2017 to 2024.
Exclusion Criteria	• Publications that did not focus on AI-driven and new technologies which were specifically designed to support SLWD in STEM education. • Publications in document types other than journal and conference papers (e.g. books, reports, magazines, etc.). • Publications that are not peer-reviewed. • Publications that are not empirical or original research articles (e.g. literature reviews). • Publications that are not in English. • Publications published before 2017 or after 2024.

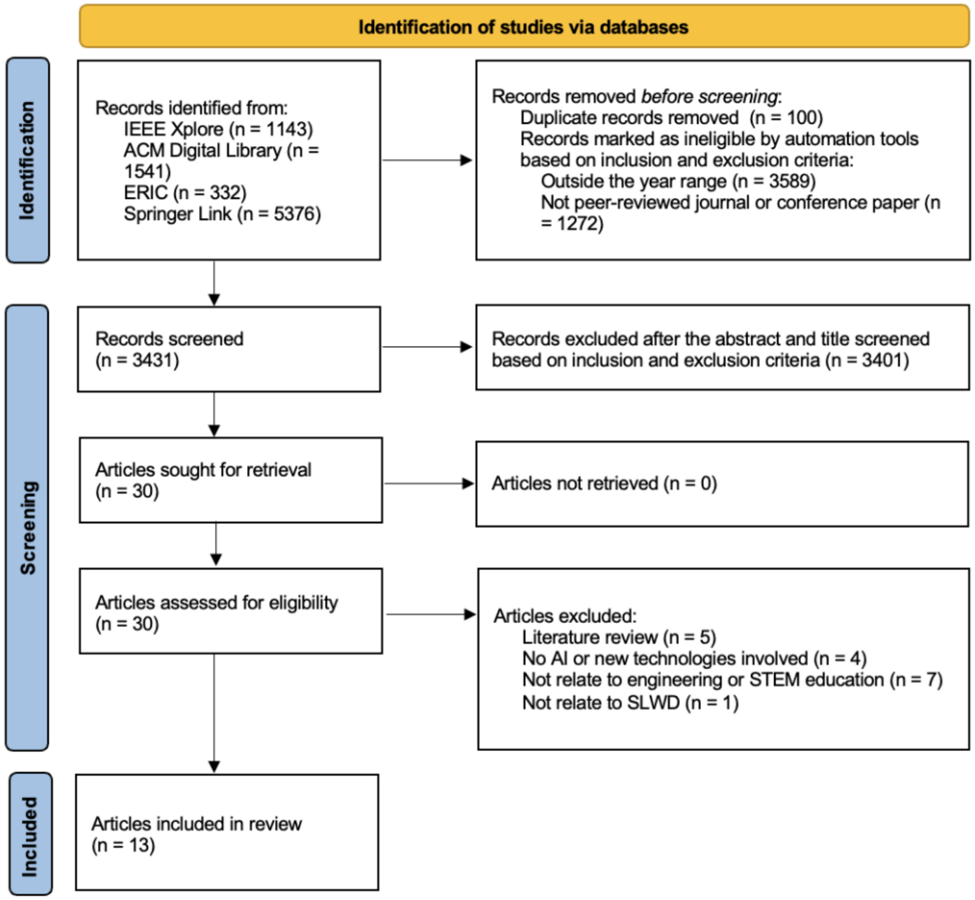

Figure 1. PRISMA flowchart of the systematic literature review.

4. Findings

Thirteen studies are considered, based in nine countries. Table 2 presents a summary of the selected studies, including details regarding their publication (authors, year of publication, country) as well as information that enables responding to the first research question posed in this review: specific type of technology, purpose of the technology, target group, and designed solution or methodology.

Table 2. Review of technologies being used in STEM education for SLWD.

Author(s) and Year	Country	Technologies	Purpose	Target Group	Education Level	Designed Solution/Methodology
Iatraki et al., (2021) [21]	Greece	Virtual Reality/Augmented Reality (VR/AR)	Investigate the design issues in the development of digital learning environments for supporting science education for students with intellectual disabilities.	Intellectual disability (ID) Students	Primary	Employed a focus group methodology to explore the effectiveness of AR and VR environments in teaching science concepts to students with ID.
Chinthaka et al., (2018) [22]	Sri Lanka	Natural Language processing, Text to speech conversion (TTS)	By touch (Braille) and voice commands' approach, along with the Cbeyond tool, provide solutions to improve the math learning experience for visually impaired students.	Visually impaired students	Primary	Developed a specialized mathematical learning tool (Cbeyond) for visually impaired students.
Galeos et al., (2020) [23]	Greece	Game-based learning	Enhance children's learning and concentration with interactive and adaptive programming games.	Attention Deficit and Hyperactivity Disorder (ADHD) students	Primary	Created an engaging computer programming game for children with ADHD.
De Silva et al., (2024) [24]	Sri Lanka	Artificial intelligence/Machine learning (AI/ML)	Improve the educational experiences and the interests towards STEM for visually impaired students based on YOLOv8, Internet of Things technology, AI and machine learning on smart devices.	Visually impaired students (VISs)	All	Developed a smart glass system to revolutionize the education of visually impaired students in science, mathematics, and the use of money, enabling independent learning, accurate object detection, and comprehensive description.
Mohammadhasani et al., (2018) [25]	Iran	Intelligent Tutoring System (ITS)	Enhance learning and concentration in math for ADHD students through a pedagogical agent that gains and guides attention, providing cognitive and emotional support.	Attention Deficit and Hyperactivity Disorder (ADHD) students	Primary	Developed a Pedagogical Agent, a virtual character designed to guide and motivate ADHD students in mathematics learning.
Al Omoush et al., (2023) [26]	Ireland	VR/AR, robotics	Enhance teaching and learning of mathematics for vision-impaired students.	Visually impaired students (VISs)	All	Incorporated robotics into mathematics education.

Author(s) and Year	Country	Technologies	Purpose	Target Group	Education Level	Designed Solution/Methodology
Topin et al., (2019) [27]	Brazil	Computer Vision (CV), Artificial Neural Networks (ANN)	Enhance Math teaching to blind or students with reduced vision.	Students blind or with reduced vision	All	Designed a mobile system that can identify the main Cartesian curves present in mathematics.
Rivas-Perez et al., (2019) [28]	Costa Rica	Convolutional Neural Network (CNN)	Improve the accessibility of Mathematics for people with visual disabilities.	Visually impaired students (VISs)	All	Developed EULER, a voice controlled mathematical editor.
Maćkowski et al., (2018) [29]	Poland	Intelligent Algorithms, Speech Rule Engine (SRE)	Develop an accessible interactive e-learning platform specifically designed for visually impaired students to support the teaching and assessment of mathematics.	Visually impaired people (VISs)	All	Designed a tutoring math platform accessible for visually impaired people.
Bouck et al., (2021) [30]	United States	Adaptive Learning, Virtual Manipulatives	Explore the effectiveness of an intervention package that includes a virtual number line and corrective feedback in teaching the addition of integers to middle school students with intellectual disabilities and autism.	Students with developmental disabilities	Secondary	Used a virtual number line and corrective feedback to teach addition of integers to middle school students with developmental disabilities.
Bossavit and Parsons, (2018) [31]	United Kingdom	Codesigned Game, Xbox Kinect	Explore the effects of involving students with ASD in design process of curriculum.	Autism spectrum disorder (ASD) students	K-12	Codesigned an educational geography game alongside students with ASD.
Wen et al., (2020) [32]	United States	E-Learning Tools	Identify design implications to help shape more inclusive and effective e-learning tools.	Specific learning disability (SLD) students	K-12	Conducted an interview study to investigate which math e-learning tools were used and how effective they were for students with SLD.
Wood et al., (2020) [33]	United States	Text to speech conversion (TTS)	Develop and evaluate strategies to improve listening comprehension of e-texts in students with moderate intellectual disabilities.	Intellectual disability (ID) Students	Primary	Improved students' ability to understand and engage with science content through adaptive and personalized teaching methods.

4.1 RQ1: Existing tools for SLWD in STEM education

Within the articles reviewed, six categories of AI tools have been used in STEM education to support SLWD. Specifically, two articles explored virtual reality/augmented reality (VR/AR); three focused on serious games and game-based learning; four examined AI/ML; two discussed natural language processing (NLP); three investigated intelligent tutoring systems (ITS); and one involved robotics. Table 3 summarizes the educational use and support of AI and new technologies for SLWD.

Table 3. AI and new technologies used in STEM education for SLWD.

AI and related Technologies	Reference Number	Numbers of Articles
Artificial intelligence/Machine learning (AI/ML)	[24], [27], [28], [32]	4
Serious Game, and Game-based learning	[23], [31], [32]	3
Intelligent Tutoring Systems (ITS)	[25], [29], [30]	3
Natural Language Process (NLP)	[22], [33]	2
Virtual Reality/Augmented Reality (VR/AR)	[21], [26]	2
Robotics	[26]	1

The data reveals that AI/ML is the most prominent category in the development of learning resources for SLWD in STEM education, with its capability for recognition and pattern identification. For instance, Topin et al. [27] examined the role of Deep Neural Networks (DNNs) in identifying and classifying Cartesian curves for visually impaired students. Similarly, Rivas-Perez et al. [28] introduced the EULER tool, a mathematical editor using Convolutional Neural Networks (CNNs) for voice recognition and mathematical symbol prediction. In addition, Chinthaka et al. [22] and Wood et al. [33] explored NLP, a sub-domain of ML, which enables the conversion of written text into auditory output, allowing visually impaired students and students with learning disabilities to access and understand content through sound. Furthermore, AI-driven ITS is able to provide structured guidance and real-time feedback for students. Specifically, Maćkowski et al. [29] developed an e-learning platform that helps visually impaired students learn mathematics through interactive exercises, offering real-time feedback and tailored recommendations based on their mistakes.

Beyond AI-driven technologies, VR/AR technologies, game-based learning, and educational robotics have also been explored as innovative educational tools. As Iatraki et al. [21] demonstrated, VR/AR technologies offer immerse experiences by allowing students to visualize complex, abstract scientific concepts, like the structure and movement of water molecules, in ways that that are difficult to experience in real-world setting. Additionally, serious games and game-based learning leverage the entertaining nature of games to facilitate learning [34]. For instance, Galeos et al. [23] incorporated structured environments with clear rules, color-coding commands, and frequent rewards to maintain focus and engagement, especially for students with ADHD. Meanwhile, Al Omoush et al. [26] further explored the use of educational robotics equipped with tactile, auditory, and haptic systems, allowing vision impaired students to explore mathematical concepts through touch and sound.

4.2 RQ2: Benefits and limitations of existing tools for SLWD in STEM education

The benefits identified for each technology in the reviewed papers were distilled into six main categories. Eight studies emphasized student engagement and motivation, eight recognized improved accessibility, seven focused on personalized learning, two highlighted student progression, seven addressed skill development, and two examined the impact on student confidence (Table 4).

Table 4. Benefits of existing AI-driven and new technologies in STEM education for SLWD.

Benefits	Reference Number	Numbers of Articles
Foster engagement and motivation	[21], [23], [25], [26], [30], [31], [32], [33]	8
Enhance accessibility and usability	[21], [23], [24], [26], [28], [29], [30], [32]	8
Facilitate personalized and independent learning	[23], [24], [25], [28], [30], [32], [33]	7
Track progress and performance	[22], [32]	2
Develop skills and deepen understanding	[22], [25], [26], [29], [30], [31], [33]	7
Boost confidence and comfort	[25], [29]	2

This review identified promoting accessibility and usability, along with fostering student engagement and motivation, as the primary benefits of utilizing AI-driven and new technologies as educational tools for SLWD. For example, Wen et al. [32] found that e-learning tools, particularly their interactive features, alleviated the anxieties of students with specific learning disorders and increased their participation. Similarly, Galeos et al. [23] developed an educational game that incorporated elements like symmetry and balanced distances between objects to ensure accessibility for children with ADHD. Another benefit of these technologies is their ability to support personalized learning. For example, the smart device developed by De Silva et al. [24] used object detection and text-to-speech to provide blind students with instant auditory feedback, enabling them to solve problems independently. Additionally, some technologies offered student progress and performance tracking. For instance, the mathematical learning tool in Chinthaka et al.'s study [22] offered a platform to evaluate student performances, simplifying the teaching process for both students and teachers. This review also found that these technologies are effective in skill development and enhancing student understandings of topics. In particular, Maćkowski et al. [29] demonstrated that the tutoring math platform significantly improved visually impaired students' understanding of mathematical formulae. Finally, this review highlighted that these technologies help bolster student confidence. After using the pedagogical agent in Mohammadhasani et al.'s study [25], students with ADHD reported feeling more comfortable and confident when learning with the tool.

Among these technologies, AI-driven tools—such as AI/ML, NLP, and AI-driven intelligent tutoring systems (ITS)—stand out for their advanced capabilities across all the benefit categories analyzed. Leveraging AI's computing power and analytical abilities, these tools effectively evaluate student strengths, weaknesses, and learning progress, enabling a tailored learning experience that fosters engagement and motivation. More importantly, AI-driven educational platforms provide real-time feedback and adaptive content, supporting personalized learning and deepening students' understanding. The integration of AI in education presents a significant opportunity to create a more personalized, engaging, and effective learning environment.

In contrast to these benefits, this review also identified several challenges associated with existing educational technologies for SLWD. Four studies addressed user experience and accessibility, four mentioned technological limitations, two discussed customization issues, three noted practical barriers, defined as resource-related constraints such as high costs, setup complexity, and extensive maintenance requirements, three identified applicability barriers, defined as constraints limiting the technology's use to specific user groups, and three examined educational effectiveness (Table 5).

Table 5. Limitations of existing AI-driven and new technologies in STEM education for SLWD.

Limitations	Reference Number	Numbers of Articles
User experience and accessibility limitations	[24], [26], [32], [33]	4
Technological limitations	[21], [27], [28], [30]	4
Customization and flexibility constraints	[23], [32]	2
Practical barriers	[26], [32], [33]	3
Applicability barriers	[25], [30], [31]	3
Limitations in educational effectiveness	[25], [30], [33]	3

Dissatisfied user experience and technological limitations were identified as the most common across all tools. For instance, Wen et al. [32] highlights that the heavy textual content of problems, coupled with the complexity of for setting up and maintaining the technology and the lack of text-to-speech or closed captioning features, made many e-learning tools unfriendly for SLWD. In this review, technological limitations are defined as those stemming from how the technology is developed, trained, or designed to function, including limitations in data, algorithmic design, and system performance in complex contexts. For example, the AR/VR environments were found to be of low resolution and therefore were disorientating to students [21]. Additionally, Rivas-Perez et al. [28] highlights the limited support for various languages and advanced mathematical concepts.

Another limitation of these tools was their lack of customization. The educational game developed by Galeos et al. [23] lacked difficulty levels and an authoring mode for teachers to create their own environments, which limited its broader application. Several technologies also posed practical barriers. For example, the robotics technology proposed by Al Omoush et al. [26] required specialized, costly equipment, and extensive teacher training, making its widespread use impractical. Additionally, some technologies were constrained by applicability barriers. Bouck et al.'s pilot study [31] was conducted with a small, high-functioning sample group, which restricted the generalizability of the findings. Lastly, educational effectiveness was another critical issue. For example, the pedagogical agent implemented by Mohammadhasani et al. [25] was assessed using tests to measure student attention level, but the researchers acknowledged that there were better metrics to assessing the tool's impact on learning.

4.3 RQ3: Proposed Solutions

To refine current design solutions based on the findings, the literature reviewed herein also proposed enhancements to AI-driven and new technologies that could be organized into four main areas: model enhancement, further accessibility and inclusion, evaluation, and technology integration and personalization. Each category includes specific examples of improvements that address the needs of SLWD in engineering and STEM education. Two studies proposed potential model enhancements, focusing on refining the models to better support SLWD. Four studies emphasized evaluation strategies, two studies focused on further accessibility and inclusion, and four studies addressed the integration of technology and personalization (Table 6).

Table 6. Proposed Solutions and Improvements of AI-driven and new technologies in STEM education for SLWD.

Proposed Solution	Reference Number	Examples
Model Enhancement	[27], [30]	- Generalize across different tools [30] - Fine-tune training parameters [30] - Increase and add new classes to datasets [27]
Further Accessibility and Inclusion	[24], [28]	- Include support in multiple languages [24], [28]
Evaluation	[25], [30], [31], [32]	- Add long-term, iterative evaluation [30] - Gather additional evidence to assess interaction methods [31] - Increase the diversity and size of the participant pool [25], [32]

Table 6 – continued

Proposed Solution	Reference Number	Examples
Technology Integration and Personalization	[21], [23], [26], [33]	- Develop and test interactive VR and AR environments [21], [26] - Expand game levels for more personalized learning [23] - Explore integrating technology, instruction, and hands-on experiences [33]

With these categories, Bouck et al. [30] proposed a future improvement in model enhancement, specifically aiming to generalize across different tools. This improvement focuses on enabling SLWD to apply skills or knowledge gained from one educational tool, such as a virtual number line, to other tools or real-world scenarios. The authors suggest that learning achieved with a specific tool should be effectively transferable to different tools. Additionally, this review identified several proposed solutions to improve accessibility and inclusion. Both De Silva et al. [24] and Rivas-Perez et al. [28] highlight the necessity of incorporating support for multiple languages in current solutions to better serve diverse populations of SLWD. Another notable potential improvement is to involve more comprehensive evaluation methods in the design process. Four papers suggest that extending the duration and scope of evaluations could provide a more accurate and thorough assessment of their results, as their existing evaluation was limited to small-scale samples. For example, Mohammadhasani et al. [25] acknowledged a gender imbalance in its participant pool, noting an overrepresentation of boys diagnosed with ADHD, which introduced bias to the current solution. To address this, the authors recommended expanding the participant pool to include more girls, correcting the gender bias, and improving the post-study analysis with the equal representation. Lastly, the integration of technology and personalization was emphasized, particularly in reviewed papers focusing on game-based learning, VR, or AR environments. Galeos et al. [23] recommended expanding the game levels within their current solution to further personalize the learning experience. A total of four papers underscored the significance of enhancing personalization within the technologies, arguing that doing so could greatly improve the educational experience for SLWD by creating a more engaging and tailored learning environment.

5. Discussion

The review explores and summarizes the diverse applications of AI-driven and new technologies in STEM education for SLWD, highlighting their potentials and limitations. Each tool addresses different challenges faced by SLWD in their learning, offering a range of benefits enhanced engagement, accessibility, personalized learning, performance tracking, skill development, deeper understanding, and increased confidence (Table 4). However, these tools also present limitations in accessibility, customization constraints, practical and applicability barriers, as well as educational inefficacy (Table 5). These findings provide educators and researchers with an overview of current practices and gaps to address in future designs.

First, the review indicates that while AI-driven technologies for SLWD in STEM education are emerging, significant research gaps remain. Comparing to technologies designed to enhance soft skills – such as social, communication [36], and writing skills [37] – the number of technologies specifically tailored for STEM education remains limited. Our literature review reveals that this scarcity is even more pronounced for tools developed specifically for post-secondary STEM education. As shown in Table 2, the majority of tools reviewed (8 out of 13), along with many others, are designed primarily for K-12 students, overlooking the distinct, more advanced challenges faced by SLWD in higher education. Unlike the K-12 education, interdisciplinary learning has been a central focus of higher education and research to meet industrial demands [38]. However, this has been a challenge for students because of factors such as lack of motivation, lack of prior experience, the increase of learning pressure and academic burden, and the interference of disciplinary factors during interdisciplinary learning [39]. These challenges can be amplified for SLWD, when they engage with complex, interdisciplinary content that requires adaptive learning environments and abstract STEM theories [40]. To address this gap, there is a clear need to design AI-driven tools specifically for post-secondary SLWD. Such tools must go beyond theoretical approaches and be applied in practical, real-world contexts to support SLWD as they navigate complex learning environments, extending beyond traditional accessibility measures.

Second, from an equity perspective, this review highlights critical disparities in equal access to AI-driven tools for SLWD in STEM education. In early education, specific learning disabilities (32%) and speech/language impairments (19%) are prevalent [41]. However, in higher education, ADHD affects 16.8% of students, and 5.3% report having learning disabilities [42]. Despite this shift in the prevalence of disabilities, only three out of the thirteen articles reviewed address ADHD and specific learning disabilities, with the majority focusing on visual and intellectual disabilities. This results in a deficit in support for high-incidence neurodevelopmental disorders, which impacts a larger population of students in post-secondary education. It also reflects a discontinuity in support during the transition to higher education, exacerbating challenges faced by SLWD. These findings underscore the need for AI-driven tools to be tailored to the specific needs of different disabilities, particularly ADHD and learning disabilities, which are more common in higher education.

Third, from a technological perspective, this review highlights the significance of integrating AI for personalized education, particularly for the SLWD. The diverse disabilities, as well as sociocultural and academic backgrounds of each SLWD, demand individualized support. AI-driven tools can collect, process, and analyze large-scale datasets, enabling the development of tailored learning experiences that address the specific needs of learners [23] and varying levels of educational and emotional maturity. In addition, AI's capacity to identify patterns in student performance can reveal accessibility and performance gaps that might otherwise go unnoticed [43]. By leveraging these insights, educators and researchers can more effectively support SLWD. Moreover, AI-driven ITS has demonstrated their effectiveness in enhancing academic performance and motivation by offering personalized, immediate feedback [44]. These systems can detect student weaknesses in real-time and provide targeted resources, reducing the risk of learning setbacks. The ability of AI to deliver this level of personalization and support is crucial for fostering inclusive and equitable learning experiences in STEM education for SLWD.

Fourth, the development of existing AI-driven tools often lacks sustained and iterative evaluation, particularly when validating empirical models. This gap is evident not only in this review, but also in other studies in the field. For instance, a study on the pedagogical framework for a personalized chatbot, CHAT-ACTS, emphasized the importance of conducting empirical evaluation studies to test the effectiveness of the proposed framework across various educational contexts and diverse learner populations [45]. Similarly, Limo et al. [46] highlight the need to validate findings across different populations and explore the long-term effects of personalized tutoring on academic achievement. These findings suggest that in future designs, iterative evaluation is crucial for maintaining the consistent validity and accuracy of AI-driven tools [47]. Without iterative assessment, AI-driven tools may not be able to adapt to the evolving needs of SLWD, limiting their educational impact. To address these evaluation challenges, particularly for the underrepresented communities, a participatory design strategy offers a promising solution. This approach actively involves SLWD, educators, and other stakeholders in the co-design process, enabling the collection of comprehensive feedback and insights [48]. By continuously evaluating user experiences, researchers can identify and address potential pitfalls, leading to more reliable and tailored technology [49].

6. Conclusions

AI-driven and new technologies present significant potentials in enhancing student performance, engagement, accessibility, confidence, and skill development. However, our review shows that the integration of AI-driven educational tools into engineering and STEM education for SLWD represents a particularly significant step toward achieving educational equity and personalized learning. The findings from our literature review underscore the advanced capacities of AI-driven tools compared to others to tailor education experiences to the unique needs of SLWD, thereby promoting a more inclusive learning environment. Despite these advancements, a significant gap persists in the current body of research, particularly concerning AI-driven technologies designed for post-secondary SLWD. Most existing studies focus on K-12 education, leaving the needs of engineering and STEM subjects in higher education underexplored.

However, several challenges remain. Accessibility and technological limitations, customization constraints, practical and applicability barriers, and educational inefficacy must be addressed to maximize the effectiveness of technologies. This study identifies that diversifying the dataset, employing more iterative evaluation methods alongside co-design strategies, and refining the technical capabilities are crucial steps for advancing this field.

Future work will focus on addressing these challenges by conducting more extensive empirical research and iterative, long-term evaluation with diverse populations of SLWD. Building on our literature review findings, we plan to continue our survey study and conduct semi-structured interviews with our targeted users to gain a more comprehensive understanding of the challenges they have faced in their educational journeys and the specific features and functionalities they seek in AI-driven educational tools. Guided by these insights, we aim to develop and assess a customized AI-driven chatbot specifically designed for personalized education for SLWD in engineering. This chatbot will provide not only tailored educational resources but also motivational support, ensuring that it can meet a wide range of learning preferences and requirements. Additionally, long-term studies utilizing the participatory design strategy will be conducted to evaluate the sustained impact of these tools on the academic performance, engagement, and overall well-being of SLWD. By continuing to refine and expand the scope of our study, we aim to contribute to the development of more effective, equitable, and inclusive AI-driven educational tools for post-secondary engineering students.

References

[1] J. S. Coleman, "The Concept of Equality of Educational Opportunity," vol. 38, no. 1, 1968.

[2] S. Deschenes, L. Cuban, and D. Tyack, "Mismatch: Historical Perspectives on Schools and Students who Don't Fit Them," vol. 103, no. 4, pp. 525–547, 2021.

[3] J. S. Coleman, "Equality of Educational Opportunity," *Equity Excell. Educ.*, vol. 6, no. 5, pp. 19–28, Sep. 1968, doi: 10.1080/0020486680060504.

[4] C. Jencks and A. Others, "Inequality: A Reassessment of the Effect of Family and Schooling in America," Basic Books, Inc, 1972.

[5] M. J. McLaughlin, "Evolving Interpretations of Educational Equity and Students with Disabilities," *Except. Child.*, vol. 76, no. 3, pp. 265–278, Apr. 2010, doi: 10.1177/001440291007600302.

[6] A. J. Artiles, “Toward an Interdisciplinary Understanding of Educational Equity and Difference: The Case of the Racialization of Ability,” *Educ. Res.*, vol. 40, no. 9, pp. 431–445, Dec. 2011, doi: 10.3102/0013189X11429391.
[7] A. H. Brinkman, G. Rea-Sandin, E. M. Lund, O. M. Fitzpatrick, M. S. Gusman, and C. L. Boness, “Shifting the Discourse on Disability: Moving to an Inclusive, Intersectional Focus,” *Am. J. Orthopsychiatry*, vol. 93, no. 1, pp. 50–62, 2023, doi: 10.1037/ort0000653.
[8] L. Dean, R. Tolhurst, R. Khanna, and K. Jehan, “‘You’re disabled, why did you have sex in the first place?’ An intersectional analysis of experiences of disabled women with regard to their sexual and reproductive health and rights in Gujarat State, India,” *Glob. Health Action*, vol. 10, no. sup2, p. 1290316, Jan. 2017, doi: 10.1080/16549716.2017.1290316.
[9] S. S. Gill *et al.*, “Transformative effects of ChatGPT on modern education: Emerging Era of AI Chatbots,” *Internet Things Cyber-Phys. Syst.*, vol. 4, pp. 19–23, Jan. 2024, doi: 10.1016/j.iotcps.2023.06.002.
[10] M. Xiao and H. Yi, “Building an efficient artificial intelligence model for personalized training in colleges and universities,” *Comput. Appl. Eng. Educ.*, vol. 29, no. 2, pp. 350–358, Mar. 2021, doi: 10.1002/cae.22235.
[11] T. Ait Baha, M. El Hajji, Y. Es-Saady, and H. Fadili, “The impact of educational chatbot on student learning experience,” *Educ. Inf. Technol.*, Sep. 2023, doi: 10.1007/s10639-023-12166-w.
[12] A. Briel, “Toward an eclectic and malleable multiagent educational assistant,” *Comput. Appl. Eng. Educ.*, p. cae.22449, Aug. 2021, doi: 10.1002/cae.22449.
[13] F. Daniel, M. Matera, V. Zaccaria, and A. Dell’Orto, “Toward truly personal chatbots: on the development of custom conversational assistants,” in *Proceedings of the 1st International Workshop on Software Engineering for Cognitive Services*, in SE4COG ’18. New York, NY, USA: Association for Computing Machinery, May 2018, pp. 31–36. doi: 10.1145/3195555.3195563.
[14] M. Chung, E. Ko, H. Joung, and S. J. Kim, “Chatbot e-service and customer satisfaction regarding luxury brands,” *J. Bus. Res.*, vol. 117, pp. 587–595, Sep. 2020, doi: 10.1016/j.jbusres.2018.10.004.
[15] N. Oquendo-Colón, C. Finelli, and L. Carroll, “The College Experiences of Undergraduate Students with ADHD: A Scoping Literature Review,” in *2023 Collaborative Network for Computing and Engineering Diversity (CoNECD) Proceedings*, New Orleans , Louisiana: ASEE Conferences, Feb. 2023, p. 44809. doi: 10.18260/1-2--44809.
[16] P. D. Barua *et al.*, “Artificial Intelligence Enabled Personalised Assistive Tools to Enhance Education of Children with Neurodevelopmental Disorders—A Review,” *Int. J. Environ. Res. Public. Health*, vol. 19, no. 3, p. 1192, Jan. 2022, doi: 10.3390/ijerph19031192.
[17] I. Bhatti, S. F. Mohi-U-din, Y. Hayat, and M. Tariq, “Artificial Intelligence Applications for Students with Learning Disabilities: A Systematic Review,” *Eur. J. Sci. Innov. Technol.*, vol. 4, no. 2, pp. 40–56, 2024.
[18] S. Z. Salas-Pilco, K. Xiao, and J. Oshima, “Artificial Intelligence and New Technologies in Inclusive Education for Minority Students: A Systematic Review,” *Sustainability*, vol. 14, no. 20, p. 13572, Oct. 2022, doi: 10.3390/su142013572.
[19] N. Komalawardhana and P. Panjaburee, “Trends and development of technology-enhanced personalized learning in science education: a systematic review of publications

from 2010 to 2022," *J. Comput. Educ.*, vol. 11, no. 3, pp. 721–742, Sep. 2024, doi: 10.1007/s40692-023-00276-w.

[20] PRISMA-P Group *et al.*, "Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement," *Syst. Rev.*, vol. 4, no. 1, p. 1, Dec. 2015, doi: 10.1186/2046-4053-4-1.

[21] G. Iatraki, M. Delimitros, I. Vrellis, and T. A. Mikropoulos, "Augmented and virtual environments for students with intellectual disability: design issues in Science Education," in *2021 International Conference on Advanced Learning Technologies (ICALT)*, Tartu, Estonia: IEEE, Jul. 2021, pp. 381–385. doi: 10.1109/ICALT52272.2021.00122.

[22] W. Chinthaka and P. Abeygunawardhana, "Cbeyond: Mathematical Learning Tool for Primary Level Visual Impaired Students," in *2018 13th International Conference on Computer Science & Education (ICCSE)*, Colombo: IEEE, Aug. 2018, pp. 1–5. doi: 10.1109/ICCSE.2018.8468805.

[23] C. Galeos, K. Karpouzis, and G. Tsatiris, "Developing an educational programming game for children with ADHD," in *2020 15th International Workshop on Semantic and Social Media Adaptation and Personalization (SMA*, Zakynthos, Greece: IEEE, Oct. 2020, pp. 1–6. doi: 10.1109/SMAP49528.2020.9248458.

[24] D. I. De Silva, S. Vidhanaarachchi, R. A. K. M. Ranasinghe, M. N. N. J. Jayasooriya, D. M. P. S. Jayawardhana, and D. K. S. Savishka, "Enhancing Learning Experiences For Visually Impaired Students With AI and Machine Learning on Smart Device," in *2024 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, Istanbul, Turkiye: IEEE, May 2024, pp. 1–6. doi: 10.1109/HORA61326.2024.10550610.

[25] N. Mohammadhasani, H. Fardanesh, J. Hatami, N. Mozayani, and R. A. Fabio, "The pedagogical agent enhances mathematics learning in ADHD students," *Educ. Inf. Technol.*, vol. 23, no. 6, pp. 2299–2308, Nov. 2018, doi: 10.1007/s10639-018-9710-x.

[26] M. H. Al Omoush and T. Mehigan, "Leveraging Robotics to Enhance Accessibility and Engagement in Mathematics Education for Vision-Impaired Students," in *2023 5th International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, Istanbul, Turkiye: IEEE, Jun. 2023, pp. 1–6. doi: 10.1109/HORA58378.2023.10156748.

[27] L. O. Topin *et al.*, "Towards Machine Learning for Enhanced Maths Teaching to the Blind," in *2019 IEEE Frontiers in Education Conference (FIE)*, Covington, KY, USA: IEEE, Oct. 2019, pp. 1–8. doi: 10.1109/FIE43999.2019.9028500.

[28] T. Rivas-Perez, A. Meza-Vega, V. Mora-Lezcano, D. Palacio-Amador, and M. Chacon-Rivas, "EULER - Mathematical Editing by Voice Input for People with Visual Impairment," in *2019 International Conference on Inclusive Technologies and Education (CONTIE)*, San Jose del Cabo, Mexico: IEEE, Oct. 2019, pp. 9–95. doi: 10.1109/CONTIE49246.2019.00012.

[29] M. S. Maćkowski, P. F. Brzoza, and D. R. Spinczyk, "Tutoring math platform accessible for visually impaired people," *Comput. Biol. Med.*, vol. 95, pp. 298–306, Apr. 2018, doi: 10.1016/j.compbiomed.2017.06.003.

[30] E. C. Bouck, H. Long, and J. Park, "Using a Virtual Number Line and Corrective Feedback to Teach Addition of Integers to Middle School Students with Developmental Disabilities," *J. Dev. Phys. Disabil.*, vol. 33, no. 1, pp. 99–116, Feb. 2021, doi: 10.1007/s10882-020-09735-z.

[31] B. Bossavit and S. Parsons, “Outcomes for design and learning when teenagers with autism codesign a serious game: A pilot study,” *J. Comput. Assist. Learn.*, vol. 34, no. 3, pp. 293–305, Jun. 2018, doi: 10.1111/jcal.12242.
[32] Z. A. Wen, E. Silverstein, Y. Zhao, A. L. Amog, K. Garnett, and S. Azenkot, “Teacher Views of Math E-learning Tools for Students with Specific Learning Disabilities,” in *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility*, Virtual Event Greece: ACM, Oct. 2020, pp. 1–13. doi: 10.1145/3373625.3417029.
[33] L. Wood, D. M. Browder, and F. Spooner, “Teaching Listening Comprehension of Science e-Texts for Students With Moderate Intellectual Disability,” *J. Spec. Educ. Technol.*, vol. 35, no. 4, pp. 272–285, Dec. 2020, doi: 10.1177/0162643419882421.
[34] C. Schrader, “Serious Games and Game-Based Learning,” in *Handbook of Open, Distance and Digital Education*, Singapore: Springer Singapore, 2022, pp. 1–14. doi: 10.1007/978-981-19-0351-9_74-1.
[35] Y. Bobalo, N. Shakhovska, and P. Stakhiv, “The Gamification Approach in Electrical Engineering Disciplines Teaching for Students with Special Needs,” in *2019 IEEE 20th International Conference on Computational Problems of Electrical Engineering (CPEE)*, Lviv-Slavske, Ukraine: IEEE, Sep. 2019, pp. 1–4. doi: 10.1109/CPEE47179.2019.8949092.
[36] C. E. Hughes *et al.*, “RAISE: Robotics & AI to improve STEM and social skills for elementary school students,” *Front. Virtual Real.*, vol. 3, p. 968312, Oct. 2022, doi: 10.3389/frvir.2022.968312.
[37] S. Tamilselvan, K. Yogeshwaran, K. Pradheep, and E. Udayakumar, “Development of Artificial Intelligence based assessment writing Robot for disable people,” in *2020 7th International Conference on Smart Structures and Systems (ICSSS)*, Chennai, India: IEEE, Jul. 2020, pp. 1–6. doi: 10.1109/ICSSS49621.2020.9202067.
[38] R. G. Klaassen, “Interdisciplinary education: a case study,” *Eur. J. Eng. Educ.*, vol. 43, no. 6, pp. 842–859, Nov. 2018, doi: 10.1080/03043797.2018.1442417.
[39] C. Xu, C.-F. Wu, D.-D. Xu, W.-Q. Lu, and K.-Y. Wang, “Challenges to Student Interdisciplinary Learning Effectiveness: An Empirical Case Study,” *J. Intell.*, vol. 10, no. 4, p. 88, Oct. 2022, doi: 10.3390/jintelligence10040088.
[40] D. Diaz and P. King, “Adapting A Post Secondary Stem Instructional Model To K 5 Mathematics Instruction,” in *2007 Annual Conference & Exposition Proceedings*, Honolulu, Hawaii: ASEE Conferences, Jun. 2007, p. 12.175.1-12.175.15. doi: 10.18260/1-2--3054.
[41] National Center for Education Statistics, “Students With Disabilities,” U.S. Department of Education, Institute of Education Sciences, Condition of Education, 2024.
[42] “Spring 2023 UG Reference Group Executive Summary,” American College Health Association, 2024.
[43] N. Z. Zacharis, “Predicting Student Academic Performance in Blended Learning Using Artificial Neural Networks,” *Int. J. Artif. Intell. Appl.*, vol. 7, no. 5, pp. 17–29, Sep. 2016, doi: 10.5121/ijaia.2016.7502.
[44] K. VanLEHN, “The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems,” *Educ. Psychol.*, vol. 46, no. 4, pp. 197–221, 2011.
[45] M. P.-C. Lin and D. Chang, “CHAT-ACTS: A pedagogical framework for personalized chatbot to enhance active learning and self-regulated learning,” *Comput. Educ. Artif. Intell.*, vol. 5, 2023.

[46] F. A. F. Limo, “Personalized tutoring: ChatGPT as a virtual tutor for personalized learning experiences,” *Przestrz. Społeczna Soc. Space*, vol. 23, no. 1, pp. 293–312, 2023.
[47] J. Chen, “STAGER checklist: Standardized testing and assessment guidelines for evaluating generative artificial intelligence reliability,” *iMetaOmics*, 2024, doi: 10.1002/imo2.7.
[48] V. Gadiraju *et al.*, “‘I wouldn’t say offensive but...’: Disability-Centered Perspectives on Large Language Models,” in *2023 ACM Conference on Fairness, Accountability, and Transparency*, 2023, pp. 205–216.
[49] A. Zhang, “Deliberating with AI: Improving Decision-Making for the Future through Participatory AI Design and Stakeholder Deliberation,” in *Proceedings of the ACM on Human-Computer Interaction*.