Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 19 No. 5 (2025) | OPEN ACCESS

https://doi.org/10.3991/ijim.v19i05.51321

PAPER

Fostering Empathy and Social-Emotional Learning in Students with Learning Disabilities through HCI and Augmented Reality

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ABSTRACT

This systematic review synthesizes the suggested approach to designing human-computer interaction (HCI) in conjunction with augmented reality (AR) applications to enhance learner empathy with learning disabilities (LDs). However, as the popularity of both AR and HCI increases within the context of education, there is a dearth of literature on integrating the two in supporting social and emotional learning (SEL) in students with LDs. SEL refers to the learning process by which a person gains academic and social competencies and can also apply, cipher, and internalize the competencies related to emotional, social, and academic aspects of human life. This review summarizes the studies published between 2015 and 2024. It discusses how the AR-based immersive and interactive learning contexts can improve these students' social and emotional learning and reduce their technophobia. It is evident from the highlighted gaps that comprehensive features, user-centered design (UCD) principles, and gradual implementation of technology are possible solutions to enhance the learning and emotional development of students with LDs. This paper highlights the existing gaps in literature and provides recommendations for future and practical research.

KEYWORDS

augmented reality (AR), multimedia and virtual environments, social and emotional learning (SEL), inclusive learning design, learning disabilities (LDs)

1 INTRODUCTION

Social and emotional learning (SEL) is important for students with learning disabilities (LDs) because it is an effective and social developmental program that focuses on providing students with skills in order to regulate their emotions, build and maintain relationships, and make responsible decisions that will foster their well-being and success in other domains of their lives as well as academic achievement [12]. However, current frameworks for implementing social and emotional learning might not suffice for

Almakky, H.G. (2025). Fostering Empathy and Social-Emotional Learning in Students with Learning Disabilities through HCI and Augmented Reality. *International Journal of Interactive Mobile Technologies (iJIM)*, 19(5), pp. 79–97. https://doi.org/10.3991/ijim.v19i05.51321

Article submitted 2024-07-23. Revision uploaded 2024-12-10. Final acceptance 2024-12-10.

this particular group of learners, and new approaches might be needed. For this reason, augmented reality (AR) may be viewed as a promising tool that enhances learning immersion and interaction, which can contribute to a higher level of social and emotional learning achievement [32]. The realistic simulations created by AR are helpful in PC for teaching empathy and emotional perspective-taking to students with LDs, as they can look at a situation from multiple points from a safe/controlled emotional perspective, as noted by Fombona et al. [9]. SEL frameworks often overlook the cognitive-neurological challenges affecting these students' emotional regulation and social interactions [27]. This research identifies a significant gap in the literature. While the importance of SEL for students with LDs is widely acknowledged, there is insufficient exploration of tailored, technology-driven solutions to enhance their emotional and social competencies. Applying human-computer interaction (HCI) frameworks in AR application development is essential to ensure effectiveness. Furthermore, applying HCI principles makes interfaces and interactions easily accessible to everyone [23], including persons with LD [5]. According to Zhou et al. [31], HCI design features help minimize technology utilization constraints, eradicate technophobia, and engender a technology-constructive learning climate when well promoted. When integrated with AR, HCI can facilitate the creation of targeted interventions for learning difficulties experienced by students with LDs. Vaiopoulou et al. [23] provide a framework for selecting effective educational apps and highlight the importance of app design in education to maximize its impact on learning. Their work focuses primarily on the young generations' education; the principles they outline are wide and broad for designing educational interventions for students with disabilities. Therefore, this research seeks to discover how applying the principles of HCI in AR applications can enhance students with LDs' understanding of emotions. It also aims to discover the HCI design approaches that may help reduce or alleviate technology phobias and possible suggestions for future research and application. LDs are defined as a range of disorders that are characterized by difficulties in learning or using skills such as reading, writing, listening, speaking, reasoning, and calculating. These are neural-based disabilities and do not define a person's intelligence since they only affect the central nervous system. LDs impede educational performance and day-to-day functioning, necessitating instruction, teaching, and learning strategies [27]. SEL is important in providing equal opportunities for the development of important competencies required to tackle life processes by students with LDs, such as handling their own emotions and developing relationships, through making the right decisions within schools, which will facilitate academic performance and overall well-being [35]. However, traditional SEL frameworks fall short on several dimensions that are probably most critical in the unique needs of these students, especially with respect to nurturing empathy and emotional understanding. In this respect, there are some common difficulties with social interactions and emotional regulation among students with LDs because of cognitive-neurological difficulties, which can be reflected in their learning experience and further inclusion [27]. Therefore, the current approaches do not seem adequate to meet these challenges, so better solutions are needed.

2 LITERATURE SEARCH

2.1 Overview

The latest literature says such immersive technologies, including AR, can support the construction of even more engaging and interactive learning environments to improve SEL outcomes for students with LD. AR allows one to create realistic simulations in which learners can view situations from many points of view—a very fruitful way to build empathy and emotional understanding [18]. Additionally, when developed under the guidelines of the HCI, the AR application will be friendly for students with disabilities [5]. Research has found that concepts of HCI design, including UCD and iterative development, can reduce the technological barriers and technophobia and thus create a better learning environment for students with LDs [40].

Bhatti et al. [13] also mention that when adaptive learning systems integrate multimodal affect recognition, the presented learning experiences are personalized to fit every student's needs, promoting effortless mastery of emotional and social skills for students with intellectual disabilities. This concept of personalization aims to address specific shortcomings of cognition and encourages a disposition toward learning. Similarly, Chalkiadakis et al. [1] and McCall [2] also agree with the inclusive education paradigm by employing AI and VR. According to their systematic review, this reveals that LD students can benefit from AR interactions that create opportunities to learn about empathy and emotional awareness. Technologically inclined design principles such as user-centered design (UCD) and feedback subsystems make these tools even more user-friendly, diminishing the effects of technophobia on learning engagement.

This is expanded by Girginova et al. [16], who explored AR campaigns that seek to elicit empathic responses through community engagement. Their evidence has established that when students with LDs use AR simulations in settings that mimic social roles, they may exhibit more appropriate interactive emotional skills. These AR experiences are designed with HCI principles in consideration to ensure that students can relate to the interfaces created through these simulations. Besides, it promotes a positive measure to improve SEL outcomes and causes students to learn how to relate to different opinions. As Thakar and Vyas [36] also stress, technologies such as AR, implemented in combination with user interface (UI) and user experience (UX) designs, enhance numeracy and the ability to comprehend emotions among students with intellectual disabilities. Combined with AR, HCI design approaches make these tools more effective at helping learners overcome cognitive obstacles and eliminate anxiety. The truth is that most HCI is gradual, and it increases in value based on regular user feedback, enhancing their performance. This continues to help reduce the students' phobia of using any form of technology and sets them up with a favorable attitude towards digital learning tools.

Wang et al. [38] give a detailed account of the importance of empathy fostered through the use of digital technology concerning students' motivation and involvement. Their work suggests that learning experiences facilitated by AR can engender a state of 'flow' within the student, which allows students to be fully immersed in learning. Such an immersive engagement helps to foster adequate emotional literacy–a key component of SEL based on empathy. Designing these AR applications based on HCI principles ensures that they are especially friendly for students with LDs and can be modified to meet their needs almost effortlessly so that they will be in a position to learn various social-emotional strengths. Lofandri and Salameh [37] explain how the intelligent e-learning monitoring system detects and recognizes students' feelings in real time using CNN to recommend intervention and support engagement using innovative technology. This supports HCI and AR's role in learning according to the learners' emotional and cognitive status.

Furthermore, Yenduri et al. [11] describe several helpful technologies, such as AR and the metaverse, for teaching and learning for learners with disabilities in higher learning. They claim that while learning design embraces accessibility, AR can bring innovative enhancements to the learning outcomes of students with learning disorders. If these technologies adhere to the HCI principles, as Huff [8] highlighted, creating environments that foster learners' empathy and emotional intelligence becomes possible. By using AR and HCI, the frustrations that students may experience are minimal, and problems like technophobia and cognitive overload are likely to be eradicated.

The present study is unique in questioning how integrating AR and HCI, at least concerning UCD and iterative development paradigms, may help build up SELs of learners with LDs. The review has focused on the feasibility of the technologies in enhancing the students' capabilities in empathy and emotional understanding, besides overcoming the fear of technology that has been an issue of concern for LD students. Thus, to ensure the maximum inclusion of appropriate articles, a multiple search method was used to capture articles examining the combination of HCI with AR in increasing empathy and improving emotional intelligence for students with learning difficulties. The search was limited to peer-reviewed journal articles published between 2015 and 2024.

Databases searched. The databases selected for this review were:

- **ERIC:** Education Resources Information Center
- **Scopus:** A multidisciplinary database covering a broad range of topics
- **Google Scholar:** A freely accessible web search engine for scholarly literature
- **PubMed:** A database of biomedical literature
- **PsycINFO:** A database of literature in psychology and related fields
- **IEEE Xplore:** A digital library for research in engineering and technology

The search strategy included the following keywords:

- "Augmented Reality"
- "Human-Computer Interaction"
- "Learning Disabilities"
- "Empathy"
- "Emotional Understanding"
- "Social Emotional Learning"
- "Technology Fear"

These keywords were applied in different permutations for a broader and more exhaustive search. Boolean operators such as AND, OR were used to narrow the search results while ensuring that all the research studies were included. Furthermore, lists of cited articles were examined to find other relevant works in the focus areas. This systematic approach sought to identify a range of publications that would help respond to the set research question and objectives and encourage a wide range of publication sources to be considered in the final analysis.

2.2 Research question

In what way can principles of HCI, incorporated with AR applications, improve empathy and the ability to understand emotions in students with learning disabilities?

2.3 Research objectives

- Evaluate the effectiveness of AR applications integrated with HCI principles in promoting empathy and emotional understanding of students who have learning disabilities.
- Identify HCI design strategies that address technology-related fears and barriers among students with learning disabilities.
- Provide proof of recommendations for future research and practice applications of HCI and AR in educational interventions for students with learning disabilities.

3 METHODOLOGY

To ensure a robust and relevant collection of studies, the following inclusion criteria were established:

1. Publication date: This research mainly included articles published between 2015 and 2024 to obtain the most recent information.
2. Peer-reviewed journal publications: Only those published in scientific peer-reviewed journals were chosen to increase the reliability of the articles.
3. Full-text availability: The application needed to include the full text of the studies to obtain specific data.
4. Target population: The studies were filtered according to the sample of students with LDs to make the conclusions more relevant to this population.
5. Interventions: Therefore, to investigate the integration of the above technologies, only papers discussing interventions, including AR applications developed according to the principles of HCI, were selected.
6. Outcomes: The research work had to state the effects on empathy, emotional intelligence, and technology phobia within the research question and objectives.

Exclusion criteria. Studies were excluded based on the following criteria:

1. Non-compliance with inclusion criteria: Any clinical trial that did not meet the above criteria was excluded from being included in the analysis.
2. Non-peer-reviewed sources: Conference papers, theses, and dissertations were excluded as secondary sources to limit the review to the highest level of evidence.
3. Irrelevance to research question: Other papers unrelated to the research question or that did not integrate HCI with LDs for AR applications were also dismissed.

Data extraction and synthesis. This study examines the following to evaluate the use of AR technology in education for students with learning disabilities:

- Study characteristics: Some of the details sought included the authors, the year of publication, the country of origin, and the size of the population sample of the study.
- HCI design elements: Data was collected on the specific concrete HCI design processes that were employed in the different AR applications.
- AR intervention details: When collecting data on the characteristics of AR interventions, it is important to determine the kind of AR technology used, the duration of the intervention, and the type of education.
- Social and emotional learning outcomes: To measure the effectiveness of the programs, information on the results in relation to empathy, the extent of emotional arguments, and technophobia was obtained.

Synthesis:

- Narrative synthesis: This analysis synthesized the individual cross-study findings using the narrative synthesis approach. This entailed categorizing the extracted data into themes and patterns, which articulated the effect of HCI and AR on empathy and the ability to understand emotions.
- Meta-analysis: The meta-analysis was performed to integrate the results of the included studies applying statistical methods. This entailed computing confidence intervals for the SEL outcomes and evaluating the synthesis of the interventions.

Statistical analysis was conducted to assess the variability of the studies, and sensitivity analysis was used to assess the potential gender moderating factors. Thus, by adopting this approach, searching for relevant articles systematically and thoroughly when focusing on applying HCI principles that help improve empathy and better understand the emotions of students with learning disabilities.

4 RESULTS

The PRISMA flow diagram (see Figure 1) illustrates studies inclusion for this systematic review: The initial searches in different databases yielded 80 records. Out of the 86 initial records obtained after deleting duplicates, 80 records were screened, and 57 further records were excluded using relevance and quality criteria. The authors of the remaining 23 articles provided the full text that was reviewed for eligibility; all 23 full-text articles were included in the qualitative synthesis and quantitative synthesis/meta-analysis.

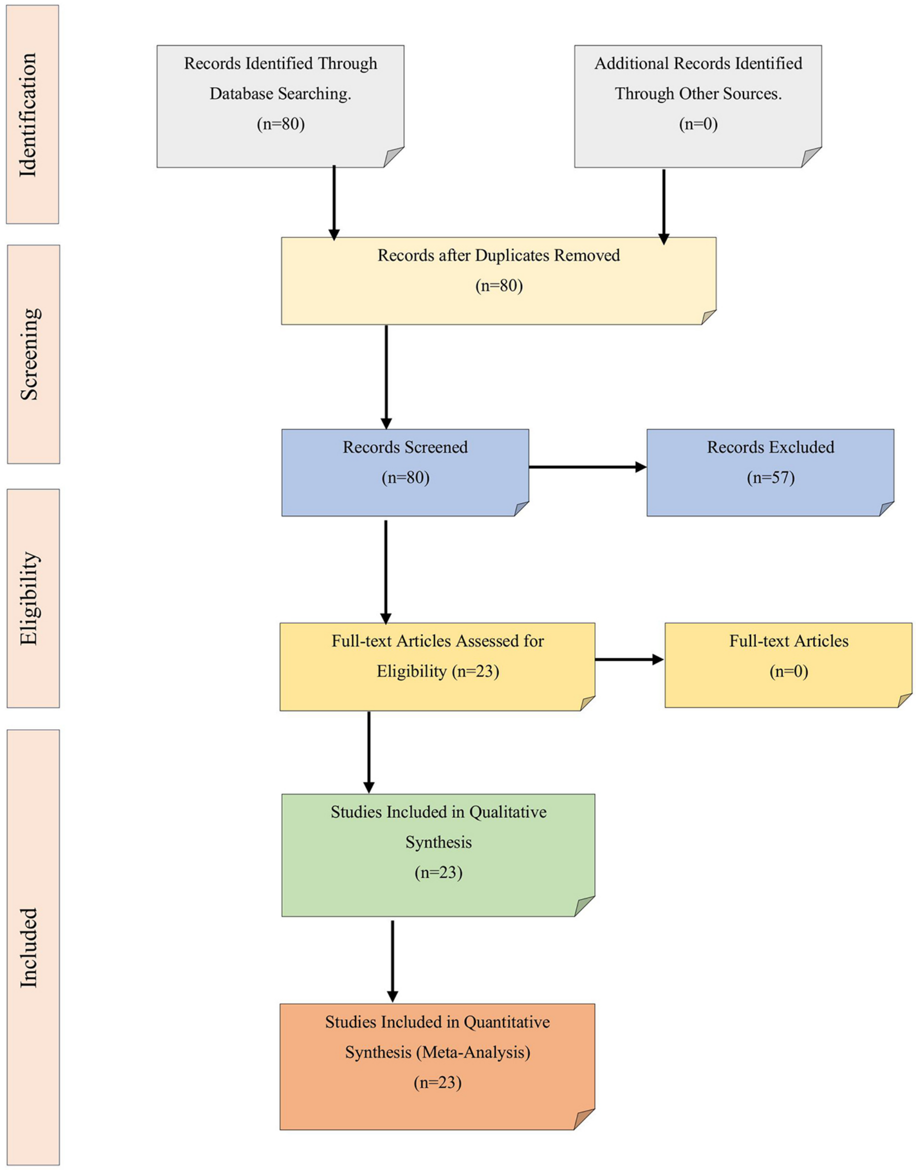

Fig. 1. PRISMA flow diagram

4.1 Overview of included studies

This systematic review encompasses a total of 23 papers. These studies were carefully chosen out of about 86 articles in the initial search using the described search strategy. The studies were published between 2015 and 2024, and the analysis will focus on the recent innovations and trends in integrating AR with HCI principles to enhance SEL in students with LDs. The studies' locations are geographically diverse, ranging from North America, Europe, Asia, and Australia. These submissions cover many different education types and cultures, giving a more extensive understanding of how AR and HCI were used worldwide. Although the settings ranged from primary schools to tertiary institutions, many were based on K-12 education. The sample size included a small pilot study with fewer than 20 participants and a larger sample size of more than 100 students.

Types of AR applications and HCI design. All the applications used across the studies embraced AR technology and showed the flexibility of utilizing AR in educational practice. The applications included:

- AR-based storytelling: Employed to develop storyline experiences that the students could engage with to stretch emotional learning and intake.
- Interactive simulations: We presented them with contingency situations of social interactions and situations in which the students could identify with the character's feelings in the interaction.
- Virtual environments: Enable learners to navigate and engage in simulation environments that facilitate learning emotional and empathetic techniques.
- AR-enhanced learning materials: Some teaching aids used are textbooks and worksheets, into which other forms of AR were incorporated to make learning more engaging.
- The HCI design strategies employed in these applications were integral to their effectiveness. Common strategies included:
- User-centered design: Engaging learners and other stakeholders to give them a say in what needs to be done and what should be offered to them and would suit them best.
- Iterative development: Structural feedback is employed when prototypes are developed, tested, and redesigned.
- Accessibility features: We ensured that the AR applications were fully accessible for students with disabilities via options like the increased font option, the description of the pictures in the text-to-speech mode, or the changes of the input tools.

Effectiveness of AR interventions. Studies show that AR interventions significantly enhance empathy and emotional understanding in students with LDs, improving their emotional recognition, empathetic behaviors, and social interactions. Compared to traditional methods, AR provides higher engagement, better retention, and greater inclusivity, making it a powerful tool for social and emotional learning.

Impact on empathy and emotional understanding. All the reviewed studies highlighted positive findings on the effects of AR interventions on the post–empathy and emotional understanding of students with LDs. Key findings included:

- Enhanced emotional recognition: Students show an enhanced rate of identifying feelings within themselves and others. This was especially true in AR-based storytelling and simulations, where students can safely view and engage with actors and emotional expressions.

- Improved empathy: Several studies based on the findings showed that students improved their empathetic behaviors, including recognizing situations from the other person's perspective and relating to other students. The audience got 'into someone else's skin' more than they did when using conventional approaches, which the students used through AR applications.
- Better social interactions: Students were given opportunities through AR interventions to learn and rehearse how they wanted to behave in social situations. This reflected real-life social interactions and relationships.

Comparison with traditional social and emotional learning methods. When compared to traditional social and emotional learning methods, AR interventions showed several advantages:

- Higher engagement: The participants generally stated that they found the applications more engaging than the traditional methods. Because the learning environment in AR is interactive, this generated positive responses from the students because of the rich interactivity [10].
- Enhanced retention: Students' overall feelings and social interaction elements were better facilitated to receive favorable reinforcement when taught through AR.
- Greater inclusivity: Social and Emotional Learning interventions previously delivered have incorporated aspects that failed to support LD students in the same way that AR has.

HCI design strategies. User-centered design is one of the leading frameworks anyone can employ while creating AR applications for learning-disabled students. This relates to the development process by involving the students, teachers, parents, and clinicians. The interaction with these several outlooks helps ensure that the intended users' needs and expectations of the AR applications will be met to make the application more useful. Regarding the context of the AR application, engaging stakeholders begins from the initial stages of planning [7]. For instance, the presented research work that deals with the applicability of AR in storytelling education of students with ASD describes the positive effects of lengthy feedback sessions with both students and their teachers. They turn out helpful in creating awareness of the users, the challenges, and the expectations they set when creating interfaces and content. Therefore, by incorporating the feedback gathered from the stakeholders, the applicability of the applications in learners' LDs can be increased in educational contexts.

Another principle of UCD that is applicable when developing AR applications is the iterative process of prototyping. This process entails the creation of several prototypes and specifying the modifications that need to be made based on user feedback. However, via iteration cycles, developers can trace and eliminate usability issues far before the design stages [41]. This approach improves and optimizes the usage and performance of AR applications and ensures that barriers to access and use in education, if any, are addressed before any large-scale implementation is considered. Likewise, aligning AR applications with educational and social studies might extend their benefits and encourage learners' interest [10]. Contextual adaptation, for its part, is how AR experiences are aligned to the learning disability that a student has in terms of learning modality, information processing capability, and social learning conduct of a student. For example, modifications to AR storytelling interfaces to elements like symbolic faces or symbols recognizable as famous ASD faces will significantly enhance emotional commitment and understanding of lessons.

Strategies to reduce technology-related fears. Fear of technology, or technophobia, becomes a significant barrier to the learning of students suffering from LDs whenever they have to use new teaching aids such as AR applications. Measures to address technophobia play essential roles in reducing barriers among students so that they embrace the available technological solutions. One of the critical approaches to managing these fears is to incorporate this AR technology into the company's working process step-by-step and in stages. Teaching expectations from AR with simple applications that contain basic tasks means that the students will feel comfortable handling the tools. This way, people can gradually expose themselves to more sophisticated AR capabilities as they become more at ease with the technology [29]. This phased approach helps alleviate the apprehension and negativity toward using technology among disabled students. Constant support and training sessions are crucial when dealing with technophobia. Facilitators, trainers, and designers are crucial in implementing practical workshops and tutorials and providing help resources. These initiatives help the students and the educators to deal with the applications of AR more positively, and they turn into a positive tool instead of a shroud.

Similarly, ergonomics to implement AR interfaces that are as easily understood as possible help reduce the complexity levels that may be unbearable to learning-disabled students. Ease of Interphase minimizes the interactions, making the technology friendly and less threatening. Thus, improving the clarity and usability of interlinked AR apps can help developers optimize the application of this technology to improve the learning process for a wide range of students. However, it is critical and known that establishing a positive learning environment is essential to combating technophobia in students [21]. This involves creating an environment for learning that does not center on AR technology in a pressured manner that will force students into experimentation. Cultivating interest and offering freedom to choose what to learn helps students develop optical familiarity with AR technology step by step and, therefore, become less scared.

Accessibility and usability features. In this case, it is essential to comprehend how to make AR applications more accessible and available for students with special needs. Some aspects of access relate to variations in abilities and preferred user interfaces that are most effective when used with AR. Moreover, it enables students to adjust the sizes of texts and fonts in the applications and the AR environment to meet individual vision requirements. This feature is also helpful for students with visual impairments or reading difficulties so that content may always remain easily readable [24]. Thus, audio descriptions of the visual content in the applications will be essential for students who rely on audio references. Accompanying audio descriptions improves understanding and interest, particularly for students with a visually impaired profile, as they explain the context and add details of the visuals portrayed through AR interfaces.

Different input methods like voice commands, touch interfaces, and gesture controls are considered to address the differences in physical capabilities and individual differences among students. These additional input schemes enable the students to engage the applications effectively, irrespective of physical coordination or other senses. Similarly, when designing applications in an AR environment, it is possible to incorporate features that enable error and make the interfaces more forgiving for the visually impaired user [24]. They amplify the positive interaction with technology by providing clear feedback and making it easy to correct mistakes, boosting the confidence of the LD students. The study incorporated these accessibility features within the AR-incorporated books and showed enhanced user engagement and performance [19]. In this way, by focusing on the accessibility and usability of AR applications, the developers can significantly enhance the learning potential of applications and provide equal opportunities for interaction for everyone in the class.

Challenges and solutions. Integrating AR in education faces challenges because students and teachers often fear new technology, which causes stress and hinders its use. Providing training, gradual introduction, support networks, and resources can help overcome these fears and improve learning for students with learning disabilities.

Technophobia among students and educators. Resistance to technological advancements is one of the critical challenges associated with integrating AR into learning institutions. Students with LDs and their teachers may feel stressed about implementing AR technologies because they are not experienced or self-assured [28, 17]. This fear can hamper AR tools, denying the students the benefits of using interactive tools that create immersive learning environments [19].

Limited accessibility and usability. Mobile AR implementations can be highly technical and may demand improved hardware and software, which can be prohibitive for schools with constrained budgets. In addition, most AR applications are developed without adequate consideration of accessibility, thus restricting students with specific disabilities from leveraging these applications optimally [21, 29]. As stated before, the problems may be additionally compounded by the absence of easily navigable interfaces and adaptable elements [24].

Inadequate teacher training and support. One should also consider the importance of teachers in enabling AR in classrooms and making it effective. Nonetheless, studies show that many educators must be trained and prepared to adequately adopt AR into the classroom and instruction [7]. Likewise, if teachers do not receive adequate professional training, they might feel discouraged by the technical characteristics of AR applications and, therefore, will use the applications sub-optimally [26].

High costs of implementation. The price range of AR devices, including headsets and compatible devices, and the costs incurred in creating and maintaining the AR software, may be too steep for the educational institution [20]. These financial challenges may not allow the incorporation of AR technologies for learning in schools, especially in schools with less funding [32].

Technical challenges and maintenance. Technical challenges, such as software and hardware glitches and the need to upgrade the system, may hamper the utilization of AR in the learning environment [42]. Due to these challenges, schools may need more technical know-how and resources to attend to these matters in real time, thus causing a great deal of disruption and annoyance to the users [41].

Innovative solutions to address technophobia. Several innovative solutions can be implemented to address technophobia among students and educators. These include a gradual introduction and familiarization with AR technology, comprehensive training programs for educators, UCD for accessibility, financial support, robust technical resources, collaborative learning environments, positive reinforcement through success stories, and seamless integration with existing educational tools.

Gradual introduction and familiarization. The key strategy for implementing AR technology would be its introduction in stages, which will assist in reducing technophobia among students and educators. It is possible to start with easy-to-use applications so that users get comfortable and use the technology more when dealing with more complicated situations [28]. This approach may lessen the stress and opposition to new technology [37].

Comprehensive training programs. Likewise, extensive training is important for educators as they become more confident and capable of applying AR applications. Such programs should include information about the technical side of AR and how AR can be implemented properly into teaching [25], [32]. Peer mentoring is another potential approach that is effective and can be continued through workshops [18].

User-centered design and accessibility features. Applications referencing AR must be designed to meet the needs of the end-users to enhance accessibility and usability. This entails using features like text zooming, text speech, and easy controls or graphic displays [17], [4]. It also involves informing students and educators about the design process so that the designed applications are what they want, reducing technophobia [11].

Financial support and cost-effective solutions. Thus, to address this barrier, the following strategies can be adopted: Schools can apply for government grants, sponsorships, and endowments, as well as partnerships with technology firms [20]. Possible ways of making AR solutions more accessible to the general public may include, for example, making cost-efficient applications like mobile apps that do not require expensive devices [29].

Robust technical support and resources. Ensuring schools have adequate technical support and resources will enable schools to address technical concerns and efficiently run AR applications for optimal benefits. This involves providing user guides, how-to videos, and a highly interactive support team [41]. Periodic updates and maintenance of the software and related services can guarantee that the applications perform optimally and are current [42].

Collaborative learning environments. To reduce technophobia among learners, educationists must encourage a collaborative learning environment that enhances peer learning. Using AR in group projects can help make the technology friendly and encourage adoption [19]. Another advantage of collaborative learning is that it enables the students to share knowledge while at the same time gaining confidence in the use of the technology [25].

Positive reinforcement and success stories. Sharing success stories depicting more positive aspects of AR technology in teaching and learning can help address challenges. Dispelling the myths and giving some examples of successful AR usage in similar educational contexts can become valuable and empowering [30], [12].

Integration with existing educational tools. Integrating AR applications with traditional educational solutions and platforms forms a single learning environment. This may help overcome the time required to implement the new technology and provide students and teachers with a better understanding of AR use [7], [41]. For instance, AR features can be integrated into typical tools such as digital text, books, and learning management systems [6].

Addressing emotional and psychological barriers. Some ways to minimize technophobia include lowering the psychological and emotional barriers that make people afraid of using advanced technologies. One way to alleviate these concerns is to create a positive attitude and permission to learn and teach, allowing students and educators to experiment with the new technology [3]. Other types of stimuli that can be defined as potentially comforting, soothing, or reassuring may also be useful [19].

5 FINDINGS

This has been evidenced in Table 1, which includes studies showing that the application of AR enhances empathy and emotional understanding among students with LDs; for instance, the pilots that involved AR-based storytelling and interactive simulations showed promising results in the learning of emotional recognition and empathy. Moreover, the user-oriented design and successive development concept also helped overcome the technophobia and attract users. For students who require special needs, the application's accessibility features, like text size and audio descriptions, ensured that the AR applications were easily understandable.

Table 1. Studies overview

Study	Year	Sample Size	AR Application Type	HCI Design Strategy	Social and Emotional Learning Outcomes	Key Findings
M. Aborokbah	2021	35	AR for Dyslexia	Not specified	Improved Reading Skills	AR tools enhanced reading abilities in children with dyslexia.
N. J. Ahuja et al.	2022	105	Intelligent Tutoring System with AR	AI Methodologies, iterative Design	Improved Learning Outcomes	AR based learning, improving cognitive memories and engagement and experiences for disabled learners.
B. Alkadhi et al.	2020	68	AR Storybooks for ASD	Co-Design Feedback Loops	Enhanced Engagement	Co-designed Arabic AR storybooks improved engagement in children with autism.
M. Antona and C. Stephanidis	2015	72	Various AR/VR Applications	Universal Access, User center Design	Increased Accessibility	Focused on making AR/VR accessible for all users.
L. Bremner	2023	25	AR Facial Expression Tracking	UCD, Prototyping	Improved Theory of Mind	AR interface improved understanding of emotions in children with ASD.
H. Cao	2021	23	Human Motion Sequence Observation	HCI Principles	Improved Observation Skills	Applied HCI principles to enhance observation skills through AR.
R. D. da Cunha et al.	2018	Various	Virtual Reality	Not specified	Support for Disabilities	VR as a support tool for intellectual and multiple disabilities.
J. Dudley et al.	2023	Various	AR/VR/Metaverse	Inclusive Design	Enhanced Accessibility	Reviewed efforts to improve accessibility in AR/VR.
P. Guilbaud et al.	2022	Various	Serious Games/VR/AI	Not specified	Prosocial Behaviors	Use of VR and AI to enhance prosocial behaviors and cognitive abilities.
L. S. Guedes et al.	2023	20	AR Usability and Accessibility	UCD	Increased Usability	Assessed AR usability and accessibility for people with intellectual disabilities.
K. Khowaja et al.	2020	various	AR for ASD	Not specified	Enhanced Learning	Systematic review of AR for learning in children with ASD.
E. L. C. Law and M. Heintz	2021	various	AR for K-12 Education	Usability and UX	Improved User Experience	Systematic review from usability and UX perspective.
L. H. Lee et al.	2021	various	Mobile Headsets	Human-City Interaction	Improved Interaction	Research on AR-driven human-city interaction.
X. Lian et al.	2023	various	AR Coloring Application	Eye-Tracking Investigation	Improved User Interface	Evaluated AR UI for children with autism using eye-tracking.
Z. Lv et al.	2022	various	Intelligent HCI	Deep Learning	Enhanced Interaction	Applied deep learning for intelligent HCI in AR.
G. Papanastasiou et al.	2019	various	AR/VR in Education	Not specified	Improved Skills	Effects of AR/VR on 21st-century skills in education.

(Continued)

Table 1. Studies overview *(Continued)*

Study	Year	Sample Size	AR Application Type	HCI Design Strategy	Social and Emotional Learning Outcomes	Key Findings
D. Prit Kaur et al.	2022	60	AR Interactive Learning	Adaptive Design	Improved Comprehension	Adaptive AR for better concept comprehension in engineering education.
M. M. Schaper and N. Pares	2022	55	AR for Social and Emotional Learning in Education	Projective AR	Enhanced Social and Emotional Learning	AR enhanced Social and Emotional Learning in educational settings.
M. Schneider	2022	100+	Digital Diagnostic Assessment	Formative assessment usability testing	Improved SEL Development, Enhanced Educator Feedback	SELDDA tool improved the evaluation and progress of social-Emotion Learning. Gaps in traditional SEL assessments.
Y. Sun et al.	2024	various	Context-Aware AR [ICAARM]	Personalized Gesture interaction	Improved Interaction	Context-aware Augmented reality Model [ICAARM] models for better interaction.
N. Tuli and A. Mantri	2021	30 preschoolers 12 teachers	Mobile AR Learning for kids [ARLE]	Usability principles user -centered design	Improved Learning and enhanced Engagement	23 usability principles and developed interactive mobile AR application the is more efficient and highly usable.
S. D. Ubur and D. Gracanin	2024	Various	Speech to text VR/AR	Speech-to-Text emotional recognition	Improved Emotional Support	VR support for emotional expressions through speech-to-text interfaces.
Z. Zhang	2024	Various	VR Technology HCI	User Experience	Enhanced Interaction	User experience in VR technology applications in gaming and identified challenges such as motion sickness accessibility issues and concerns in future developments and interactive experiences.

6 DISCUSSION

These findings align with prior research on the efficiency of AR and HCI for educational applications regarding empathy development and emotional understanding in students with LDs. The studies included in this review indicate that AR-based interventions significantly enhance a student's ability to recognize and appropriately respond to others' emotions and evoke empathetic behavior. In this direction, Papanastasiou et al. [10] proved that AR and VR practices enhance 21st-century skills, including emotional and social competencies. The previous literature underlined that AR enhances student approaches and motivation, which is very important for LD students who often experience difficulties learning with traditional learning techniques or approaches [4].

Moreover, this study supports the findings of Guedes et al. [21], who highlighted that the application of the UCD is vital for enhancing the effectiveness of AR applications for students with disabilities. Suppose AR applications are developed adhering to UCD principles, such as incorporating features that improve accessibility and the application of iterative design. In that case, problems like technophobia and social phobia among learners with LDs can be solved. It not only improves the utility of the technology but also makes the learning process less exclusive.

One of the key benefits this review describes is the gradual phase-in of AR technologies to avoid technophobia among students with LDs. This agrees with Zhou et al. [31], who maintain that the gradual implementation of the new learning technology reduces anxiety and further enhances comfort over time. One of the prime benefits distinguishing AR from other traditional methods of SEL is that it allows students to practice emotional skills in a safe and controlled environment without any real-world consequences of failure.

These findings are positive, but some challenges remain. For example, as noted by da Cunha et al. [32], the implementation cost of AR technologies needs to be lowered for many schools to adopt, especially in those with less funding allocation. Besides this, the need for proper training in AR applications among teachers hampers the appropriate utilization of such technology in a classroom setting, as identified by Schneider [26]. In addition to this financial enabling, professional development programs are necessary for educators to be trained in using AR and HCI effectively in teaching practices.

This review emphasizes how AR and HCI can help enhance SEL among students with LDs. Technophobia is reduced when the design applied is user-centered, development is iterative, and the technology is implemented gradually; this, in turn, improves the emotional and social competencies of the students. These findings extend the extant literature, especially the studies of Papanastasiou et al. [10] and Zhou et al. [31], by making AR-based intervention effective in responding to students with LDs' specific learning needs.

6.1 Future research

As such, several recommendations should be implemented to enhance research in the field of HCI and AR in social and emotional learning for learners with LD in the future. Firstly, a dearth of empirical studies focuses on the most effective ways of incorporating AR into current learning models. Future studies should examine how integrating the AR application can improve the teaching-learning process and social and emotional learning competencies at various levels and contexts.

Secondly, future research should also investigate the existence of newer technologies and the enhancements that HCI can bring to AR systems in education. Advancements such as artificial intelligence-based innovative learning models and high sensory feedback in an AR context provide potential directions for increasing user interest and learning effectiveness. These technologies may help redesign learning experiences and provide learning as per students' requirements more than the current model. Last, future studies should assess the effectiveness and sustainability of AR interventions for learning support of students with disabilities in school settings. More research should evaluate the benefits of using AR technologies in learning situations, the retention of its benefits in the long run, and potential intervention approaches to support communities of practice experiencing difficulties in incorporating technologies in learning. The fruition of these research priorities can enable educators, developers, and policymakers to harness the potential of continually advancing technology, including HCI-supported AR devices, to enhance access to quality education for learners with learning disabilities.

7 CONCLUSION

This systematic review has sought to examine the future of HCI combined with AR in the application of SEL while teaching learning disability students. Through 1969 articles published between 2015 and 2024, this review has made several findings regarding the effectiveness and content of those interventions.

The analyzed papers reveal quite distinctly how precisely practical applications developed through the assistance of the HCI approach in AR cause increased empathy and EL among students with LDs. They give prospects for enacting genuine and fascinating settings to acquire safe social abilities [17]. Therefore, applying general theories such as user experience, assistive and Universal Design, AR technologies fulfill all the learners' requirements and enrich their learning process [21], [7].

User-centered design strategies are essential in crafting AR applications that users with LDs can access and utilize effectively. Adding features such as interfaces, voice, or simple command-based navigation increases their accessibility and effectiveness in teaching and learning [24], [29]. Also, active measures to combat technophobia, including the use of a gradual integrated approach and organizational training for teachers, are the key factors contributing to the successful implementation of AR in schools [19], [25].

7.1 Recommendations

Applying universal design principles ensures that AR applications are made available to all students without regard to disabilities. Antona and Stephanidis [24] noted that this includes offering multiple ways of representation, communication, and interaction with the AR environment. Considering the cases mentioned, developing ongoing professional learning for educators regarding AR technologies is crucial. Preservice teachers must understand that workshops, learning networks, and technical support can help them confidently incorporate AR into their teaching practices [7], [27].

Foster collaborative learning environments: Promote ways of learning that promote collaborative learning and where AR applications can be integrated. Peer communication and group work increase participation and facilitate the acquisition of social skills by learners with LDs [19], [25].

Ensure scalability and sustainability: AR solutions should be designed to apply to various educational contexts and should not require frequent updating or extensive maintenance. This is done by working with technology developers to devise affordable and deployable solutions within existing educational contexts [20], [42].

Evaluate and adapt: To work efficiently, periodically monitor the impact of the AR interventions and their contribution to students' outcomes.

Policy implications for inclusive education:

Integrating AR technology in education holds transformative potential for managing learning-disabled children. To harness this potential, it is crucial to allocate adequate funding, develop inclusive education policies, collaborate with stakeholders, promote research and innovation, and ensure equity and access in AR implementation:

- Allocate funding for technology integration: Related governmental agencies and institutions of learning should allocate adequate funds for funding the application of AR technology in managing learning-disabled children. This comprises funding targeted at the purchase of hardware, the creation of applications, and the provision of professional development for teachers [20], [10].
- Develop inclusive education policies: This will include developing policies enabling clients to use AR and other advanced technologies to grasp various lessons. Policies should promote and raise awareness about accommodations for students with disabilities regarding classroom learning tools [25], [34].

- Collaborate with stakeholders: Develop cooperation between teachers and technology designers, ministries of education, and advocacy organizations to co-design integrated learning opportunities. In this way, the stakeholders can respond to the systematic challenges and management of the progress and technologies in educational environments [21], [12].
- Promote research and innovation: Support various research studies investigating the practical application of HCI, AR, and social and emotional learning for learners with LDs. Providing grants for research and development projects and supporting partnerships between universities and businesses can enhance research and develop inclusive education [42], [29].
  - Ensure equity and access: Campaign for equal distribution and distribution of the funds to cover the cost of AR implementation for all students regardless of their financial background or school location. Digital divides and the lack of access to digital tools are critical issues that should be considered in the framework of inclusive education policies [24].
  - Relationship with policy concerns: Policy support is vital to ensuring that AR becomes the tool that can help create a culture of understanding and enable the development of empathy, emotional intelligence, and social skills. By sharing our practices and undertaking further research into and experimentation with AR technologies, it is possible to improve the accessibility and efficacy of the learning processes for every learner.

Therefore, it is clear that using AR applications based on HCI can create an excellent opportunity for promoting social and emotional learning in learners with LD. Through the lens of UCD and access to authentic professional learning, educators and technologists can optimize the affordances of AR technologies in classrooms.

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