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SURVEY

From Assistive Technologies to Metaverse–Technologies in Inclusive Higher Education for Students With Specific Learning Difficulties: A Review

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ABSTRACT The development of new technologies and their expanding use in a wide range of educational environments are driving the transformation of higher education. Assistive technologies are cutting-edge technologies that can help students learn more effectively and make education accessible to everyone. Assistive technologies can enhance, maintain, or improve the capacities of students with learning difficulties. Students with learning difficulties will be greatly benefited from the use of assistive technologies. If these technologies are used effectively, students with learning difficulties can compete with their peers and complete their academic tasks. The aim of this review is to better understand the role of assistive technologies in providing inclusive higher education for students with learning difficulties. The review begins with the introduction of learning difficulties and their causes; inclusive education and the need for assistive technologies; the motivation behind this review; and a summary of related reviews on assistive technologies for students with learning difficulties in inclusive higher education. Then, we discuss the preliminaries of the types of learning difficulties and assistive technologies. Later, we discuss the effects of assistive technologies on inclusive higher education for students with learning difficulties. Additionally, we discuss supporting tools and related projects available in inclusive higher education for students with learning difficulties. We also explore the challenges and potential solutions related to using assistive technologies in higher education to provide inclusive education for students with learning difficulties. We conclude the review with a discussion on promising future directions.

INDEX TERMS Learning difficulties, inclusive higher education, assistive technologies.

I. INTRODUCTION

A learning difficulty is any abnormality of the body or mind that hinders a person's ability to do certain tasks and interact with the outside world. According to the World Health Organization (WHO), 15% of the global population is disabled, of whom 2% to 4% have significant learning difficulties. WHO global estimation indicates that learning difficulties are rising due to an ageing population, and the rapid spread of chronic diseases [1]. According to a United Nations

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Children's Fund (UNICEF) study, around 240 million children worldwide are facing issues with learning difficulties. Most assessments related to the well-being of children indicate that children with learning difficulties have a worse quality of life than children without learning difficulties [2]. Students with learning difficulties may suffer from emotional, mental, physical, or developmental problems. Education will provide students with learning difficulties with a feeling of self-worth. Learning difficulties are an underrated but major element in educational discrimination. Students with learning difficulties are among the most underserved categories in adequate higher education. Every student with learning difficulty must receive proper inclusive education for their growth and social development.

A. CAUSES OF LEARNING DIFFICULTIES

With the assistance of modern technologies, researchers could find the causes of learning difficulties. Some learning difficulties are caused by prenatal and neonatal hazards, psychological and physical stress, and environmental exposure. Several risk factors are present by birth and run in families, according to recent studies [3]. Therefore, there is an increased risk of learning difficulties in children of the parents who have learning difficulties. To better understand learning difficulties, it is essential to investigate how students' brains adapt to reading, writing, and solving mathematical problems [4]. More individuals with learning difficulties suffer from physical and psychological illnesses. There are curable conditions associated with a person's learning difficulties. Autism, Attention Deficit Hyperactivity Disorder, Schizophrenia, Mania, and Pica are a few of the conditions that may lead to learning difficulties [5]. Problematic behaviour may also indicate underlying mental or physical health issues. Additionally, family members, educators, and caretakers must assist the students in overcoming these obstacles [6]. Students with learning difficulties have fewer opportunities to get an inclusive technical education, but this barrier may be overcome with the use of assistive technologies. Numerous studies have identified methods for assisting individuals with learning difficulties.

B. INCLUSIVE EDUCATION FOR STUDENTS WITH LEARNING DIFFICULTIES

Traditionally, students with learning difficulties were seen as inferior and barred from attending normal classes due to their cognitive disorders. They were educated at specialized institutions of higher learning. Inclusive education allows the integration of students with learning difficulties into regular classrooms along with normal students. This will help them to face real-world problems [7]. The Declarations of Salamanca on Special Education in 1994 outlined the ideas of inclusive education. The declaration emphasizes about the commitment to education for all students, acknowledging the need and urgency of providing education to all students, adolescents, and adults within the regular education system [8]. Regular education with focus on inclusiveness is the most effective strategy for eradicating discriminatory attitudes, developing welcoming communities, building an inclusive society, and achieving education for all [9]. In addition, inclusive education will provide an effective education for most students, that will boost the efficiency of the education system as a whole [10].

C. NEED OF ASSISTIVE TECHNOLOGIES FOR STUDENTS WITH LEARNING DIFFICULTIES IN HIGHER EDUCATION

Students with different types of learning difficulties confront various obstacles in higher education. They are excluded from school, society, and mainstream development programs due to lack of crucial support and fair participation opportunities [11]. If technology is implemented properly, students with learning difficulties will be able to participate in the general education curriculum because they will have access to simpler and more adaptable methods that aid in completing their tasks [12]. It is vital to pick assistive technology based on a student's requirements, but not based on their difficulties category. As assistive technologies are intended to assist the students to perform certain objectives, it is important to choose the appropriate tool for the task [13]. Assistive technology may include hardware, software, and peripherals that aid students with learning difficulties in completing their tasks efficiently [14]. Utilizing assistive technologies in higher education will aid students with learning difficulties in remaining competitive with their peers, fostering social engagement, boosting self-confidence, and enhancing academic success.

D. MOTIVATION

In this section, we discuss the motivation for conducting this review, and is depicted in Fig.1. Our study is limited to those assistive technologies that make it possible for students with learning difficulties to overcome the challenges they face while competing with their peers. Our work has limited focus on the students with physical impairments, as these assistive technologies reviewed in our study may not address all physical disabilities, which require a separate focus. These assistive technologies for physical impairments not only need to focus on alternative or customized devices but also need to address the student's learning difficulties along with their physical impairments as a whole.

The motivation to conduct this study is as follows:

1) TO ENSURE STUDENTS WITH LEARNING DIFFICULTIES TO HAVE THE SAME ACCESS TO HIGHER EDUCATION

Students with learning difficulties, such as dyslexia or autism, struggle to adapt to the conventional learning environment. They have difficulty following instructions, course content, and even their textbooks. They need individualized instructions and cannot withstand the pressure of competition. Moreover, these students are often bullied by their classmates, which may further demoralize them [15]. Innovative assistive

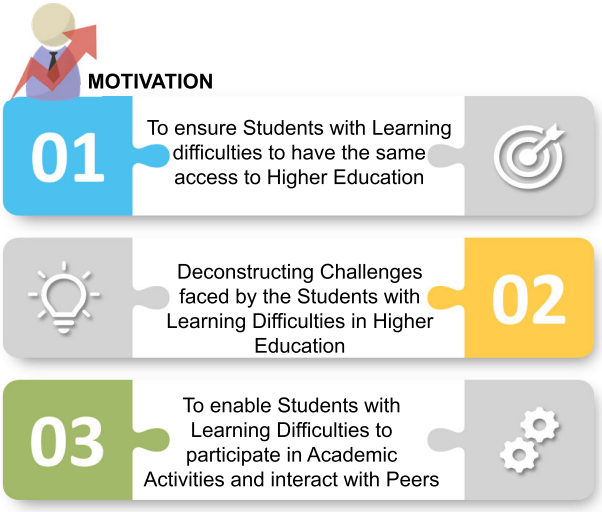

FIGURE 1. Motivation for Review.

technologies and a personalized learning environment can help students overcome these problems and make them ready to compete with their classmates and do well in academics [16].

2) DECONSTRUCTING CHALLENGES FACED BY THE STUDENTS WITH LEARNING DIFFICULTIES IN HIGHER EDUCATION

Academically struggling students with learning disabilities may experience stress [17]. Possible stressful sentiments of low self-worth may arise as a result. Many students may not perform in the classroom because they fear making some mistakes in their work [18]. Those with learning difficulties with self-determination, with the help of assistive technologies, can overcome the stigma of having a learning difficulty and deal with the problems of higher education effectively [19].

3) TO ENABLE STUDENTS WITH LEARNING DIFFICULTIES TO PARTICIPATE IN ACADEMIC ACTIVITIES AND INTERACT WITH PEERS

The use of assistive technologies will provide the students to experience experiential learning. Students can engage in independent academic activities or work collaboratively with other students instead of idly waiting for assistance [20]. The use of assistive technologies allow the students with learning difficulties to learn at their own pace. This self-paced learning results in less pressure and improved communication skills, attention, and behaviour [21]. Assistive technologies can help students with learning difficulties engage more readily in cooperative learning activities, as students with learning difficulties may not possess either the needed academic or collaborative skills to participate fully [22]. With the help of assistive technologies, students can gain independence as they can complete written assignments with minimal or no assistance [23].

TABLE 1. List of key acronyms.

Acronyms	Description
ADD	Attention Deficit Hyperactivity Disorder
AI	Artificial Intelligence
AR	Augmented Reality
ARC	Augmented Classroom
ATIA	Assistive Technology Industry Association
BCI	Brain Computer Interface
CAPD	Central Auditory Processing Disorder
DT	Digital Twin
DCD	Developmental Co-ordination Disorder
HMD	Head Mount Display
HCI	Human-Computer Interaction
IoT	Internet of Things
IEEE	Institute of Electrical and Electronics Engineers
MHD	Mental Health Disorders
NDD	Neuro Developmental Disorder
NVLD	Nonverbal Learning Disorder
NGSS	Next Generation Science Standards
PD	Psychological Disorders
PSO	Particle Swam Optimization
SVM	Support Vector Machine
UNESCO	United Nations Educational, Scientific and Cultural Organization
VR	Virtual Reality
WHO	World Health Organization
WIPO	World Intellectual Property Organization
XR	Extended Reality
3D	3Dimension

E. RELATED WORKS AND CONTRIBUTIONS

Several researchers have worked on assistive technologies for students with learning difficulties in inclusive higher education. The overview of these studies is provided in Table 2.

To assist reading and writing, tablets featuring text-to-speech and speech-to-text capabilities have been launched in recent years [28]. Since 1980s, the challenges faced by students with learning difficulties in written and spoken language, arithmetic, reasoning and memory have been mitigated with the use of various assistive technologies. However, very few scientific studies have examined the advantages of these methodologies. Idor Svensson et al. evaluated the influence of assistive technologies on students with learning difficulties. In their research, 149 individual students participated. The intervention group was provided with 24 training sessions in assistive technologies, whereas the control group received routine care. In a single year, the intervention and control groups attained the same degree of improvement as the normative population. They found that the use of assistive technologies improved reading skills, especially for students with learning difficulties. It was also observed that the intervention boosted motivation leading to task completion. Furthermore, their research demonstrated the challenges of assessing individuals with learning difficulties in terms of their capacity to comprehend and interpret information [24].

The landscape of higher education is constantly changing as a result of the quick adoption and spread of new technologies in teaching and learning methods [29]. Assistive technologies, which include a variety of specialised tools, are used to help students access education and participate freely and actively in the learning process, which improves learning and promotes the educational system [30]. Pritika Reddy et al.

TABLE 2. Summary of related reviews on assistive technologies for students with learning difficulties in inclusive higher education.

Ref	Contributions	Limitations
[24]	This study investigated the effectiveness of assistive technology for students with learning difficulties.	This study limits the most recent technical developments in assistive technology, which can help in inclusive higher education.
[25]	This study explored the impact of assistive technology on mathematics in higher education.	This study did not provide insights into how this assistive technology can help students with learning difficulties in inclusive higher education.
[26]	This study explored the role of artificial intelligence in personalized assistive technology for neurodevelopmental disorders students in their education.	This study did not address the problems associated with incorporating AI as an assistive technology for students with learning difficulties in inclusive higher education.
[27]	This study compared an assisted e-learning interface amongst students with and without visual and auditory impairments.	This study did not address the difficulties in adapting the e-learning interface for students with visual and hearing difficulties.
Our work	Our work explored the role of assistive technologies in providing inclusive education for students with learning difficulties in higher education	–

examined students' perceptions on the use of various assistive technologies, including mobile learning, tablet learning, lecture capture, gamification, and online intelligent systems for assisting the teachers and students to teach/learn mathematics in higher education at the university level. They also assessed the opinions of assistive technologies among mathematics students in online mode. Their findings concluded that assistive technologies helped students with learning disabilities to understand mathematics better, and the students showed a positive outlook on the use of these technologies in mathematical education [25].

Neurodevelopmental disorders (NDDs), which also include developmental disabilities and specific learning difficulties like attention deficit hyperactivity disorder (ADHD), dyslexia, and autism spectrum disorders (ASD), as well as a wide range of mental health disorders (MHDs), including stress, anxiety, psychotic disorders, and severe depression, are frequently associated with psychological disorders (PDs) that first emerge in adolescence or early childhood [31], [32], [33]. Over the last 20 years, there have been notable increases in the diagnosis of mental diseases on a global scale as well as rapid growth in the rate of a number of mental health problems [34]. Depending on the kind of PD, students may struggle with socialisation, communication, and adapting to changes in their environment, which could make it difficult for them to concentrate effectively. To improve outcomes of the students, treatment has to be carried out quickly and effectively [35]. In order to address learning difficulties in students with a variety of NDDs, Prabal Datta Barua et al. examined the complexity and effectiveness of AI-assisted solutions created using machine learning models. Their study provided a summary of the data showing how AI may be utilised to improve social interaction and support training. They concluded that AI solutions aren't completely effective at resolving the problems associated with learning difficulties. They recommended that in the future, AI may be improved with an emphasis on assisting students with NDDs [26].

In summary, researchers used a variety of technologies to assist students with a variety of learning difficulties. To the best of our knowledge, no research has been undertaken on the usage of different assistive technologies to aid higher education students with learning difficulties which provided the motivation for this review. This research examines the role of assistive technologies in providing inclusive education to students with learning difficulties in higher education. The main contributions of this review are as follows:

- Firstly, we present a brief overview of learning disabilities and assistive technologies.
- Secondly, we discuss the significance of assistive technologies in higher education in ensuring inclusive education for individuals with learning difficulties.
- Thirdly, we discuss about various tools that will help students with various learning disabilities to overcome their challenges in inclusive higher education.
- Fourthly, we discuss about some of the interesting projects such as INCED, FAIRNESS INCLUSIVE, INCLUSION TEAM, ELLEN, and ACCESSIBLE PEER INTERACTION WITH DISABLED YOUTH which promote inclusive education.
- Finally, we discuss the challenges faced in usage of assistive technologies and potential future directions.

F. SYSTEMATIC LITERATURE REVIEW

The following phases constitute the literature review that was used in this study to investigate the role of assistive technologies for students with learning difficulties in higher education. First, we discuss the shortcomings of previous review articles and the reasons for conducting this study. Investigating relevant scientific and research publications on the use of assistive technology for students with learning difficulties in higher education is the next step. We place a strong emphasis on peer-reviewed, high-quality papers published in reputable books, conferences, seminars, symposiums,

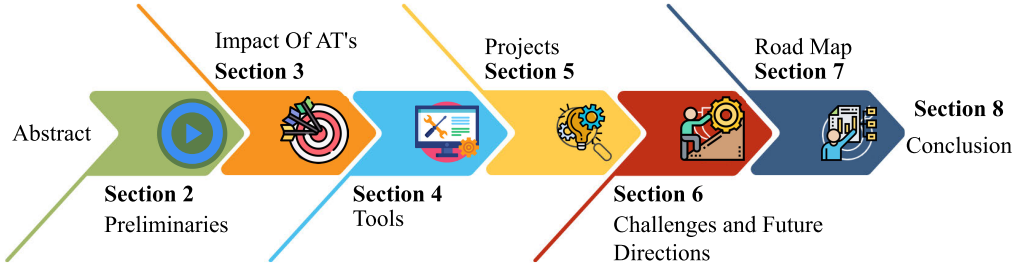

FIGURE 2. The Schematic Organisation of the Role of Assistive Technologies in Providing Inclusive Education for Students with Learning Difficulties in Higher Education.

and journals. The references utilized in this study were found on well-known archive services including Google Scholar and arXiv as well as well-regarded publications like Springer Nature, Wiley, Elsevier, Taylor and Francis, MDPI, and IEEE. Additionally, the keywords AI, XR, computer vision, the metaverse, HCI, and digital twins are utilised to identify relevant references and publications about assistive technology for learning difficulties in inclusive higher education such as Dyslexia, Dyspraxia, Dyscalculia, Dysgraphia, Auditory Processing Disorder, Visual Processing Disorder, Nonverbal Learning Disorder, and Apraxia of Speech. The retrieved articles are all screened based on their titles in the next phase. We didn't include any papers with poor-quality material from predatory journals. After that, we reviewed the abstracts of the papers to determine their contributions. The data needed for our analysis of the use of assistive technology for students with learning difficulties in higher education is extracted in the final step [36].

G. PAPER ORGANIZATION

Section II presents the preliminaries of assistive technologies and types of learning difficulties. In Section III, we discuss the impact of assistive technologies in providing inclusive education for students with learning difficulties in higher education, which includes AI, XR, the metaverse, HCI, and digital twins. Then we discuss the projects working toward inclusive education for students with learning difficulties in higher education in Section IV. Next, Section V is an overview of assistive technology tools. To drive further studies on assistive technologies for learning difficulties students in higher education, in section VI, we discuss challenges in integrating assistive technologies for students with learning disabilities in higher education and future directions. Section VII is the road map. Finally, we conclude the paper in Section VIII. For clarity, the organisation of this review is presented in Fig. 2, and a list of frequently used acronyms is listed in Table 1.

II. PRELIMINARIES

This section provides an overview of learning difficulties, which are identified based on a systematic literature review, followed by a discussion of assistive technology for learning difficulties in higher education.

A. TYPES OF LEARNING DIFFICULTIES

The type of various learning difficulties and their effects are discussed in this section

1) DYSLEXIA

Dyslexia is a learning disorder. Identifying speech sounds, reading, and decoding letters and words can be challenging for students with dyslexia. Students with dyslexia may also have trouble speaking and expressing themselves, and their ideas [37]. They may also find it hard to organise their thoughts during talks. Despite the impairment in language processing regions of the brain caused by dyslexia, students with dyslexia can compete with their peers with the aid of assistive technologies and appropriate intervention.

2) DYSPRAXIA

Dyspraxia is also known as developmental coordination disorder or DCD. Dyspraxia is a motor disorder based on the brain. It influences large and fine motor skills, motor planning, and coordination [38]. Despite the fact that it can influence cognitive skills, it is unrelated to intelligence. A student with dyspraxia has difficulty with movement and coordination. Students may have difficulty handling objects and may also tend to bump into things. The student may also have trouble speaking, be sensitive to light, touch, taste, or smell, and have trouble moving his or her eyes.

3) DYSCALCULIA

Dyscalculia makes it challenging to understand, and process arithmetic [39]. In addition to counting and simple mental math difficulties, students have trouble telling time and following directions. The following abilities are affected by dyscalculia: problems with comprehending how numbers operate and their relationships, mathematical problem-solving difficulties, difficulty with learning basic calculations, and they also face difficulty in compiling and documenting data.

4) DYSGRAPHIA

The neurological condition known as dysgraphia impairs writing and fine motor skills. It is a learning difficulty that affects almost every element of writing, including spelling, legibility, word size, and expression of a tense grip that might

result in a hurting hand. Bad spatial planning, inconsistent writing, poor spelling and missing or incomplete words are all symptoms of dysgraphia [40].

5) AUDITORY PROCESSING DISORDER

It is also known as Central Auditory Processing Disorder (CAPD) because it affects a person's ability to detect, understand, and identify sounds while having normal hearing. Significant difficulty understanding speech, particularly in noisy environments; difficulty following multi-step spoken instructions delivered without visual aids; distraction by loud or unexpected sounds; difficulty paying attention to lengthy lectures or other extended listening sessions; difficulty remembering and/or efficiently summarising verbally delivered information; and difficulty reading, spelling, and/or writing are some of the symptoms of CAPD [41].

6) VISUAL PROCESSING DISORDER

A student with Visual Processing Disorder(VPD) has difficulty comprehending visual information. The student may struggle with reading or distinguishing between similar-looking objects. Those with visual processing problems may experience difficulties with hand-eye coordination. Students with visual processing disorder face difficulties like Confuse words that look similar, reverse letters or numbers, Lacking adequate reading comprehension, make copying errors and frequently forgetting letters, numbers, and words, being bad spellers, having uneven or poorly spaced handwriting and having difficulty in understanding multi-step instructions, and have trouble telling time and comprehending the idea of time [42], [43].

7) NONVERBAL LEARNING DISORDER

The most underdiagnosed, misunderstood, and ignored learning impairment is nonverbal learning disorder (NVLD). Impaired visual, spatial, and organisational skills, difficulty recognising and interpreting nonverbal signals, and poor motor function are all symptoms of the neurological condition. The symptoms of NVLD also include problems related to social interactions, reading nonverbal signs, understanding facial expressions, using appropriate language in social situations, coordination of the body, and fine motor abilities. Students affected by NVLD may face difficulties with organisation, planning, and concentration, as well as reading comprehension and writing expression at a higher educational level [44].

8) APRAXIA OF SPEECH

A student with apraxia of speech struggles to talk clearly and make appropriate gestures. In apraxia of speech, the speech muscles are not weak. Rather, the brain has problems directing and/or coordinating the motions, so the muscles do not function appropriately. Apraxia in students may cause difficulty in imitating and producing sounds on their own, may add new sounds, omit sounds, or pronounce sounds incorrectly, and may pronounce something correctly one time and incorrectly the next [45].

B. ASSISTIVE TECHNOLOGIES

Anything software, hardware or peripherals that aid students with learning difficulties in overcoming their educational obstacles and developing new skills fall under the umbrella of assistive technology. Students with learning difficulties need assistive technology to improve their abilities. They will be able to receive a high-quality education on par with their peers using assistive technology.

Definition 1: According to WHO, the systems and services involved in providing assistive products and services are collectively referred to as assistive technology. [46].

Definition 2: According to the Assistive Technology Industry Association (ATIA), any tool, piece of equipment, piece of software, or product used to enhance, maintain, or strengthen the functional capacities of individuals with disabilities is known as assistive technology. [47].

Definition 3: The United States Code defines assistive technology as any tool, apparatus, or system, whether purchased commercially off-the-shelf, adapted, or customized, that can be used to enhance, maintain, or improve the functional capacity of people with impairments [48].

Definition 4: According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), anything that is utilized to enhance, maintain, or improve the functional capacities of people with impairments is considered assistive technology [49].

Definition 5: According to the Institute of Electrical and Electronics Engineers (IEEE), anything that aids a person in achieving increased performance, function, or quicker access to information is considered assistive technology. [50].

Definition 6: According to The European Accessibility Act (EU, 2019), assistive technology refers to any device, appliance, service, or combination of processes, including computer programs, that is used to maximize, maintain, replace, or enhance the functional skills of people with disabilities. [51].

Definition 7: According to the International Organisation for Standardisation's (ISO9999(2022)) standard on assistive products, assistive technology is any item that was produced with a specific focus on serving the needs of people with disabilities or that is generally available and used by or for people with disabilities [52].

Definition 8: According to the World Intellectual Property Organization (WIPO), the term ''assistive technology'' refers to a broad range of technologies and goods, from relatively simple gadgets like a walking stick or reading glasses to sophisticated, high-tech systems like assistive robots or software that recognizes gestures or emotions. [51].

In summary, assistive technology refers to technologies and services that help people with impairments enhance their functional capacity. It comprises tools, equipment, software, and items that improve, maintain, or increase their capacities.

The United States Code, UNESCO, IEEE, EU, ISO 9999, and WIPO all describe assistive technology as anything intended to meet the requirements of individuals with disabilities.

III. THE SIGNIFICANCE OF ASSISTIVE TECHNOLOGY IN HIGHER EDUCATION IN ENSURING INCLUSIVE EDUCATION FOR INDIVIDUALS WITH LEARNING DIFFICULTIES

Based on the systematic literature review, it is understood that the development of assistive tools in the future will be heavily reliant on contemporary technologies like AI, XR, IoT, HCI, digital twins, and the metaverse. There are numerous studies that concentrate on lower-end assistive technology for learning difficulties [53]. To the best of our knowledge, there is no review that addresses all of these cutting-edge technologies for assisting students with learning difficulties. In this section, we address the role of AI, XR, IoT, HCI, digital twins, and the metaverse as assistive technologies in inclusive education that assist students to overcome their learning difficulties.

A. ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) represents significant advances in computer science and data processing that are rapidly revolutionizing numerous sectors [54]. AI refers to the simulation of human intelligence in machines that are programmed to replicate human thought and behaviour [55]. The use of AI makes inclusive education a reality. Students with learning difficulties can be integrated into regular classrooms and educated alongside their peers [56]. AI is advancing rapidly in the education sector and reducing the gap between students and teachers.

Learning-difficulty-specific cognitive systems are also being developed by researchers using AI [57]. Google and Microsoft are developing AI-based tools such as the immersive reader and Google Docs that can assist students with learning difficulties. The early identification of students with learning difficulties can be facilitated by AI [58]. AI can assist students in enhancing their reading comprehension by reading the text aloud and also providing comprehensive feedback on written work. AI enhances fluency in reading for students with learning difficulties. Students with autism struggle with both verbal and nonverbal communication. Social skill development can be difficult for them. To solve this problem, QTrobot was created. This humanoid robot was developed to teach social skills to autistic children. The robot NAO and the virtual assistant Siri are two more examples that help students with autism spectrum disorder (ASD) learn social skills. Tools like ActiveMath employ AI techniques to allow students greater flexibility in finding a convenient learning environment. The AI-enabled Widex's Evoke will help students improve their hearing capabilities. Grammarly is an AI-based writing assistant that will improve the writing skills of students with learning difficulties.

AI can help in the early detection of learning difficulties. This can help students understand their condition and prepare for future challenges. A. Jothi Prabha et al. created an eye movement analysis model for the detection of dyslexia. They used an eye tracker to observe eye movement. The eye movement data includes fixations, saccades, transients, and distortions of the participants. Principal component analysis was used to identify high-level properties from raw eye tracker data. For the diagnosis of dyslexia in students, a PSO-based Hybrid Kernel (SVM-PSO) was created. Their results showed the proposed model's prediction accuracy was 95% more accurate than that of the Linear SVM model. The model was validated on 187 individuals. They concluded that with the use of eye movement data and machine learning, the development of very precise prediction models was possible. Their method was also offered as a screening tool for dyslexia diagnosis [59].

Students with learning difficulties have more emotional and behavioural challenges in the classroom than their peers without learning difficulties. In order to understand this issue, Nihal Ouherrou et al. conducted research on the benefits of using information and communication technology to understand the emotional factors of students with learning difficulties in online classrooms. In order to analyse the effects of the virtual learning environment, 42 students were divided into two groups. They considered seven basic facial expressions (fear, anger, disgust, surprise, happiness, neutral, and sorrow) and assessed students' emotions using AI while they played a learning game. The results indicated that students with learning difficulties experience the same range of emotions as children without learning difficulties. Furthermore, they concluded that students with learning difficulties report fewer negative emotions compared to their peers in virtual learning environments [60].

Tools and intelligent learning environments based on AI can be used to create successful individualised educational techniques for children with learning difficulties. Students with special needs are not as likely to use e-learning as students without special needs. Not much is known about the barriers and facilitators that cause this difference. The opinions of 21 teachers who took part in preliminary trials of an adaptive learning system based on multimodal affect recognition for students with learning disabilities and autism were gathered by Penny J. Standen et al. through focus groups and interviews. The adaptive selection of learning materials is driven by the system's multimodal detection of emotional state and scoring of performance. The teachers' thoughts on the possible effects of the system were summed up in five themes. These themes focused on learning, engagement, and factors that might affect adoption. These were how the system could change the way they taught, how it could affect how well students learned, how it could affect the relationships between teachers and students, how easy it was to use, and how it could be set up. Even though the teachers who volunteered as testers were very interested, they pointed out barriers to adoption that needed to be fixed. Their findings showed how important it is for teachers and students to be involved in the process of design and development [61].

Phaedra S. analysed the historical development of intelligent learning environments. In addition, they reported the significant challenges that arise with the inclusion of intelligent learning environments. Furthermore, they examined a variety of novel strategies for addressing these issues, such as teacher training, the employment of instructional robots, and responsive systems. They concluded that AI in education is rapidly altering traditional views on teaching and learning. They also stated that traditional school and classroom models will change a lot over the next few years and decades as technology improves and spreads throughout educational institutions [62].

Using multimodal sensor data and machine learning, Penelope J. Standen et al. found that learning is linked to three emotional states: engagement, frustration, and boredom. Then, they figured out how to present the learning content so that the learner stays in the best emotional state and learns as quickly as possible. 67 people between the ages of 6 and 18 took part in a series of sessions using the adaptive learning system so that it could be evaluated. Sessions alternated between using the system to choose the learning content based on how the learner felt, how well they learned (intervention), and just how well they learned (control). Lack of boredom was the state with the strongest link to achievement, with both frustration and engagement positively related to achievement. They concluded that the intervention sessions were much more interesting and less boring than the control sessions, but the amount of work done did not change much. Their results suggest that activities that match the needs and emotions of the learner do increase engagement and that the system promotes emotional states that help learning. They suggested that longer exposure is also needed to figure out what effect it has on learning [63].

In summary, AI has the ability to transform education by creating cutting-edge teaching tools for students with special needs. In order to provide more intelligent solutions, the industry is expanding, demanding more study and cooperation between educators, app developers, and engineers. When AI is used as an assistant in making decisions, it is challenging to explain the decisions made by AI because of its black-box nature. The students' personal data may be required for training these AI models, and protecting the privacy of the students data is also a concern.

B. EXTENDED REALITY

The combination of virtual environments, human-machine interactions, and wearable technologies is collectively referred to as extended reality (XR). The term "XR" encompasses both virtual reality (VR) and augmented reality (AR). Through the use of VR, users may interact with objects and other people in a manner that seems authentic. To add digital elements to a real-world situation, AR uses a smartphone, tablet, or headset. Mixed reality (MR) brings together the real and virtual worlds by using powerful computer technology, images, and input methods [64].

VR and AR can assist students with learning difficulties in many ways in their academic endeavours [65]. The students with learning difficulties are immersed in a 3D world like CoSpaces Edu which contains auditory, touch, smell, and gustatory inputs. Students can interact by wearing a head-mounted display (HMD) and a haptic glove or by using a regular desktop PC and VR software [66]. By adding 3D effects to actual information, AR applications such as Google Lens allow users to remain unbiased observers and recognise the augmented effects. A VR environment such as Google Expeditions will allow students with learning difficulties to participate in activities that are unrestricted by their impairment and allow them to study in the most effective way possible. VR can also help promote positive views towards people with learning difficulties among their peers [67]. Individualised VR settings provide autistic children with the opportunity to learn social interaction and nonverbal cues [68], [69]. Virtual environments or input stimulation are adaptable to student preferences [70]. VR and AR can promote motivation, facilitate engagement, strengthen cognitive skills, and improve memory in students with learning difficulties. They can also improve communication skills, especially among students with hearing problems [71]. VR can help autistic students with social interaction [72]. AR can improve language through the use of games provided by applications like Assemblr [73], [74]. Narrator AR applications can inspire students with learning difficulties to improve their handwriting.

Students with learning difficulties have physical, mental, and communicative limitations [75]. Teaching individuals with learning difficulties requires a specific blend of methods and tools. VR is one of these technologies that will serve as an effective learning aid for students with learning difficulties. Arik Kurniawati et al. offered these students VR games. This game motivates students to acquire items in a VR-based educational environment. The game helps students practise identifying, selecting, and pointing at things in response to visual and audio stimulation. Students with learning difficulties, autism, and learning difficulties participated in their studies. The results indicated that the game is completely simple and accessible for students with learning difficulties. They determined that all participants understood the instructions with little assistance [76].

ADHD, sometimes known as hyperactivity among students, is a prevalent neurodevelopmental disorder. ADHD is characterised largely by hyperactivity, inattention, and behavioural impulsivity. Traditional treatments often rely on clinicians and parents, who may observe and analyse a patient's behaviour using behavioural scales; however, these treatments are time-consuming and ineffective in measuring behaviour. In their experiment, Yunchuan Tan et al. combined several sensor technologies, such as eye movement sensors and electroencephalography sensors (EEG), and used virtual reality technology to develop an assessment and diagnostic approach for ADHD. This system provided a virtual classroom environment and included a number of activities,

including an audio exam. The continuous performance tasks and the Wisconsin card sorting test were used to evaluate the students' attention, ability to think abstractly, and cognitive capability. They introduced distracting elements to their experiment and analysed the test participants' attention. In order to assess the subject's sustained attention and attention shift, they combined their test results with physiological data such as head and eye movements and EEG [77]. They concluded that their approach can improve the levels of concentration in students with learning difficulties.

Jorge Fernandez Herrero et al. suggest a concept and application for an immersive VR system with a head-mounted display to develop and teach the emotional and social abilities of students with autism spectrum disorders. They chose two groups of seven high-functioning ASD students with comparable intellectual aptitudes. In the first group, they used immersive VR as a pedagogical tool to recreate virtual socialising contexts over the course of 10 sessions, using their own intervention design to address social and emotional competencies. As the control group, the second group is not subjected to any intervention throughout the intervention period. The degrees of adaptation and the observed improvements suggested that immersive VR in the format described is consistent with the sensory preferences and visuospatial abilities of the ASD children who participated in this research. They concluded that immersive VR can be used effectively as a teaching tool for children with ASD [78].

In summary, XR can be used to successfully improve the skills and abilities of people with dyslexia, social anxiety, ADHD, linguistic impairments, physical or motor disabilities, Down syndrome, and cognitive deficits. The compatibility of these XR devices with other assistive technologies and devices remains a challenge due to their major design flaws and lack of standards.

C. HUMAN–COMPUTER INTERACTION

Human-computer interaction (HCI) is a field of study that looks at the design of computer technology and, in particular, how users interact with computers. In HCI, cognitive science principles and methods allow software engineering and the human aspects of computing systems to work well together. HCI includes using gesture, touch, and even interaction via brain signals [79].

Universal design for HCI promotes inclusive education that produces accessible products for all students, including those with learning difficulties. The products accommodate individual preferences and abilities and efficiently transmit essential information independent of environmental conditions or the user's sensory capabilities. They are manipulable, reachable, approachable, and usable regardless of body size, posture, or mobility [80]. These design principles result in products that are compatible with assistive technology and are more usable for everyone [81]. Students with learning difficulties struggle with conventional forms of expression, such as writing, but can demonstrate their comprehension in a number of innovative HCI ways by using video or screen-casting tools, including Clips, iMovie, Audacity, and others [82]. HCI provides a readily accessible collaborative environment in which students may produce and share project-based and other related materials using online storage tools such as Dropbox. HCI also helps in the creation of student-response tools that improve student-teacher interaction. OneNote Web Clipper is a highly adjustable immersive reader that has options for changing the text size and line spacing, showing the parts of speech, and more. A student with visual difficulty may use VoiceOver to describe what is on the screen using synthetic voice or braille (with a linked braille display). Students may draw thoughts with the aid of HCI visual tools like Draw.io and Popplet. These HCI tools with universal design will support inclusive education and assist students in overcoming their learning challenges.

The intelligent math e-tutoring system developed by Zikai Alex Wen et al. attempts to eliminate students' negative emotional responses. The technology identifies potential negative emotional actions by evaluating gaze, touchscreen inputs, and reaction time. The program then employs intervention strategies to prevent students from becoming irritated. Formative research carried out with five instructors of students with learning difficulties helped to develop this design. Teachers believed that the establishment of these intervention strategies would benefit students with learning difficulties and stated that among the intervention strategies available to them, giving students 'brain breaks' is the newest and most beneficial. Additionally, the instructors proposed that the system could be customised to identify negative emotional responses, in order to assist students with learning difficulties [83].

Brain-Computer Interface (BCI) technology is an important aspect of HCI. Bio-signals acquired by wearable sensors are attracting significant interest beyond the traditional medical arena in new paradigms such as education [84]. Attention is a biosignal that may be detected and analysed using BCI technology by measuring the frequency of alpha (8–13 Hz) and beta (14–30 Hz) waves. Attention and learning are highly interdependent. Typically, students with attention difficulties also have learning difficulties. According to several instructors and professional experts, students' attention spans are decreasing [85]. To address this issue, Mohammed Serrhini et al. evaluated students' attention in online education. During the learning process, students' attention is maintained by an EEG-based attention evaluation system. Attention data is maintained in a database and used by signal-processing algorithms to comprehend student knowledge growth. They concluded that BCI can be used to enhance learning levels in computer-based education [86].

The use of manual sign systems is a means of communication between students with learning difficulties and their teachers. Due to a lack of learning support resources, instructors experience several practical obstacles while instructing children in manual sign language. To address these concerns, Youjin Choi et al. teamed up with instructors to design the Sondam Rhythm Game, a gesture-based rhythm game

that aids the instruction of manual sign language. They conducted a four-week study with five teachers and eight students with learning difficulties. Based on video annotation and interviews, their game-based method to teach manual sign language has shown significant results. Their method increased children's attention span and motivation, as well as the number of spontaneous motions performed without prompting. In order to enhance teaching paradigms for eight students with learning difficulties, additional practical concerns and learning obstacles were identified. Based on their outcomes, they concluded that their proposed model method could be used to help learners improve their sign language abilities [87].

In summary, by enabling students to engage with technology using gestures, touch, and even brain signals, HCI can assist students in overcoming their learning challenges [88]. Personalised user interfaces and design issues continue to be challenging issues for the HCI domain.

D. INTERNET OF THINGS

A system for connecting computers, mechanical and digital devices, things, or people with distinctive identities and the ability to transfer data using a human-to-human or computer-to-human interface is known as the Internet of Things (IoT). Both computers and humans can use IoT devices. IoT devices can transfer data over a network [89]. The IoT is considered by some to be a transformative force in education. The application of digital technologies is not just about making education omnipresent but also it is also about making conventional systems of education more efficient and inclusive. IoT plays an important role in making education more interactive, collaborative, and accessible to all [90]. IoT devices afford students reliable access to all learning resources and communication channels, and they help teachers keep track of student learning and progression in real-time [91]. Smart boards may be used in a similar manner to a blackboard for writing with a marker and can also show topic-related visuals and images to students. Global Positioning System (GPS) tracker-equipped school buses, smart security cameras, cellphones, and tablets with instructional applications will alter how schools and educational institutions have traditionally functioned. Teachers are concerned about student attendance, which is a daily requirement in schools. IoT can provide a solution for tracking and analysing student attendance for several purposes. Students are more engaged in virtual classrooms facilitated by smartphone applications [92]. The integration of IoT tools and smart devices will enable classroom surroundings to be sound and light-sensitive to accommodate children with sensory disorders [93]. In academia, IoT sensors collect data and automatically propose academic topics of interest to students for future learning processes [94]. These qualities make it more practical, and accessible for students, instructors, and parents. It is a well-known reality that a quick transition of teaching methods and techniques cannot be done, but these gadgets are being customised and updated with the necessary software gradually and over time.

According to statistics, ASD has resulted in serious learning disorders. To address this issue, Raja et al. used a Raspberry Pi to construct a system for evaluating the effectiveness of a smart monitor in assisting students with autism to learn and enhance their quality of life. They suggested a framework to support students with autism by assisting them in making choices, responding by telling parents what they are interested in, and identifying their needs. They implement and evaluate a novel IoT-based system for supporting learning and enhancing the quality of life for students with autism. They claimed that their system could assist students with autism in understanding any subject [95].

Anna Lekova et al. designed, produced, and experimentally validated a Speech and Language Therapy (SLT) system for students with communication impairments. Their approach is able to interact with the IoT in order to assist SLT services in many educational and social contexts. It can link various assistive devices, APIs, online services, and agents to meet the particular requirements of each student using the intervention. Node-RED is used to link a humanoid NAO-type robot, an Emotiv EPOC+ brain headset, an emotionally expressive EmoSan robot, and a Kinect depth sensor. It is a flow-based tool for visual programming without the need to write code, and it can operate locally or on the IoT. The proposed system is sufficiently broad to be adapted to various kinds of therapy and to enable additional assistive devices and cloud services [96].

Permanent or temporary Vision impairments present a number of obstacles in the daily life of a student with learning difficulties. A student with vision impairment may be unable to distinguish between colours, which is a crucial aspect of work in various sectors. Humayun Rashid et al. developed a colour-detecting system for the visually impaired. They addressed two extremely crucial difficulties for visually impaired individuals overcoming obstacles and falling. The proposed system combines the most recent hardware components, including an improved central processing unit, sensors for IoT, and a cloud-based architecture that effectively detects colour and obstacles. Moreover, it also alerts visually impaired individuals about colour and obstacles in multiple languages. In the event of fall detection, this proposed system also transmits a fall notice to the caretaker of the visually impaired individual, which is a major component of this work.

In summary, IoT can transform conventional learning methods and help students overcome their learning difficulties [97]. Security, standards, and dependence on AI judgements are challenges associated with the use of IoT in providing support for students with specific learning difficulties.

E. DIGITAL TWINS

The idea of using ''digital twins'' comes from NASA's Apollo program, in which at least two identical space vehicles

were built. This allowed engineers to replicate the conditions of the spaceship during the trip, and the vehicle that stayed on Earth was called the twin [98]. In 2002, Michael Grieves was the first person to talk about a Digital Twin (DT) [99], [100]. Previous research on DT definitions has shown that each system is made up of two parts: the physical system and a virtual system that includes all of the physical system's knowledge. Siemens describes it "A digital twin is a digital copy of a real product or process that is used to study and predict how it will work in the real world." Throughout the life-cycle of a product, digital twins are used to predict, simulate, and improve the product and manufacturing system before investing in real prototypes and assets [101], [102], [103].

A DT can help teachers understand their students better and reduce the integration problems of students with learning difficulties into inclusive higher education. Students with learning difficulties may find it difficult if they are repeatedly challenged to modify their classroom behaviour. The teachers may not have a good understanding of these students' behaviour. If a DT is built for a student, it enables teachers to carry out analysis of behaviour on the DT to give student-related insights and help teachers best support the academic and behavioural outcomes of their students. DTs also enable students with learning difficulties to work on digitally depicted scenarios and prepare them for the challenges of the real world. The combination of DT and VR will assist students in overcoming the challenges they face as a result of their learning difficulties.

In conclusion, DT offers significant potential to address educational and behavioural issues relevant to students with learning difficulties. The application of DTs as assistive technology remains largely unexplored territory. A major challenge for the widespread application of DTs is the inaccurate representation of the twin, since the construction of the twin relies on many different technologies, including AI and IoT, among others, and any errors in those interconnected technologies will result in the creation of an incorrect twin.

F. THE METAVERSE

The word "meta" is a Greek word that signifies "more complete" or transcending," and "Verse" is an abbreviated form of "universe." In his famous science fiction novel 'Snow Crash, published in 1992, Neal Stephenson first introduced the term metaverse, in which people use digital avatars to control and compete with one another in order to advance their position. The use of VR and AR equipment has helped the metaverse become more widespread [104]. The metaverse is often described as a collection of socially conscious 3D virtual worlds [105].

The metaverse is a near-term technology offering significant opportunities for affording inclusive higher education. Regardless of their actual location and learning difficulties in the metaverse, students and teachers can meet in the digital world using their VR headsets, promoting inclusive higher education. This capability can improve the teaching of individuals with learning difficulties. Inclusive design of the metaverse is, however, crucial to long-term adoption in a number of domains, including education [106]. The metaverse with XR has endless possibilities, with a potential influence on higher education that is especially significant for students with learning difficulties [107]. An inclusive metaverse-based school would allow teachers to not only speak about their discoveries but also demonstrate them in a 3D environment. Together with their classmates, students with learning difficulties can engage in serious questioning and use experiences to assist in their academic development. No longer will students with learning disabilities be forced to sit in a traditional classroom with nothing to do. They can instead learn alongside their peers due to the educational and social opportunities afforded by the metaverse [108].

The use of the metaverse in inclusive education offers several potential advantages over traditional models, allowing students with learning difficulties to experience historical sites or conduct dangerous experiments in a secure, virtual setting alongside their classmates [109]. Moreover, the metaverse learning environments can encourage safety in a manner that traditional classrooms cannot [110]. Educators will have total control over student interactions in the metaverse and will be able to prohibit bullying. Thus, students with learning difficulties may concentrate on their education without worrying about bullies or other disruptions. Roblox, Minecraft, Decentraland, Sandbox, Axie Infinity, and Fortnite are some of the metaverse projects [111].

In conclusion, the metaverse offers significant potential for supporting students with learning challenges since it is a hybrid of cutting-edge and established technologies. The standardisation and interoperability of multiple technologies enable the metaverse to present a significant opportunity as an assistive technology for students with learning difficulties.

IV. TOOLS

In this section, we discuss a variety of tools for assisting students with various learning difficulties. An overview of these tools are shown in Table 3.

A. KURZWEIL 3000

It is educational software designed to assist children with reading difficulties at home, at school, or in the workplace. This freeware includes OpenDyslexic typeface and text magnification to improve the readability of text for dyslexic students. Its 31 Natural Text-to-Speech voices are accessible in 18 dialects and languages, allowing students to access the same materials as their classmates. For a more meaningful learning experience, a test-preparation toolbar is accessible to students who wish to build their own evaluation [112].

B. QTrobot

QTrobot is a small, expressive AI-enabled humanoid developed for use by therapists and teachers. Children with autism spectrum disorder are taught communication, emotions, and

TABLE 3. An overview of tools for assisting students with learning difficulties.

Tool Name	Disability Assisted	AT	Functionality
KURZWEIL 3000	Dyslexia	AI	It enables Text-to-Speech voices are accessible in 18 dialects and languages.
QTrobot	Autism	AI	It can teach communication, emotions, and social skills through the use of facial expressions, gestures, and games.
ActiveMath	Dyscalculia	AI	It can assist students develop interactive courses depending on the student's goals, preferences, skills, and prior knowledge.
Widex's Evoke	CAPD	AI	It learns from the listening preferences of users throughout the world, bringing the development toward improved hearing out of the laboratory and into the real world.
Microsoft Immersive Reader	Dyslexia, Dysgraphia, CAPD, VPD, and NVLD	AI	It Enhance reading and writing for people of all ages and abilities.
Grammarly	Dysgraphia, CAPD, VPD, and NVLD	AI	It recognise faults in writing and look for a suitable replacement.
Google Glass	CAPD, VPD, and NVLD	IoT, XR and AI	It provides basic voice or vision commands for online and Internet engagement.
Google Expeditions	ALL	XR	Itis essentially a collection of XR experiences and "field excursions" offered by Google.
Merge Cube	ALL	XR	It makes possible to study and interact with manipulate 3D digital things.
CoSpaces Edu	ALL	XR	It helps students to create and engage with interactive media content.
Assemblr	ALL	XR	Assemblr will enable educators to construct 3D objects and scenarios for classroom.
Narrator AR	Dysgraphia, CAPD, VPD, and NVLD	XR	Narrator AR helps students improve their handwriting.
Augmented Classroom	ALL	XR	It lets teachers provide their students access to 3D augmented environment.
Roblox	ALL	Metaverse	it is a resource for teaching students about computer programming, animation, 3D design, and application development.
Minecraft	ALL	Metaverse	It is a digital world designed to foster innovation, teamwork, and problem-solving though gaming.
VoiceOver	VPD and NVLD	AI	It can describe what's on the screen in synthetic voice or braille through a linked braille display.
Voice Dream Reader	dyslexia	AI	It is a fully functional document manager that enhances the built-in text to speech functionality with additional personalization options.
TouchCast Studio	ALL	AI	It is a application that provides students with all the tools they need to create interactive films with hyperlinked hotspots.
Book Creator	ALL	AI	It isa blank canvas on which students may generate an ebook.

social skills through the use of facial expressions, gestures, and games [113], [114].

C. ActiveMath

ActiveMath is a web-based AI-learning system that develops interactive (mathematics) courses depending on the student's goals, preferences, skills, and prior knowledge. The material is delivered in an XML-based, semantic manner. The required information is acquired from a knowledge base for each student, and the course is constructed based on educational guidelines. The student is then provided with the course using a conventional web browser. ActiveMath is distinguished by its incorporation of independent mathematical service systems. This facilitates exploratory learning, realistically complicated activities, and the acquisition of proof methods [115].

D. WIDEX's EVOKE

Widex's EVOKE is the first hearing aid in the world to incorporate machine learning. Every day, it improves the audio experience of every user. In addition, it learns from the listening preferences of users throughout the world, bringing the development toward improved hearing out of the laboratory and into the real world [116].

E. MICROSOFT IMMERSIVE READER

The free AI tool Microsoft's Immersive Reader enhance reading and writing for people of all ages and abilities. It is integrated into Word, OneNote, Outlook, Office Lens, Microsoft Teams, Reading Progress, Forms, Flipgrid, Minecraft Education Edition, and the Edge web browser [117].

F. GRAMMARLY

Grammarly is a typing assistant that uses AI and the cloud to check for problems in spelling, grammar, punctuation, clarity, engagement, and delivery. AI is used to recognise faults and look for a suitable replacement. Additionally, it gives users the option to customise their language, tone, and context [118].

G. GOOGLE GLASS

Google Glass will provide basic voice or vision commands for online and Internet engagement. Google Glasses can easily power mobile devices like smartphones or tablets and may be thought of as wearable computers in this fundamental sense. The basic identification tool for blind and visually impaired people using the Google Glass camera. This viewpoint makes it possible to describe Google Glass as an assistive technology [119].

H. GOOGLE EXPEDITIONS

Google Expeditions is essentially a collection of AR and VR experiences and ''field excursions'' offered by Google. Some of the 'expeditions' are more supported than others with lesson plans, supporting links, and background information [120].

I. MERGE CUBE

The Merge Cube makes it possible to study and interact with the digital world in a whole new manner by letting you manipulate 3D digital things. In addition to many other things, students may inspect a DNA molecule, research the Earth's core, dissect a virtual frog, hold and share their own 3D creations, and explore a galaxy in the palm of their hand [121].

J. CoSpaces EDU

Users of CoSpaces, a web-based XR tool, may create and engage with interactive media content. CoSpaces allows students to demonstrate their knowledge in fresh ways by

building interactive virtual settings that might be simple or complex but are still user-friendly for beginners [122].

K. ASSEMBLR

Assemblr will enable educators to construct 3D objects and scenarios for classroom usage. Students will have a better learning experience while utilising the Assemblr application to engage in AR, and VR [123].

L. NARRATOR AR

An augmented reality software, Narrator AR helps students improve their handwriting. When a child's handwritten name is scanned, the application superimposes an animation showing the name blasting off the paper in the form of a rocket or a rainbow unicorn trail. Using the Narrator AR Mobile application, students can make a connection with their writing as virtual letters are lifted from the paper [124].

M. AUGMENTED CLASSROOM

The purpose of the CleverBooks Augmented Classroom (ARC) is to let teachers provide their students access engaging, interactive courses by delivering content in fully immersive, 3D augmented settings. When used in the classroom, ARC's 3D environment has been shown to boost student engagement and motivation, leading to better academic outcomes [125].

N. ROBLOX

Roblox Studio is a free, family-friendly resource for teaching students about computer programming, animation, 3D design, and application development. Using Roblox Studio in the classroom boosts students' self-esteem by giving them a real-world platform on which to practice the scientific inquiry skills outlined in the Next Generation Science Standards (NGSS). Students can travel across time and space in Roblox adventures that are set up for exploration, investigation, and experimentation. Students may experience and analyse scientific events, go back in time to ancient Rome, and even construct virtual robots to compete against one another in friendly or hostile team challenges [126].

O. MINECRAFT

The educational version of Minecraft is a digital world designed to foster innovation, teamwork, and problem-solving through gaming. Teachers worldwide can use Minecraft education edition to capture their students' interest in a wide range of disciplines and make abstract concepts more concrete [127].

P. VoiceOver

The iOS operating system has a built-in screen reader called VoiceOver. It can describe what's on the screen in synthetic voice or braille through a linked braille display for the visually impaired [128].

Q. VOICE DREAM READER

Voice Dream Reader is a fully functional document manager that enhances the built-in text-to-speech functionality with additional personalisation options. These options include masking to display only a small portion of the text, support for dyslexia-friendly fonts, fully customisable colours for word and sentence highlighting, and more. Documents may be imported from a number of sources, such as Google Drive, Dropbox, and Bookshare, a programme that provides students with qualifying reading difficulties with free access to books in accessible formats [129].

R. TouchCast STUDIO

TouchCast Studio is a free iPad application that provides students with all the tools they need to create interactive films with hyperlinked hotspots. Students can utilise a variety of video applications to link to supporting research on the Internet, ask questions through polls, link to an accessible script of their film, and more. The application has many complicated features, like a built-in teleprompter and green-screen features that let students work themselves from different places. It also works with multiple iPhone cameras [130].

S. BOOK CREATOR

The Book Creator provides a blank canvas on which students may generate an ebook to demonstrate their comprehension and incorporate all of their media. Each book may have text, photographs with descriptive learnings, audio, and video. The free, fully-functional version of Book Creator for iPad may be used to produce one book. Upgrade to the premium version to have access to limitless publishing and comic book templates. There is also a Chromebook-compatible web-based version of Book Creator; with this edition, users may generate up to 40 free booklets [131].

V. PROJECTS

In this section, we discuss some related projects that work toward students with learning difficulties and inclusive education. The overview of the related projects that work towards students with learning difficulties and inclusive education is shown in Table 4

A. IncED

This project is managed by the private organisation Vivere kool MTU and funded by Erasmus+, the European Union's education, training, youth, and sports programme. This project focuses on inclusion, fostering equality and non-discrimination, and using modern teaching-learning techniques. The project's objectives are to better understand concepts of mixed-ability and inclusive collaboration and to highlight it as a possibility rather than a challenge, to adapt current systems and build innovative educational games and methodologies for collaborating in mixed-ability groups that can be used in non-formal and formal learning contexts for students aged 13 to 18 years old, to promote inclusive education among various types of stakeholders, and to improve the youth workforce [132].

TABLE 4. Overview of related projects that work towards the student with learning difficulties and inclusive education.

Project Name	Key Action	Action Type	Countries covered
IncED	Partnerships for cooperation and exchanges of practices	Cooperation partnerships in youth	Latvia, Portugal, Estonia, and Spain
Fairness Inclusive	Learning Mobility of Individuals	Youth mobility	Russia, Romania, France, and Germany
InClusion Team	Cooperation for innovation and the exchange of good practices	Strategic Partnerships for school education	Portugal, Greece, and Spain
ELLeN	Cooperation for innovation and the exchange of good practices	Strategic Partnerships for higher education	Germany, Austria, and Belgium
Accessible Peer Interaction with Disabled Youth	Accessible peer interaction with disabled youth	To impact young people, thereby investing in the future and providing the proper basis for a spillover effect into wider society and into the working environment.	Bulgaria, Belgium, Austria, and United Kingdom

B. FAIRNESS INCLUSIVE

This project is handled by the Kreisau Initiative association and funded by Erasmus+, the European Union's programme for education, training, youth, and sport. This project focuses on disability and special needs, equality and access for the underprivileged. One of the primary objectives of the initiative is to engage disadvantaged youth in international educational activities. This engagement help the emancipation of young people so that they may lead more independent lives and treat others with tolerance, solidarity, and respect in the future. The underlying belief of this objective is that it increases their social inclusion and minimises their marginalisation [133].

C. InClusion TEAM

This project is managed by Fyllingsdale High School in Norway. The partners include universities, secondary schools, a public teacher training centre, and educationally focused non-governmental organisations. Erasmus+, the European Union's programme for education, training, youth, and sport, is funding this project. This project focuses on new technologies, digital skills, access for the disadvantaged, and particular requirements for those with impairments. The project aims to establish a learning community in which universities, schools, teacher training centres, and non-governmental organisations share best practices for teaching ICT to students and individuals with special needs. The collaborating parties intend to equip educators with training and expand access to high-quality learning tools, and materials [134].

D. ELLeN

This project is managed by Goethe University Frankfurt and funded by Erasmus+, the European Union's education, training, youth, and sport programme. In this project, a teacher will teach students how to research the needs of a certain group of learners by interviewing those learners. In other words, neurodiverse learners will be treated as experts in their own learning process. By helping pre-service teachers build up their Inquiry-based learning skills and competencies, this initiative also shows how, in partnership with neurodiverse learners, the strengths and needs of the target population's learners can be identified, evaluated, and met in learning environments [135].

E. ACCESSIBLE PEER INTERACTION WITH DISABLED YOUTH

The National Association of Professionals Working with People with Disabilities manages this project (NARHU, Bulgaria). This initiative is supported by Erasmus+, the education, training, youth, and sports programme of the European Union. This project targets youth workers and leaders, student leaders, student bodies, youth organisation leaders, and representatives of disabled youth organisations. The work aims to assist youth workers in developing and disseminating effective strategies for reaching out to marginalised youth, refugees, asylum seekers, and migrants, as well as combating racism and intolerance among young people [136].

VI. CHALLENGES AND FUTURE DIRECTIONS

This section discusses challenges and future directions of assistive technologies for students with learning difficulties in higher education. An overview of these challenges and future directions is depicted in Fig. 3.

A. PERSONALIZATION OF ASSISTIVE TECHNOLOGIES

1) CHALLENGE

It is not possible for a single assistive technology to represent a universal solution to the learning challenges faced by all learners with learning difficulties. The need for these assistive technologies varies with the needs and preferences of each student with learning difficulties. Some students may or may not need the full functionality of a particular assistive technology, while others may require a combination of the functionality of many assistive technologies. Personalisation of these assistive technologies is very important for inclusive education, but it still remains a challenge that must be addressed.

2) POTENTIAL SOLUTION

Students with learning difficulties may customise their assistive technology to meet their needs in a virtual world by using automated 3D modelling and printing. The organisations must also permit mass customisation of educational aids that help students overcome their learning difficulties [137].

B. DESIGN ISSUES

1) CHALLENGE

A variety of computer interfaces and technologies will be used for academic purposes by students without

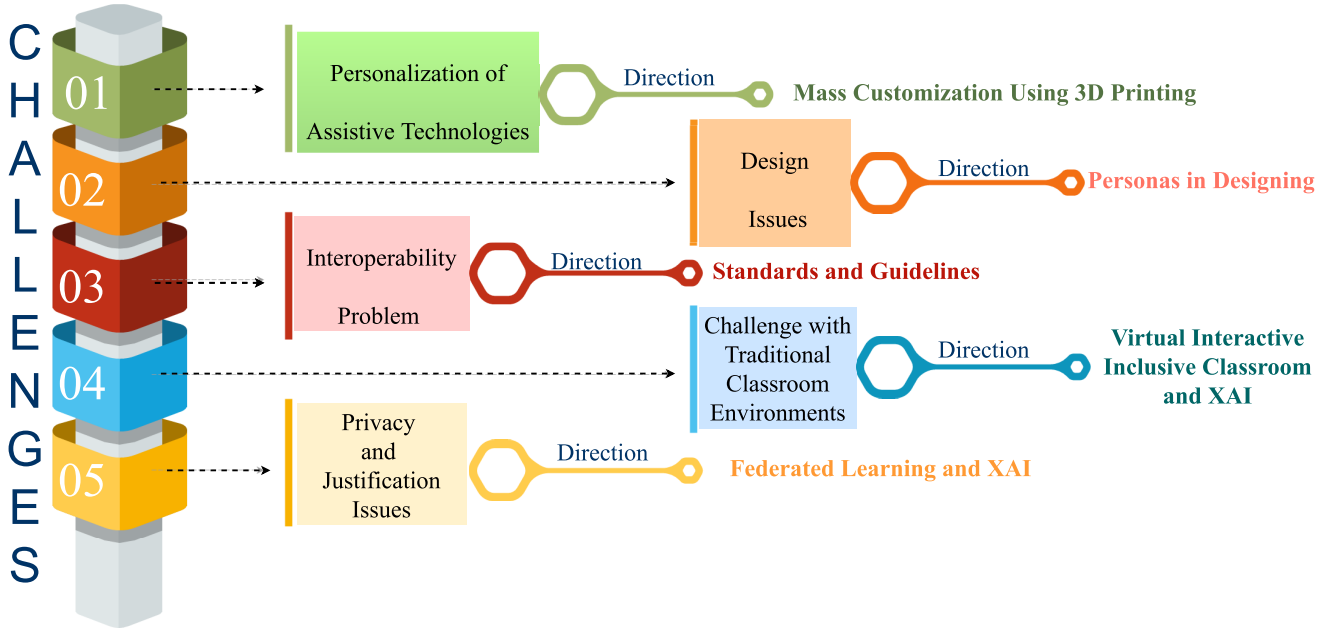

FIGURE 3. Challenges and Future Directions of Assistive Technologies for Students with Learning Difficulties in Higher Education.

learning difficulties. Individuals with learning difficulties need a personalised environment, which may or may not be available in their classroom environments. If the instructor does not provide such assistive technology to the students, the concept of inclusive education would be compromised. The challenge with HCI still exists, and it is not feasible for students with learning difficulties to use the same computer interfaces and technology as effectively as their classmates.

2) POTENTIAL SOLUTION

The use of personas in designing an HCI takes into account a variety of characters with and without learning difficulties, which aids in the better design of services and products that can be utilised by everyone regardless of any difficulties [138].

C. INTEROPERABILITY PROBLEM AMONG ASSISTIVE TECHNOLOGIES

1) CHALLENGE

The devices and technologies used in the creation of various assistive technologies may not have been developed by a single organisation. There are currently no interoperability standards or regulations in place for assistive technology like the metaverse. As a result, these assistive technologies will raise integration and interoperability challenges. This could result in the student losing focus in an inclusive educational environment.

2) POTENTIAL SOLUTION

Instead of only providing best practises, there is a need for standards that address these issues relating to the creation of assistive technologies. These guidelines need to specify the industry standards for developing assistive technologies. Furthermore, verification and certification from the scientific community are required before an assistive technology is delivered to the market. There should be specific guidelines for utilising them while adapting to the real world. This will allow enterprises to build assistive devices more quickly and at a lower cost. Additionally, this will also solve the interoperability problems with different assistive technologies [139].

D. CHALLENGE WITH TRADITIONAL CLASSROOM ENVIRONMENTS

1) CHALLENGE

Traditional classroom environments may have a negative impact on all students to some extent, at some time, and in some way, but students with learning difficulties are more vulnerable. This difficulty stems from their difficulties with speaking, writing, or thinking. Incorporating assistive technology into a conventional classroom environment exacerbates the challenge by requiring students to bring gadgets to class and use them to overcome their difficulties. These students' gadgets are unusual among their classmates, and if any technical difficulties arise, they further exacerbate their problems.

2) POTENTIAL SOLUTION

A Virtual Interactive Inclusive Classroom (VIIC) can help students with learning difficulties overcome the challenges they face in traditional classroom settings. Students can interact with one another in this class while taking classes from a convenient location. The interactive, inclusive virtual classrooms will use cutting-edge technology such as Explainable Artificial Intelligence (XAI) to help students make decisions,

sophisticated Mixed Reality (MR) for in-person interactions, and advanced robotic assistance that can be linked with the brain of a student with learning difficulties to help them do academic tasks. Thus, VIIC can help students overcome their disabilities and compete with their peers [140].

E. PRIVACY AND JUSTIFICATION ISSUES

1) CHALLENGE

AI can be combined with other technologies, such as digital twins, IoT, HCI, and the metaverse, to produce better outcomes. Students with learning difficulties must share personal data to receive decision-making assistance from AI models that support other technologies. These AI models cannot provide privacy for data provided by students with learning difficulties, which may create distrust of assistive technologies. The recommendations from AI-based assistive technologies cannot be completely relied on as they are black box in nature [141].

2) POTENTIAL SOLUTION

Federated learning can help with the problem of data privacy in assistive technologies. Federated learning addresses data ownership and privacy by guaranteeing that data never leaves dispersed node devices. Simultaneously, the global model is updated and distributed to all network nodes. This ensures the privacy of the students' data [142], [143]. XAI can make AI-based decisions more justifiable and accountable. XAI is a set of procedures and techniques that allow users to understand and rely on the outcomes. XAI will increase the accountability of recommendations. XAI can explain the anticipated outcomes and any potential biases. It aids in describing a suggestion's accuracy, fairness, and transparency and improves decision-making. XAI increases trust and confidence in assistive technology suggestions [144].

VII. ROADMAP

Based on the findings of the systematic literature review that we carried out, AI, XR, IoT, HCI, digital twins, and the metaverse are the potential technologies that can assist students with learning difficulties. In the past few decades, AI and HCI have played a significant role in supporting students who struggle with a variety of learning difficulties. As research progresses, AI and HCI as forms of assistive technology will continue to develop. IoT as an assistive technology enhances voice and vision and also provides real-time data on various challenges faced by students with learning difficulties using sensors. AR and VR, as assistive technologies, will effectively assist students with learning difficulties in engaging in activities and social integration. Even though the IoT, AR, and VR are already being used as assistive technologies in developed countries, it will take a significant amount of time for these technologies to catch on in developing or underdeveloped countries. Assistive technologies like digital twins require a huge number of IoT sensors to work effectively, and these digital twins, which are replicas of real-world objects, can help experts mitigate the challenges of learning difficulties virtually before being applied to the real world. The metaverse as assistive technology, which is enabled by various technologies like blockchain [145], edge computing, quantum computing, 3D modelling, XR, IoT, 6G, AI, and others, will make students with learning difficulties equivalent to their peers. The digital twins and the metaverse will be the future of assistive technologies that will help students overcome the challenges raised by their learning difficulties.

VIII. CONCLUSION

This survey aims to understand the potential role of a range of recent developments in technology in providing inclusive education for students with learning disorders in higher education. Throughout this process, we have analysed the learning and support needs that arise as a result of a student's learning difficulties and how these recently developed technologies can support inclusive education for students with learning difficulties. We have searched a range of online digital libraries to locate journal articles and conference papers relevant to our study. According to our examination of the relevant literature, there has been little research on assistive technologies related to XR, IoT, digital twins, and the metaverse. The use of AI and HCI as assistive technologies is more prevalent than other technologies. It is also understood that research on aiding students with learning difficulties in primary education is more widespread than in higher education. The selection of these technologies within this review is also supported by recent reports identifying them as important developments in educational technology for higher education in the near, mid, and long-term future. Our review has also highlighted projects related to assistive technology for inclusive education and students with learning difficulties in higher education. We also proposed strategies that may aid individuals with learning difficulties in higher education. Moreover, we highlighted the challenges of using assistive technology to provide inclusive education for students with learning difficulties in higher education and provided potential solutions. We aim to provide a road map to describe an accessible and inclusive higher education system using important and highly promising technologies to support students with learning difficulties.

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