How Artificial Intelligence Is Impacting on the STEM Education of Students with Disabilities: A Five Years Review

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Abstract: Artificial intelligence promises to revolutionize our life, bringing significant advances in any fields: health, education, work and leisure time. This paper analyzes the last 5-year literature concerning the use of AI for supporting people with disabilities in education. The aim is to investigate the current state of art of accessible applications in the STEM (Science, Technology, Engineering, Mathematics) field and understand if contents and tools are accessible for all, regardless of personal need and abilities. Personalization and adaptation emerge as fundamental factors when designing for people with disabilities. Privacy and ethics aspects often neglected are very relevant. The analysis suggests that the STEM field still suffers from accessibility gaps, and current tools need to evolve and be increased to be exploited by different disabilities and ensure the same opportunities for every student, engaging, motivating, and empowering them..

1 INTRODUCTION

People with Disabilities (PD) can experience many difficulties and obstacles when studying, if materials are not fully accessible, ie. suitable for their sensorial needs, learning pace, interaction and cognitive abilities. Artificial Intelligence (AI) can greatly support students with disabilities in different ways (Jadán-Guerrero et al., 2024). First of all personalized learning and adaptive systems (Katonane Gyonyoru 2024, Tapalova & Zhiyenbayeva, 2022) can improve students' performance, engagement, and motivation. AI tutors and chatbots can leverage difficulties and obstacles encountered by people with sensorial, cognitive or physical impairment supporting students in their educational path (Neha et al., 2024, Nacheva & Czaplewski 2024). Unfortunately few attention is devoted to accessibility of chatbots for visually impaired (Grassini et al. 2024).

Accessibility of educational content and materials is necessary for a student with disability, to have the same possibilities to study and build a satisfying career as any other person. This requires different assistive technologies and tools being adopted for different impairments. Content simplification is useful to improve comprehension for students with cognitive and learning disabilities (Heuer & Glassman, 2023). Specific AI tools assist and empower students with disabilities. They include assistive technologies (de Freitas, et al., 2022), real-time AI captioning systems very useful for deaf and hard-of-hearing students (Coy et al., 2024), text-to-speech systems to support people with learning disabilities (Bhatti et al. 2024) and real-time image recognition and description crucial for the visually impaired and blind students to be able to understand the educational meaning delivered by the image (Islam et al., 2023).

AI based emotional recognition systems and chatbots can support students with emotional or cognitive disabilities in deal with different situations and scenarious. They are able to detect emotional states and deliver them in an accessible way offering cognitive and behaviour support for students with learning disabilities or attention disorders (Neha et al., 2024, Hopcan et al., 2023). Last, concerning physical disability, AI-based Wearable Devices and robots assist students in mobility and movements (Pancholi et al.2024). However despite this great progress in AI applied to educational field, students

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still can experience difficulties and obstacles, especially in STEM education field where images are frequent content and accessibility problem are still present (Buzzi et al. 2024).

This study is part of the PRIN project 2022HXLH47 “STEMMA -Science, Technology, Engineering, Mathematics, Motivation and Accessibility” (funded by the European Union - Next Generation EU, Mission 4 Component C2 CUP B53D23019500006). We carried out a systematic review study to understand how AI based technology is actually exploited in education in the STEM field. Specifically, this study aims to answer the following research questions:

RQ1: What are applications of AI in the field of inclusive education?

RQ2: In the STEM field, there are effective AI-based tools for inclusive education?

The paper is organized in 5 section. After this introduction the method is described in section 2. Section 3 includes a table summarizing main features of the selected paper. Section 4 discusses results showing how literature progresses in this field and analyzing current trend and future research challenges. Last conclusion ends the paper.

2 METHOD

Considering the focus of our search is on STEM field accessibility for students with disabilities, an extensive search has been carried out by this paper authors in 2 popular scientific databases: Google Scholar which includes main scientific publishers (IEEE Xplore, ACM, Elsevier, Springer, Elsevier, Acta, etc.) and PubMed, more oriented to clinical and psychological fields. As previously mentioned our focus is on accessibility of STEM content and educational journey. Applying 3 keywords “artificial intelligence” and “students with disabilities” and “stem” since 2020 (last 5 years) we retrieved 15.800 results in scholar and only 1 in PubMed. So we decided to increase the Keywords to restrict the search output of Google Scholar in a more manageable number of items and to discard PubMed since it seems to not be focused on ICT field.

Refining the search with Google Scholar, 7 Keywords have been selected in order to limit the number of results in a set to easily screen manually by researchers: “artificial intelligence" and "students with disabilities" and "app" and "stem" and "inclusion" and "education" and "user experience". We included the term “app” to try selecting actual implementation and the terms "inclusion" and "education" and "user experience" to select HCI oriented studies.

Applying the filters: since 2020 and review studies we retrieved 143 item results in Google.scholar.com. Figure 1 shows results distributed by years, also detailing the review studies. The number of total papers is very increased in the last 2 years, confirming the increased interest in this research field. This review included papers published until September 2024.

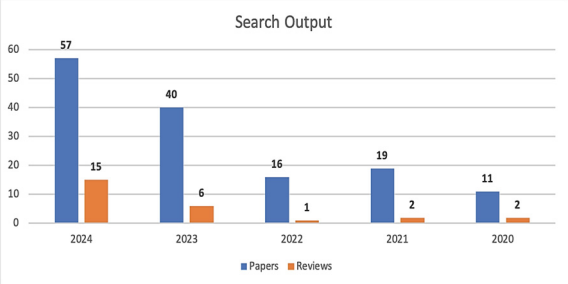

Figure 1: The graph shows the total of retrieved papers by year, and the reviews studies.

The screening process started with a 1st iteration consisting in reading title and abstract to verify the focus on AI and the educational field. General studies do not involving artificial intelligence or not related to the education field as well as low-quality papers (by predatory publishers) have been discarded. In this process about 2/3 of retrieved items were discarded (N=91), reducing the candidate papers to 52. A 2nd iteration consisted in reading the papers and selecting the more focused on our research focus, i.e. students with disability. Unfortunately although mentioning students with disability many papers were not focused on this population. Then after the second screening only 21 papers have been eligible for our study.

3 THE STUDY

The selected papers have been categorized by a) content type (theoric study, review, implementation) b) Purpose or Use of AI c) Target Disabilities, d) Technology/Method, e) user test. In case of system or application the last parameter records if the app or system has been tested with targeted users. Table 1 organizes the analyzed studies versus the selected parameters.

Table 1: Select papers ordered by years.

SOURCE	Type	PURPOSE Or USE of AI	TARGET Disability	Technology/ Method	TEST
Pierrès et al. 2024	Systematic Review	Could the use of AI in higher education hinder students with disabilities?	All disabilities		
Kim et al. 2024	Theoric study	Improving communication and promoting social inclusion for hearing-impaired users	Hearing-impaired	Mobile applications	yes
Bhatti et al. 2024	Review	Reviewing/assessing AI applications for students with learning disabilities	Learning disabilities		
Rai et al. 2024	Implementation	Ethical and social impact of AI driven analysis for students with learning disabilities	Learning disabilities		
Song et al. 2024	Theoric study	Developing a framework for inclusive AI learning design for diverse learners	Learning disabilities		
Hamash et al. 2024	Review	Systematic Review of Extended Reality in Education for the Visually Impaired	Visually Impaired		
Stalmach et al. 2024	Theoric study	Research study of digital learning methods that promote inclusive learning in schools	Learning disabilities		
Mogavi et al. 2024	Theoric study	Assessing ChatGPT in education: a qualitative study exploring early adopters' utilization and perceptions	All disabilities		
Shivashankar et al. 2024	Theoric study	AI's potential in crafting an inclusive, personalized and efficient learning environment for children with disabilities	All disabilities		
Sumak et al. 2024	Focused Review	To identify and discuss benefits and challenges of AI-based tools in inclusive higher education	All disabilities		
Watters et al. 2024	Implementation	Make hands-on laboratory tasks accessible. The Denver Virtual Lab Assistant enables students with VI to perform the laboratory using voice control. The Assistant can be accessed via smartphone or Amazon Echo device	Visually impaired	Amazon Web Services, Alexa Skills Kit, microcontroller Raspberry Pi. Compatible with Talking LabQuest	
Zhai et al. 2023	Systematic Review	Systematic review on AI and education for student with special needs	Learning disabilities		
Frolli et al. 2023	Theoric study	Artificial intelligence (AI) to generate images based on text descriptions, facilitating communication for individuals with autism	Students with ASD		
Contreras-Ortiz et al. 2023	Systematic review	Systematic review: E-Learning Ecosystems for people with ASD	Students with ASD	PRISMA approach (2017 – 2022 studies)	
Iniesto et al. 2023	Implementation	Creation and test of conversational user interfaces (CUIs) to facilitate web interaction for students with disabilities	Visual and learning disabilities	MS Azure Cognitive Services. Direct Line speech. AI Services QnA Maker and Language Understanding	
Herdliska & Zhai 2023	Use of SW in science classes	AI-based scientific inquiry to K-12 students in a way that science is manifested (Google Teachable Machine)	Learning disabilities		
Hughes et al. 2022	Implementation	Robotics & AI to improve STEM and social skills for students with ASD	Students with ASD		yes
Das 2021	Implementation	Making computer science concepts accessible to K-12 students who are Deaf/Hard of Hearing, Blind/Low Vision and those with motor disabilities providing technical strategies to break accessibility barriers	Visually Impaired/ Hearing impaired/ Motor disabilities		yes
Lai 2021	Theoric study	Recommendations for secondary and higher education in terms of digital assessment formats, content, and approach to enhance learning of mathematics.	All disabilities		
Zingoni et al 2021	Design for Implementation	BeSpecial exploits AI to suggest the most suitable strategies for each student (best practices for teachers and digital tools to deliver more accessible contents)	Dyslexya		Yes
Das et al. 2021	Theoric study	Producing videos and developing an accessible block-based web application for deaf/hard hearing students	Hearing-impaired users		

4 DISCUSSION

In this review we analyze scientific studies involving AI for enhancing education of students with disabilities. Impaired functioning of perception channels makes the STEM journey of students more challenging. Deaf students in STEM fields often face challenges due to a lack of teachers experienced in working with deaf individuals, missing the deep knowledge their communication needs. This can result in deaf students feeling discomforted or unable to study STEM subjects (Meghdari & Alemi 2020).

For blind and visually impaired students STEM is intrinsically difficult since it is hard to appropriately decode diagrams, formulas, functions, i.e. to be able to fully understand the semantic value of complex images. Alternative text for digital images does not guarantee that the description is accurate especially if performed by automated tools, including AI large language model (LLM) (Buzzi et al. 2024). The alternative text should be accurate and descriptive while concise as possible, to not overload the user with information not useful (Leotta et al 2023).

Learning disabilities as well as students with ASD can very benefit from personalization and adaptation. Stalmach et al. (2024) investigate numerous digitally enhanced learning methods, focusing on students with special needs in an inclusive learning environment. These approaches have the potential of improving students' academic skills and social performance, but, due to the unicity of each student with learning disability, their effectiveness depends on the competence, flexibility, and adaptability of the teacher delivering accessible instructions and providing adequate support.

Review studies included in this analysis, investigate general aspects for all disabilities such as ethics, privacy, educational and social impact, or focus on a specific theme (focused reviews, system or apps implementation, etc.). In the following first we describe these general studies and after we move on focused studies organizing them by type of disability.

Pierrès et al. (2024) carried out a review analyzing 72 articles presenting AI educational technologies in higher education and observed that there is a clear lack of ethical consideration for students with disabilities. Many of analyzed articles did not consider ethics and mainly focus on privacy, transparency, or bias. The perspective of people with disabilities is rarely considered and they are at discrimination risk for bias and exclusion, when AI is exploited for assessing students. Mogavi et al. (2024) investigated the adoption and perception of ChatGPT in education by analyzing qualitative data collected from social media platforms. Content creation and editing emerged as the most prevalent applications of this technology in higher education (78.11%). However opportunities for ChatGPT to support learning are undermined by concrete risks associated with overreliance on this tool: critical thinking and creativity limitation, lack of a deep understanding, that could favor laziness and passivity.

Song et al. (2024) proposed a framework for inclusive AI learning design grounded in recent literature on AI learning and the principles of UDL (Universal Design for Learning). The proposed framework relies on "AI Five Big Ideas" and emphasizes inclusivity by funding on the three UDL principles i.e., engagement ("why"), representation ("what") and action & expression ("how").

Shivashankar & Bakthavatchaalam (2024) explored the development of data-driven management practices and policies to address the educational needs of children with disabilities proposing a model for helping that all students, regardless of their abilities, have the opportunity to have success at school. Artificial Intelligence in education can offer personalized learning experiences, adaptive assessments, and smart content delivery, transforming the way students learn and interact with educational content (Aithal, & Maiya 2023).

Contreras-Ortiz et al. (2023) analyzed 20-years of scientific ~~of~~ literature observing the evolution of AI approaches from static data to currently sophisticated large language models able to deal with huge amount of real-time multi-modal data (e.g., student-teacher/peer interaction data, click-stream information, web-browsing data).

Aldoukhi et al. (2023) analyzed personal assistants like Siri, Alexa, and Google Assistant to support students with disabilities in accessing information and communicate naturally via voice. AI-powered real-time captioning and speech recognition software can aid the hearing-impaired and students with physical disabilities. Predictive text and natural language processing system can support people with cognitive disabilities, while smart devices and chatbots can enable greater control and access supporting students. Adaptive learning software exploits artificial intelligence to customize the educational training path and satisfy the unique needs of every students. Personalized instruction and feedback can be delivered via AI tutors.

Zhai & Panjwani-Charania (2023) carried out a systematic review on AI and education for student with special needs categorizing the application field: Adaptive learning was the most frequent use of AI in

the educational field. AI is used to deliver learning support based on individual learning needs. This includes intelligent, serious games, intelligent tutoring systems, or advanced e-learning management system. Intelligent tutor exploits dynamic machine learning models to detected student's learning difficulties and recommend a personalized learning strategy. Intelligent assistants support effectively students with ASD or dyslexia. Exploiting AI to enhance Augmentative and Alternative Communication (AAC) increases the ease of verbal communication for students. AI tools correct frequent text writing errors of students with dyslexia. AI based chat assistants provide accessibility support to students.

Iniesto et al. (2023) created conversational user interfaces (CUIs) that supports written and spoken dialogue, as a simpler a natural interaction alternative to static web forms filled by students with disabilities.

Concerning engagement and monitoring students' progress over time, machine learning and AI models are exploited to understand the user's progress and support the user in achieving mastery (mastery learning) and facial expression recognition to predicting student engagement.

4.1 Visually Impaired

Watters et al. (2021) implemented a new AI tool, the MSU Denver Virtual Lab Assistant that enables visually impaired students to perform the hands-on laboratory autonomously using voice control. This is very important for student autonomy and self-confidence. The system accessed through any smartphone or via Amazon Echo assists the student in the science lab tasks. It is designed to be applicable to different science laboratory works. This AI based system is an inclusive tool making accessible science education lab tasks to visually impaired. Sounds augmentation associated to haptic and tactical feedback delivers sensory information and enable an Augmented Reality experience for visually impaired users, tailored to meet specific needs of the user. In this context artificial intelligence personalizes the learning experiences and delivers real-time feedback in the educational applications (Hamash et al., 2024).

4.2 Hearing-Impaired

Kim et al (2024) investigates the usability of communication-assistive applications for hearing-impaired users, with a focus on enhancing user experience and promoting social inclusion showing that improvements are necessary. The increasing employ of AI requires more inclusive research methodologies that involve disabled individuals in designing of apps, products and services. It is crucial considering the unique requirements and experiences of hearing-impaired users, when developing user interfaces that favor relations and social support.

Das et al (2020) investigates how to improve Computer Science and coding skill in K-12 deaf/hard hearing students delivering Sign Language video resources and an interactive funny block-based coding learning environment (web application) where students can control programmatically a robot, in order to favor and stimulate independent learning and creative problem solving (based on MIT's Scratch).

4.3 Motor Impaired

Das (2021) suggests how to create Accessible Block-Based Programming tools for students with different needs. Motor Disabilities population can exploit speech-to-text converters and the case for language understanding by using AI to enhance these solutions.

4.4 Learning Disabilities

This impairment impacts in one or more processes involved in language comprehension or usage and reduced ability in listening, thinking, speaking, reading, writing, spelling or performing mathematical computations (dyslexia, dyscalculia, ...). Bhatti et al. (2024) carried out a systematic review on Artificial Intelligence Applications for Students with Learning Disabilities. Seven distinct types of AI applications can support students with learning disabilities: adaptive learning emerged as the most prevalent, facial expression analysis, chat robots, communication assistants, mastery learning systems, intelligent tutors, and interactive robots. They show the great potential of AI in enhancing the educational experience for students with learning disabilities.

Rai et al. (2024) integrated AI capabilities (for gesture recognition) to provide recommendations for enhancing education through a decision support system (DSS). Exploiting artificial intelligence to select appropriate study strategies can contribute to reduce the negative effects of learning disabilities on student academic performance. This is achieved by offering personalized interventions, adjusting educational methods to match students' cognitive profiles, and promoting inclusivity. In this way academic results improve for any students, regardless of their abilities.

Zingoni et al. (2021) exploits students' clinical reports of dyslexia, survey results, and psychometric

test results as inputs to train AI algorithms, in order to be able to predict individual needs (e.g., concentration, memory impairments) and provide support and adaptive strategies (e.g., conceptual maps, schemes, highlighted keywords).

4.5 Autism Spectrum Disorder

Interaction is an important challenge especially for students with Autism spectrum disorder (ASD). Interactive and social robot offering an unambiguous and predictable answer, can support students exploiting multimodal machine learning ~~to~~ for engagement in the classroom. Best results in interventions with students with ASD are observed exploiting: a) technology devices (e.g., touch screens, smartphones, laptops, smart glasses), b) AI-based systems, serious games, augmented reality, and robots. Lack of generalization is one of the most challenging factors to counteract, related to heterogeneity of the population, the intervention duration, and complexity of skills (Mallik et al 2023).

Hughes et al. (2022) created an virtual learning environment that assists children with autism in STEM skills along with improving social-emotional and communication skills. The AI based system delivers interactive, personalized, and individualized process matching needs of students with ASD. The system control if students are at the tablet and are making progress on the programming tasks. Results suggest that creating student-driven AI tools, that students can use to assist their self-regulation in any environment, could help neurodivergent people being represented in STEM fields.

In addition to personalized learning and communication support AI-based tool can provide Behavioral and Emotional Support: detecting patterns of behaviors and providing feedback to help individuals to keep behaviors adequate to the context and training them to regulate their emotions (Frolli et al., 2023).

Despite the large amount of STEM literature, only few studies focus on STEM and students with disabilities and accessibility of SW tools, digital materials, and multimedia educational contents. Lai (2021) analyzes literature and accessibility of software for learning math currently on the market providing useful recommendations in terms of assessment formats, content, and approach to enhance learning for students with disabilities in higher education. There is not an accessible tool that would promote learning for everyone but a good tool suits the needs of the pupils and teachers. Herdliska & Zhai (2023) investigates the use of Google Teachable Machine, an AI application, to lead science classes. Teachable Machine exploits AI and machine learning to develop algorithms that could solve complex, concrete problems, offering a great support for STEM topics for students with learning disabilities.

5 CONCLUSION

AI is rapidly transforming the educational ecosystem by making learning more inclusive by empowering students with disabilities in deal with their academic path. AI models still need to progress for ensuring accessibility for people with disabilities, specifically need to improve readability. Understandability of chatbot output in fact depends on the prompt's focus and current readability metrics do not discriminate whether the text is useful or not (Nacheva & Czaplewski 2024).

Important suggestions for promoting inclusion through the application of Artificial Intelligence can be delivered by caregivers (both teachers and parents) for identifying challenges and proposing the implementation of adapted educational resources (Jadán-Guerrero et al., 2024). This requires adequate infrastructure, specialized tools, inclusive methodologies, and software to facilitate the learning process and avoid educational gap.

To answer this study's research questions, there are a number of AI applications in the field of inclusive education addressing need of different disability but only few of them propose solutions focused on STEM contents, suggesting that more research is needed in this way area. Moreover the effectiveness of AI-based tools in the STEM field needs more effort since the most of studies do not collect data regarding tests or effective use in classroom with students with disabilities. Very few apps and systems are actually implemented, tested and used at large scale. It is urgent to create free, reliable and usable open source solutions to benefit students with disability in order to filling the STEM filed gap and really offer fair opportunities for any students.

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