SURVEY

A Survey on E-Learning Recommendation Systems for Autistic People

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ABSTRACT Autism, also known as Autism Spectrum Disorder (ASD) or Asperger's syndrome, has an impact on cognition, social relationships, and behavior. Based on these characteristics and their learning interests, e-learning (Electronic Learning) recommendation systems attempt to provide personalized recommendations. This may enhance the learning ability of individuals with ASD. However, some technological challenges limit the ability of the population to use support scenarios and prevent efficient learning. This study tries to review e-learning recommender systems for individuals with ASD. The main identified aspects are 1) lack of design principles while building customized e-learning platforms for those with ASD; 2) technological limitations to developing recommender systems for e-learning, and 3) suggestions that reduce field limitations. The studies additionally discovered that social communication and psychological abilities had the greatest focus of study. A small number of studies mentioned the participant's ASD level, the majority of the articles highlighted the beneficial effects of designing a content-based recommender system specifically for those with ASD.

INDEX TERMS Applied behavior analysis (ABA), assistive technology (AT), autism spectrum disorder (ASD), content recommender system, collaborative filtering recommender system, electronic learning (E-learning), hybrid recommender system, information and communication system (ICT).

I. INTRODUCTION

The World Health Organization (WHO) estimates that there are nearly one billion disabled people in the world. One such disability is Autism spectrum disorder (ASD) a neurobiological disease impacting social relationships, interactions, and behavior [1]. If it is not diagnosed in early childhood it affects later in future, and its prevalence is higher in boys [2], [3], [4]. Certain individuals with ASD can live independently, whereas others require lifelong care. Common characteristics include sensory hypersensitivity, lack of interest in activities, and repetitive behaviors [5]. These factors significantly affect learning as shown in FIGURE 1. However, autistic people can

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progress in their development and lead meaningful lives with appropriate support [1].

In an E-learning system, adaptability is the most essential feature. Therefore, online learning can be customized to meet unique requirements and preferences like learning interests, profiles of users, and prior experience, these factors will influence the system more [6]. Therefore, adaptability promotes accessible education, particularly for individuals with specific schooling needs who strive to enhance their functional capabilities [7]. For comprehensive support of specially-abled people, the assistive technology (AT) concept is integrated with the Information and Communication System (ICT) that leads to linking between devices and services, incorporating adaptability and assistive technology into the education system leads to the best solution [8]. Individuals

with disabilities encounter challenges in terms of academic achievement, employment prospects, and poverty rate. Information and Communication Technology (ICT), particularly the Internet, has become essential for supporting inclusion and providing access to knowledge [9]. Educational technologies improve academic performance, develop social skills, address everyday challenges, and enhance workforce inclusion for individuals with disabilities [10]. For individuals with Autism, computer-human interaction offers a safe and focused environment for targeted development. Technologies such as specialized input devices, systems powered by AI, arcade games, extended reality, and robot machineries have shown positive outcomes in supporting individuals with ASD [11], [12]. Designing e-learning systems requires an understanding of the interactions of individuals with disabilities within the learning environment to identify areas for improvement. Careful consideration of the clinical context for individuals with ASD is essential in designing effective recommendation systems [13], [14].
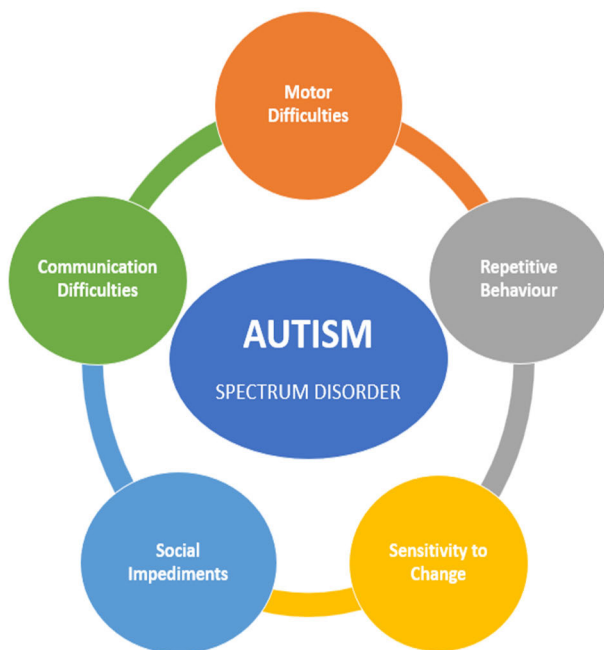

FIGURE 1. Characteristics of autism spectrum disorder.

This paper provides an overview of various models of recommendations utilized as an educational tool in the online learning domain and evaluates the pros and cons of current recommendation models, mainly for persons with disabilities such as autism. The specific objectives of this review are as follows:

Conducting an analysis and synthesis of research work in e-learning content recommendation systems for people with autism. Identifying the various recommendation techniques employed, the parameters and attributes utilized as input for suggestion model, the procedures employed during

each recommending stage, similarity measurements utilized, and assessment criteria used in content recommendation model for online learning, specially designed for Autism. Identifying the various characteristics of individuals with ASD should be considered while designing an e-learning recommendation system.

II. RESEARCH METHOD
In the following section, the authors aim to convey the fundamentals of recommendation system and different approaches for implementing recommendation system and an associated systematic study of autism-friendly e-learning recommender system, data source details and inclusion and exclusion criteria for paper selection for this review.

A. RECOMMENDATION SYSTEMS
E-learning systems have seen massive growth over the past decade. E-learning platforms have curated an immense collection of learning resources encompassing a wide variety of formats and media types. These resources are extensively diverse and offer learners a rich and varied learning experience [15]. The overwhelming amount of information in online learning environments has created a demand for personalization. Several recommendation strategies have been used in studies to deal with information saturation. These techniques are designed to filter out unnecessary information from learning resources and offer customized content specifically tailored to their unique needs and preferences of learners [16]. The learning method is impacted by the unique requirements, objectives, and preferences of each learners, and learners exhibit distinct features, such as background information, history of learning, competency stage, learning approach, and activities [17], which further complicates the task of recommending ideal learning resources for each learner. A major challenge in these systems is the dynamic nature of the user interests, preferences, and needs, which evolve over time. Consequently, in e-learning environments, recommendation systems should focus on addressing the specific requirements and characteristics of learners themselves. Additionally, these recommendation systems assist educators while designing the learning process by taking into account of desires and individual needs of the learners [18]. A recommendation system's fundamental goal is to assist users and discover relevant items.

B. CONTENT-BASED RECOMMENDATION APPROACH
This kind of recommendation system makes us of content analysis to examine documents, resources, and other items that users have already assessed. Through this analysis, a recommendation model was constructed by considering diverse interests of users, and then they assigned an attribute value to the keyword depending on frequency of occurrences in that resource. Recommendations are then generated by referencing the profiles of individual users and suggesting different items with similar attributes [19].

C. COLLABORATIVE FILTERING-BASED RECOMMENDATION APPROACH

This type of recommendation approach has been widely adopted in numerous fields, highlighting its broad usage. In collaborative filtering-based recommendation systems, considers the correlation between resources and users, suggestions are recommended, where feedback of other learners with the same interests is considered while making suggestions. Feedback may be implicit and explicitly obtained from the system users to generate personalized recommendations [20], [21].

D. HYBRID RECOMMENDATION APPROACH

Hybrid approaches in recommendation systems aim to combine the strengths of various approaches while mitigating their limitations. The best-known hybrid approach involves integrating content-based and collaborative filtering approaches. However, other kind of hybrid approaches incorporate different aspects. The primary objective is to simultaneously integrate or combine multiple techniques to implement a hybrid system capable of providing more comprehensive and improved recommendations [22], [23].
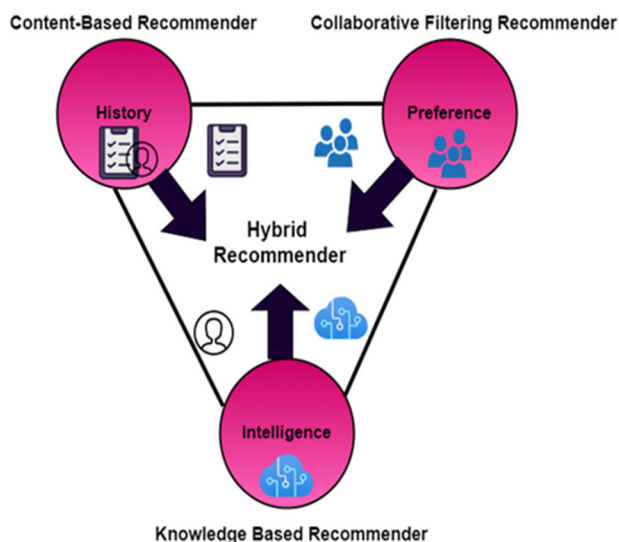

FIGURE 2. Recommendation system types.

E. KNOWLEDGE-BASED RECOMMENDATION APPROACH

Several recommender systems utilize semantics or knowledge driven recommendation systems for online education. These systems encompass both context and ontology-based approaches. By leveraging ontology, these knowledge-based systems structure and organize details regarding the content and participants involved in the e-recommendation (Electronic recommendation) process. Concerning, these systems effectively map learning resources relevant to individual learners by leveraging relational knowledge [23]. These

different types of recommender systems are presented in FIGURE 2.

F. DATA SOURCE

To conduct this study an exhaustive search was made across digital databases including Science Direct, Springer IEEE-Xplore, and Scopus. The researchers carefully examined and extracted key elements from the identified studies, including abstract, summary, and key phrases from various documents, including articles from journals conference publications. Through this process, the authors were able to identify the most crucial topics that needed to be addressed to provide answers to the research issues guiding their study.

G. STUDY SELECTION

To identify recent research in personalized recommendations for Autistic people in the field of e-learning, the researchers conducted an online database search from 2007 to 2023. The terms "e-learning recommendation system", "Autism", "recommender system for people with disability", "adaptive e-learning" and "e-learning recommender system for people with Autism" are used to identify the papers. FIGURE 3 block diagram shows article selection, and number of articles excluded form study, there are total of 112 papers selected initially, from this collection finally 26 articles were chosen for further analysis according to selection specification:

- Articles include techniques for making recommendation to individuals with Autism
- Articles that include the special characteristics of persons with Autism
- Articles proposing E-learning
- Articles explaining the detailed methodology of design
- Articles which are published in recent years.

After retrieving these papers for study, the authors examined them. Initially, they assessed each paper's title, abstraction, summary, and key terms for identifying most appropriate scientific articles for review. In subsequent stage, optimally recognized papers were used for a more comprehensive analysis. The authors have thoroughly examined the entire content of these papers. Articles that satisfied the requirements were the only ones picked for an in-depth review and further examination.

FIGURE 4 reveals an increasing trend in the number of publications related to personalized recommendation technologies for people with ASD in e-learning environments between the year 2018 to 2022. Furthermore, there was a significant leap in publication numbers during this period, indicating substantial progress in research output in the domain of e-learning recommendation systems for people with Autistic disorder. Moreover, technological advancements are making it possible for anyone, regardless of their disability, to obtain e-learning.
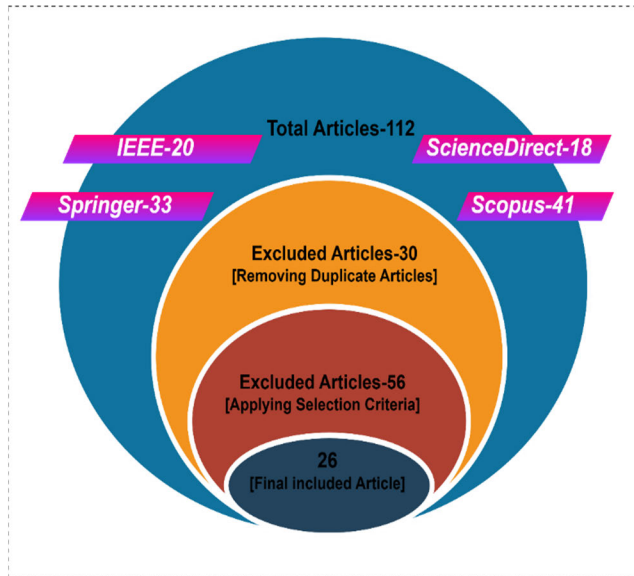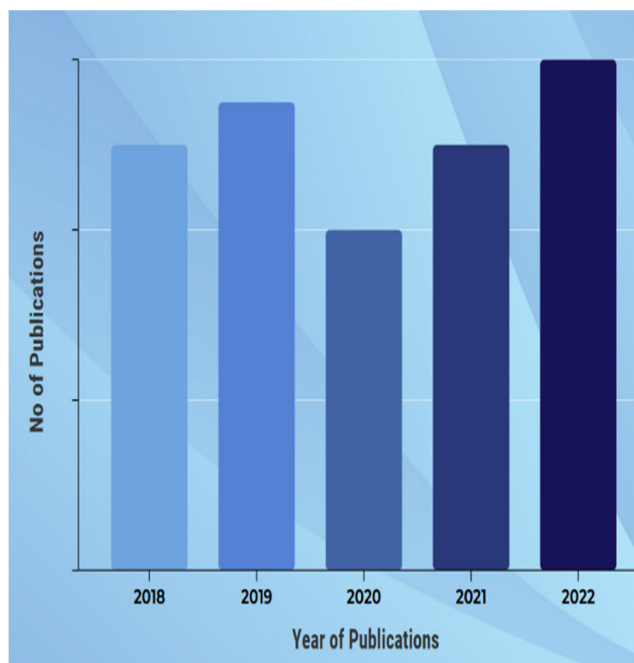
FIGURE 3. Flow of data source selection.

FIGURE 4. Distribution of articles by year of publications.

III. RESULTS AND DISCUSSION

E-learning recommender systems are trending technologies in education systems, where the application mainly focuses on the learner's interest and prioritizes the available resources such that it fulfils user needs with irrespective of disability. TABLE 1 represents the analysis result of the primary study of the review, it exhibits that there are several researches done for providing the e-education (Electronic education) systems for individuals with disability by incorporating several modern techniques in recent years, and also explains the main contribution of each work, this table shows that there are variety of applications and equipment's are designed for providing the personalized e-learning facility for learner with disabilities like autism spectrum disorder.

E-learning systems should incorporate an assessment of the visual engagement of individuals with Autistic disorder because of their challenges in maintaining visual contact. It is necessary to evaluate the percentage of time and duration that individuals with ASD remain visually connected to technological tools while using them. By monitoring visual engagement during e-learning activities, valuable insights can be gained regarding attention and engagement levels. These details can be utilized to customize the e-learning experience, providing appropriate support, and for enhancing the system's design to better cater to the unique needs of learners.

The selected studies encompassed a broad category of topics as shown in FIGURE 5, but several skills emerged as the central focus of research, TABLE 2 summarizes the skills that are analyzed, for persons with autism spectrum disorder. To a lesser extent, other abilities were investigated as well, including those linked to the profession, physical capabilities, behavioral abilities, and using public transportation. It is essential to remember that the information provided is the outcome of skills and their frequency.
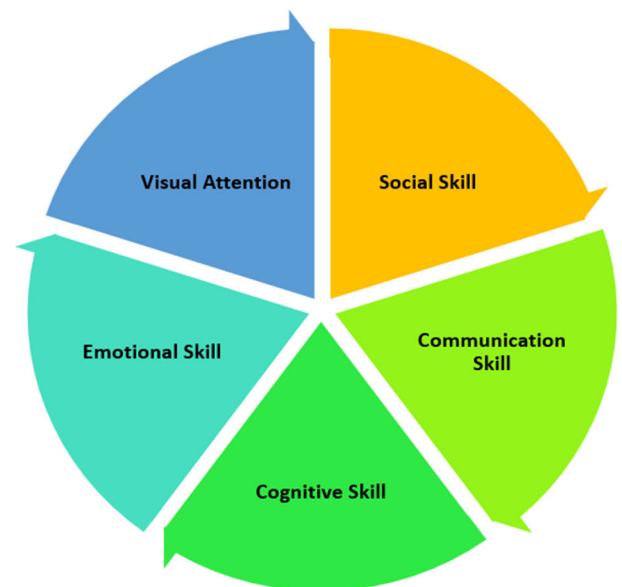

FIGURE 5. Autism skills targeted in publications.

The review identifies recent trends in designing e-learning recommender systems that fulfill the independent needs of individuals with Asperger's syndrome. An autistic person's social environment is important factors that strongly influence the learning process while implementing an e-learning system, as well as scientific, pedagogical, and psychological infrastructure that influences individuals with ASD.

TABLE 1. Year of publication, technology implemented main contribution summary of 26 articles of primary study.

ID	REFERENCE	YEAR	TECHNOLOGY IMPLEMENTED	MAIN CONTRIBUTION
1	[14]	2018	E-learning platform design	The author presents the results of an investigation comparing the effectiveness of live training and e-learning in teaching listener response programs. The live training method showed slightly better skill acquisition than the e-learning method. However, participants of the e-learning system reported higher satisfaction than in live training.
2	[24]	2018	Virtual educational platform	The authors of this article explain the difficulties and design problems they face when creating virtual educational resources for autistic learners. Although this paper is based on an overview of the literature, it offers relevant information and useful findings regarding design standards for such applications. The authors recognize and address the major issues and design factors that must be taken into consideration while creating virtual training programs for Autistic individuals by reviewing key concerns in this area.
3	[25]	2018	Robot design	This study presents a technological structure that, with the assistance of a humanoid robot, incorporates different visual signals to discover behavioral patterns throughout the treatment of autism spectrum disorder (ASD). This framework combines multiple visual cues to effectively monitor and analyze behavioral patterns throughout ASD treatment. By integrating these cues, including those provided by a humanoid robot, the framework provides insightful analysis of behavioral progress and trends of individuals undergoing ASD treatment.
4	[26]	2018	Virtual Reality	The idea of autonomously artificial human beings was used in this study to model and practice fundamental abilities in society including expressing Greetings, initiating conversations, and actively listening and speaking. This work focused on developing virtual human agents capable of autonomously engaging in these social interactions. By incorporating this concept, this article aims to provide a realistic and interactive environment for practicing and improving essential social skills.
5	[27]	2018	E-learning platform design	The author utilized a pilot program in which participants, consisting of caregivers of learners with autism, were enrolled in an e-learning course that focused on ABA (Applied Behavior Analysis) principles and strategies. The course was designed to accommodate Czech caregivers' needs and was delivered online to provide flexibility and accessibility. The study employed a combination of techniques, incorporating prior and post-course assessments and also qualitative interviews, to evaluate the outcomes of the training program.
6	[28]	2019	E-learning platform design	The author developed a learning game specifically designed to assist young children with autistic disorders in learning and generalizing their visual preformation skills. The game incorporated dynamic scenarios to provide an interactive and engaging learning environment. The primary goal is to support children with ASD in developing and generalizing their visual perception abilities. By designing this learning game, the author aims to enrich the educational opportunities for younger children with autism, promoting their visual preformation skills.
7	[29]	2019	Robot implementation	The purpose of the study was to examine whether or not autistic youngsters could cooperate while interacting to robot. The experiment involved the inclusion of specific measurements in the experiment to examine people's reactions to various robotic machine behaviors. These metrics encompass aspects like body movements, head orientation, magnitude, and kinetic force. By incorporating these metrics, the researchers aimed to achieve insight into mutual attentiveness dynamics in kids with ASD and the robot, shedding light on potential areas for advancement and intervention in enhancing joint attention skills.
8	[30]	2019	Virtual reality tool design	In this study, a cyber-human framework for full immersion education is proposed. This framework specifically targets two distinct domains: orthopedic surgery training for residents in medicine and science learning for autistic learner. It emphasizes the use of immersive technologies to create realistic and engaging learning experiences in these areas. By developing this cyber-human framework, the authors aimed to enhance the educational outcomes and engagement of medical residents in orthopedic surgery and facilitate science learning for individual with ASD.

TABLE 1. *(Continued.)* Year of publication, technology implemented main contribution summary of 26 articles of primary study.

9	[31]	2019	Serious game design	In order to improve the responsive identification of lexical items in adolescents having autism spectrum disorder (ASD), the authors of this study developed a serious game. The serious game was specifically designed to engage and motivate autistic children's while facilitating their ability to recognize and understand various vocabulary items.
10	[32]	2019	E-learning application	The goal of this initiative is to create a comprehensive, assistive intervention education programmer for adults with autism spectrum disorder, with a focus on public transportation. This initiative aims to expertise and build the confidence they need to efficiently use public transportation systems. The researchers created a comprehensive intervention training program that offered sincere and useful experiences in utilizing public transportation through diligent design and evaluation. The program's success was rigorously evaluated, ensuring its applicability and relevance to people with ASD.
11	[33]	2019	E-learning platform design	In this paper, the author provides overall glance for examining the use of online learning platforms for individuals with cognitive disabilities. The review found that online interventions could be effective in improving cognitive skills and educational outcomes in this population. These benefits include increased accessibility, flexibility, and engagement. However, challenges, such as technological accessibility and desire for additional support, have also been identified.
12	[34]	2020	Virtual tool design	This study addresses the difficulties and problems associated with the design they encounter when developing virtual training tools for people with autism spectrum disorder (ASD). Despite being founded on literature research, the report provides helpful insights and relevant conclusions regarding the design standards for such applications. The authors recognize and address the major difficulties and design issues that are more significant when creating virtual training programs for people with ASD by reviewing the body of knowledge in the area.
13	[35]	2020	Virtual reality tool design	The study presents, the existing methodology for CVLEs (Computer Vision-Based Learning Environments) and the difficulties involved in implementing platform for autistic people were investigated. This study evaluates methods and behaviors currently utilized by CVLEs and explored the particular difficulties and limitations experienced when implementing them on people with ASD.
14	[36]	2020	Online learning platform	This study introduces an innovative mathematical education e-learning model to incorporates two important components: a classifier for identifying emotions and a technique for controlling emotions. The proposed model aims to enrich the learning experience by effectively recognizing and addressing learners' emotional states during the mathematics learning process. The emotion recognition classifier is responsible for identifying and analyzing the students' feelings as they communicate with the e-learning platform.
15	[37]	2020	Virtual E-learning application	While creating and implementation of a virtual reality environment in schools for educational purposes, a significant aspect involved the creation of realistic and customizable avatars. These avatars were carefully designed to closely resemble real-life individuals and provide options for customization, allowing users to personalize their virtual representations. By incorporating these realistic and customizable avatars, the virtual reality environment aimed to enhance the immersive and engaging experiences of students within the school context.
16	[38]	2021	Mobile application using assistive technology	The proposed work introduces a mobile application called "Squizzy" as assistive technology for autistic children. The author implemented scrum methodology to lead the development process of the application. They mainly considered autism in kids aged between 5 to 15 years, and they mainly targeted their social interaction skills.
17	[39]	2021	Virtual E-learning application	This study provides the foundation for implementing sound creation technology as an essential part of interventions for autistic children. The study emphasizes the potential of sonification, a method of converting data into sound, as a way to deliver efficient support and intervention for autistic individual.

TABLE 1. *(Continued.)* Year of publication, technology implemented main contribution summary of 26 articles of primary study.

18	[40]	2021	Virtual learning platform	The authors of the present study were able to create a system based on the cloud that will enable the expansion of virtual reality educational applications that were specially evolved for programs for adolescents with autism. To meet the special needs of people with Autism, the approach presented in this study concentrates on developing immersive and compelling learning experiences. The system makes use of cloud-based technologies to enable the development and distribution for immersive learning applications that assist and facilitate skill development and effective learning.
19	[41]	2021	E-learning platform design	Design and implementation of mobile application for autism spectrum disorder individual is main object of this article. The implemented application mainly supports the e-learning of children age group 8-14. This study examines the evaluation of the application's performance and emphasizes the importance of including interactive features. It emphasizes how e-learning based mobile applications can offer individualized and convenient educational support for adolescents with ASD.
20	[42]	2021	E-learning platform design	In the present article, the author describes how the vocabulary and terminology used in two online programmers on autism education and technological advances sparked comments from the e-learning audience. Participants preferred the persons first language and emphasized the importance of inclusive and respectful terminology. This study highlights the impact of language choices on learner engagement and emphasizes the need for sensitivity and respect in discussing autism.
21	[43]	2022	Online learning application	This paper outlines how organizational ICT (information and communication technology) was included in the present e-SL (Electronic-service learning) paradigm, which replaced the prior SL (service learning) strategy. To aid with this shift, the authors have created an online learning environment. Four groups made up the participants in this effort, each focused on a different project aimed at individuals with autism. These projects focused on various subjects, including two related to physics and engineering and one centered on recycling. The experiment was conducted mainly on teenagers and adults with ASD.
22	[44]	2022	E-learning platform design	This article proposes a design for an inclusive e-learning system adapted to the demands of individuals with autism. The model aims to address challenges, such as sensory sensitivity and social interaction difficulties. This emphasizes the importance of accommodating the unique characteristics of autism to promote engagement and learning outcomes in online education
23	[45]	2022	Mobile application design	This paper presents a study that focuses on designing, implementing, and evaluating a mobile learning game and explores two learning approaches within the context of educational games: gradually examines dynamic complexity adjustment of system with higher difficulty levels. The application incorporates these approaches to adapt to the complexity of game, depending on the player's abilities. The researchers aim to investigate the effectiveness of these approaches in enhancing the learning opportunities within the game.
24	[46]	2022	Digital Biomarkers	In this paper, the authors discuss a project that aims to build prediction models to track three critical domains in children with autism spectrum disorder (ASD): turn-taking, collaborative focus, and mimicking It entails examining behavioral characteristics like body language, focus, and expressions in the face. This article aims to provide training for autistic children and enhance their social skills. The project evaluated 61 children aged 3–6 years old.
25	[47]	2022	Mobile application design	The authors designed and developed a mobile application specifically designed to promote empathy in kids with Asperger's syndrome. The implementation of application involved utilizing the principles of design thinking. To ensure the effectiveness of the application, experts with regular interactions with individuals with ASD evaluated their acceptability and usability. Their expertise and insights are crucial in assessing and refining the application to reach the specific needs and preferences of kids with ASD.
26	[48]	2022	Mobile application design	In this paper, the author developed a multi-classifier-based recommender system to assist the activity on the day-by-day bases for autistic people the implemented classifier helps with diagnosis and decision-making for individual with autism and their therapist.

TABLE 2. Distribution of articles according to autism skills targeted in publications.

Skills Targeted	Social Skill	Communication Skill	Cognitive Skill	Emotional Skill	Visual Attention
No of articles	5	4	5	6	6

IV. CONCLUSION

The principal goal of the current work is, assisting the formulation of effective e-learning strategies for Autistic individual. These traits make it difficult for a people to communicating, concentrating, managing emotions, and interacting with others. These factors directly influence the learning process. Recognizing these challenges, to address the specific requirements of individuals with ASD and enhance their learning experiences within the context of e-learning. The consensus among experts from different fields underscores the importance of early detection in mitigating these deficiencies. Furthermore, emphasized the importance of learning technologies in this context and tried to recognizing the significance of early intervention, and also highlighted that utilizing learning technologies is vital for providing effective support to individuals with ASD. By leveraging appropriate e-learning technologies, interventions can be implemented early, facilitating positive outcomes and addressing the challenges faced by individuals with ASD.

Another factor affecting the implementation of e-learning systems is the absence of design guidelines that are particularly concerned with the educational requirements of those having Autism. Therefore, study attempted to determine appropriate information required for establishing e-learning recommender systems for people with autism. The conclusions drawn from studying the developments in educational technology shows that there is little scope for correcting application-specific skill gaps and inadequacies. However, these drawbacks can be reduced by adopting a wider perspective that covers the essential elements present in such a system. Recognizing these areas for development provides an opportunity to improve the applications and create a more thorough strategy.

While implementing teaching and learning activities, using a recommendation approach enables greater comprehension of whether Autistic individual participate with various aspects of their environments. This study recognizes unresolved issues in the development of online education communities. The work emphasizes the significance of the best available technological tools so that people with ASD can be effectively involved in society and have better daily functioning. In addition, owing to the complexity of ASD, researchers have emphasized the significance of establishing guidelines when developing online learning platforms and modifying them according to their requirements. For future work, the authors identified suggestions that can be implemented in virtual educational recommendation domain for people with autism. Another significant discovery is that the bulk of research endeavors have been allocated to improving one's social abilities, with relatively little attention paid to how individuals with Autistic nature identify and regulate their emotions. The author identifies the below mentioned suggestions that can be incorporated into the online educational recommendation platform for individuals with autism.

- **Participants:** Most studies do not consider the age of children while designing recommendation system, so it is suggested that recommendations must include age-appropriate content for children with autism.
- **Level of Severity**: Most of the authors did not consider the severity level of children with autism, so it is recommended to consider the level of severity while implementing a recommendation system.
- **Personalized Recommendation**: The implementation system should be personalized and customized in accordance with the unique requirements and health conditions of individuals with ASD.
- **Cold-Start Problem**: Studies have not discussed new user cold-start issue therefore, it is suggested that while designing the recommendation system, it is essential to consider the user profile and feedback while generating recommendations.

CONFLICTS OF INTEREST

"The authors have no conflicts of interest to declare that are relevant to the content of this article."

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