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PERSONALISED PRESENTATION OF MATHEMATICS FOR VISUALLY IMPAIRED OR DYSLEXIC STUDENTS: CHALLENGES AND BENEFITS

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Abstract

Artificial Intelligence in Education (AIEd) has the potential to transform learning by providing personalised and adaptive environments and enabling more effective assessment and feedback (Luckin et al., 2016). Implementing AIEd has different challenges involving accommodating different learning styles, understanding how learners interact with tools, creating accessible technology for students with learning or sensory disabilities, and managing cognitive load and stress. The potential benefits of using AIEd for the personalised presentation supports inclusive learning environments, including improved understanding, accessibility to learning (Costas-Jauregui et al., 2021), reduced stress (Hsu et al., 2021), and cognitive load (Turan & Goktas, 2016), to improve mathematical understanding and student confidence. Neto et al. (2021) argue that the opportunity to utilise robots to enhance inclusive classroom experiences lies in their ability to utilise their physical attributes, multimodal feedback systems, customised social behaviours, and sensory functions. The potential benefits promote the development of inclusive and intelligent educational frameworks. In this paper, the authors examine the potential of using AIEd combined with robotics to provide a personalised learning framework for students with learning disabilities (e.g., dyslexia) and sensory disabilities (e.g., vision impairment/blindness). The paper will assess the challenges and benefits of the AIEd framework combined with robotics for inclusive mathematics education.

Keywords:

Artificial Intelligence in Education (AIEd), Universal Design for Learning (UDL), Virtual Reality/Augmented Reality (VR/AR), Human Computer Interaction (HCI), Robotics, Mathematics Education, Extensive Academic Emotion (EAE).

1. Introduction and Background

Mathematics education can be challenging for some students, particularly students with visual impairments or dyslexia. Traditional teaching methods often rely on visual cues, making it difficult for visually impaired students to understand mathematical concepts fully. While students with dyslexia experience challenges that include difficulties with reading, writing, spelling, and phonemic awareness (Lyon, Shaywitz, & Shaywitz, 2003). These difficulties can lead to academic and occupational struggles, as well as negative emotional outcomes such as low self-esteem and anxiety (Shehu, Zhilla, & Dervishi, 2015). In addition, they may also experience challenges with executive function, working memory, and attention (Sesma et al., 2009). These challenges can significantly impact mathematics education, so educators must be aware of them to provide appropriate support and accommodations.

1.1 A Framework for Inclusion: Promoting Disability Rights in Education in Ireland and Europe

The United Nations adopted the Convention on the Rights of Persons with Disabilities (CRPD) in 2006, and both Ireland and the European Union (EU) have ratified it (European Union, 2006). The CRPD aims to protect and promote the rights of persons with disabilities, including in education. In Ireland, the Disability Act 2005 provides a framework for providing services for people with disabilities, including in education. The act requires public bodies, including schools, to provide reasonable accommodations for people with disabilities (electronic Irish Statute Book, 2005). The Employment Equality Acts 1998-2015 and the Equal Status Acts 2000-2015 also prohibit discrimination against people with disabilities in employment and education (Government of Ireland, 2015a; Government of Ireland, 2015b). Additionally, the National Disability Inclusion Strategy 2017-2021 in

Ireland provides a framework for promoting the inclusion of people with disabilities in all aspects of life, including education (Gov.ie, 2017). These regulations and strategies demonstrate a commitment to promoting the inclusion of people with disabilities in education in Ireland and Europe and highlight the need to design inclusive educational frameworks.

2. Towards Establishing Effective Personalisation for the Presentation of Mathematics to Individual Learners

Universal Design for Learning (UDL) framework is based on designing educational materials and environments that are accessible and effective for all learners, regardless of their backgrounds or abilities. This includes providing multiple means of representation, expression, and engagement that allow students to access and interact with information in ways that work best for them (McKenzie & Dalton, 2020), which might mean providing materials in alternative formats, such as Braille or audio recordings, for visually impaired students. For dyslexic students, this might mean providing materials with alternative text formats or using assistive technology to support reading and writing. Using the UDL framework, educators can create more accessible and effective learning environments that benefit all students, including those with disabilities or learning differences.

Other inclusive educational programs that are effective in teaching mathematics to visually impaired and dyslexic students include the Sonification Sandbox and the MathTrax (Garcia et al., 2019). These systems also focus on providing multiple means of representation and engagement to support diverse learners. Choosing an inclusive educational framework ultimately depends on the student's needs, learning styles, available resources, and technology.

Humans process information in various ways, including through visual and verbal modalities and other cognitive factors such as personality traits. The Felder-Silverman Learning Style Model (FSLSM) and Myers-Briggs Type Indicator (MBTI) are two widely used models for understanding how people learn (Felder & Silverman, 1988; Myers & Briggs Foundation, 2019). The FSLSM identifies four dimensions of learning styles: sensing vs intuitive, visual vs verbal, active vs reflective, and sequential vs global. While the Myers-Briggs Type Indicator (MBTI) identifies four dichotomies of personality types, including extraversion vs introversion, sensing vs intuition, thinking vs feeling and judging vs perceiving. Both (FSLSM) and (MBTI) might help educators personalise the presentation of mathematics to individual learners (Adewale et al., 2019; Ivanov et al., 2019). Stein et al. (2019) argue that while the MBTI has the potential to aid educators in personalising instruction, it can be difficult to collect comprehensive and precise information about the personality types of individuals.

A study by Mehigan et al. (2011) found that eye-tracking technology can accurately identify learners' preferred processing styles and that different types of learners may benefit from different presentation formats. The study evaluated the findings using gaze patterns, heat maps, and fixation count. By identifying learners' preferred processing styles, educators and curriculum designers can tailor the presentation of mathematical content to suit the needs of individual learners better, potentially leading to more effective learning outcomes in UDL.

Robots have the potential to improve education. Salas-Pilco (2020) found that using robots in educational environments benefited learners. The study investigated the influence of robots on students' physical, social-emotional, and intellectual learning outcomes, where each student displayed distinct learning trajectories.

2.1 Cognitive load and stress affect learning and academic achievement in educational psychology

Research on academic emotions (AE) suggests that emotions play a critical role in how individuals experience cognitive load and stress (Pekrun, 2006; Pekrun et al., 2002). Negative emotions such as stress can cause external cognitive load as thoughts about emotions, emotion regulation processes, and learning tasks compete for working memory resources; positive emotions can also have the same effect (Oaksford et al., 1996).

Educators can reduce cognitive load and stress by implementing strategies that promote self-regulation and positive academic emotions, such as providing clear and structured learning materials, giving feedback that emphasises effort and improvement, and encouraging student autonomy and choice (Pascoe, Hetrick & Parker, 2019). AIEd frameworks can help students cope with increased cognitive load and stress management.

There has been an increasing focus on (AE) in the past few years. To further this concept, Mehigan, and Pitt (2019) suggest incorporating emotional factors from HCI research into the design of interactive systems, resulting in the concept of Extensive Academic Emotion (EAE). When examining the role of AIEd, the idea of (EAE) can potentially impact student engagement and achievement positively or negatively.

EAE can potentially improve learning outcomes and increase engagement by fostering positive academic emotions while decreasing cognitive load and stress. The use of Virtual Reality/Augmented Reality (VR/AR) and other HCI technologies can facilitate immersive and interactive learning experiences, aiding learners in developing a more comprehensive understanding of intricate concepts and in applying their knowledge in practical, real-world situations (Zhu, 2016).

3. Towards the Development of Technologies for the Inclusive Presentation of Mathematical Content

Traditional mathematical notation heavily relies on visual representations, which can be challenging for students with visual impairments (Máckowski et al., 2018). Dyslexic students may struggle to decode and comprehend written mathematical symbols and notation (Nieminen & Pesonen, 2019). Thus, developing technology that can present mathematical content in a way that is accessible to these learners is crucial.

The use of artificial intelligence (AI) in education has the potential to benefit all students, including visually impaired and dyslexic students. AI can provide alternative modalities for presenting information, such as graphics, animations, and tactile feedback (Mukhiddinov & Kim, 2021).

AI technologies can provide alternative means of accessing information through text-to-speech or speech-to-text conversion (Abhishek et al., 2022), enhancing mathematics education for visually impaired students. Additionally, robots could provide personalised and adaptive learning experiences tailored to each student's needs and abilities (Johal et al., 2018). For example, using a robot tutor has improved reading comprehension and fluency in dyslexic students (Belpaeme et al., 2018).

Robots are great for implementing new educational methods, such as teaching through exploration (Jamet et al., 2018) and personalising instruction using AI. That is due to the robots' physical embodiment, movement, voice, and vision capabilities, which have encouraged their adoption as assistive technology (Neto et al., 2021). According to (Daniela & Lytras, 2018), educational robots can have multiple benefits utilised to construct knowledge and an assistive aid for students who struggle in certain subject areas. Additionally, educational robots can potentially transform the classroom culture by fostering an inclusive learning environment where all students feel accepted and engaged.

(VR/AR) technologies can provide multisensory experiences that help students visualise, touch, and hear mathematical concepts, thereby enhancing the student's understanding and engagement with the subject matter (Lorusso et al., 2021; Donally, 2022), which can offer a promising approach to teaching Mathematics to blind and dyslexic students.

However, there are also potential challenges in using VR/AR technologies to teach mathematics to blind and dyslexic students. One challenge is the cost of the technology, which can be prohibitive for many schools and educational institutions (Vuorinen et al., 2018). Another challenge is the need for specialised software and training for teachers to use these technologies in the classroom effectively (Smith & Hattingh, 2020). Additionally, some students may experience discomfort or motion sickness when using VR/AR technologies, which can negatively impact their learning experience (Tychsen & Foeller, 2019). Despite these challenges, using VR/AR technologies in mathematics education holds excellent potential for providing personalised and inclusive learning experiences.

4. Understanding Learner Interaction with AIEd and Other Learning Technologies

Incorporating personalised delivery of mathematical education along with multimodal feedback and immersive environments can provide multiple benefits for students with dyslexia or visual impairments. These benefits may include the following:

- Inclusion:
  Multimodal feedback and immersive environments enable students with dyslexia or vision impairments to participate fully in mathematics classes, eliminating learning barriers, enhancing collaboration opportunities with other students and teachers, and promoting inclusivity.

- Improved learning, accessibility and understanding:
  Personalised interaction can enhance the accessibility for visually impaired students, enabling them to access information more easily and process it more effectively (Máckowski et al., 2018). Furthermore, it also provides multiple sensory channels for processing information and enables all students to engage with mathematical concepts more effectively.

- Reduced stress:
  Immersive environments can help to reduce stress and anxiety in students with dyslexia or vision impairments by creating a more relaxed and engaging learning environment (Hsu et al., 2021).

- Reduced cognitive load:
  Research has shown that learners' cognitive load and motivation can be affected by the design and usability of learning tools and requires a deep understanding of the learners' needs and preferences (Zhu & Simon, 1987). Multimodal feedback and immersive environments can help reduce cognitive load for students with dyslexia or vision impairments by presenting information clearly and concisely and enabling students to engage with concepts at their own pace (Turan & Goktas, 2016).

Creating a user-friendly AIEd system that includes all students in the learning process is crucial; this involves understanding the elements that affect users' interaction with the system, such as the content's suitability for the users' learning objectives and the user interface's overall quality (Holmes et al., 2022).

According to Roll and Wylie (2016), AI in education (AIEd) has made significant technological and theoretical progress, resulting in successful pedagogical outcomes. One notable application of AIEd is using intelligent tutors for personalised content delivery, feedback provision, and progress monitoring, as highlighted by Bayne (2015). Guan et al. (2020) suggest that AI can provide specialised support, bridge knowledge gaps, and enable instructors to deliver effective and efficient adaptive instruction.

Several aspects of education have included (AI), including curriculum development, personalised learning materials, evaluation, and teacher-student interaction. The advantages of interactive learning environments (ILEs) include monitoring and analysing students' progress, offering feedback, and facilitating effective engagement and interaction between students and teachers (Alam, 2021). Robots can be developed using (AI), computers, and integrated support equipment to enhance students' learning experiences. Collaborative robots (cobots) can work alongside human teachers to teach basic skills while adapting to each student's abilities (Timms, 2016).

Conclusion

The paper outlines insights into the challenges and benefits of implementing a combined framework of AIEd and robotics for the personalised presentation of mathematics. Additionally, the authors identify potential benefits and challenges of personalised presentation of mathematical equations with multimodal feedback and immersive environments for students with dyslexia or vision impairments. The paper explores the potential development of an AIEd framework and its implementation towards creating a holistic tool for developing an inclusive learning environment for mathematical education.

AI, VR, AR, and robotics could become increasingly essential in mathematics learning, providing students with more interactive and personalised ways to engage with mathematical concepts. However, these technologies pose several challenges, such as appropriate training for educators, equitable access to these resources, and concerns about privacy and data security. The future plans for integrating these technologies in mathematics education include using adaptive learning systems, personalised content, and more immersive learning experiences. These technologies can potentially revolutionise how we teach and learn mathematics. However, we must also address these challenges and ethical considerations.

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