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Review

The Utilization of Augmented Reality Technology for Sustainable Skill Development for People with Special Needs: A Systematic Literature Review

Nadire Cavus [1,2], Karwan Al-Dosakee [1,2,3,*], Abdo Abdi [4] and Siyar Sadiq [5]

[1] Department of Computer Information Systems, Near East University, Mersin 10, TR-99138 Nicosia, Turkey; nadire.cavus@neu.edu.tr
[2] Computer Information Systems Research and Technology Centre, Near East University, 99138 Nicosia, Cyprus
[3] Department of Computer Science, University of Duhok, Duhok 1006 AJ, Iraq
[4] Department of Information Technology, Duhok Polytechnic University, Duhok 1006 Mazi Qr, Iraq; abdo.abdi@dpu.edu.krd
[5] Department of Special Education, University of Duhok, Duhok 1006 AJ, Iraq; siyar.sadiq@uod.ac
* Correspondence: karwan@uod.ac; Tel.: +964-7504507819

Abstract: New technologies such as Augmented Reality can be used to enhance the possibility of obtaining new experiences to assist people with special needs. However, in the literature, there are not enough studies conducted on the use of Augmented Reality as an assistive technology, especially for people with special needs. The purpose of this study is to highlight the use of Augmented Reality technology on people with special needs for skill development. This systematic literature review includes recent and high-quality articles from chosen prestige databases between the years 2010 and 2020. The selected studies which fitted the eligibility selection criteria have been analyzed and synthesized. The study findings reveal the importance of using AR technology to assist individuals with special needs in their skill development process, to help them become more independent. We hope this study will enlighten researchers and the developers of AR tools. It has been recommended that more studies be done on the sustainable use of AR as an assistive technology, particularly for children with special needs, to make their life easier.

Keywords: augmented reality; people with special needs; special education; sustainable development; skill acquisition

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1. Introduction

Information technology is evolving and accelerating expeditiously. According to Abad-Segura [1], rapid technological advancements have led to a comprehensive and effective change in people's perception of modern life. One of these powerful technologies is Augmented Reality (AR). It is a real-time interactive technology that enables the end-user to integrate 3D virtual models into the real environment [2]. AR technology is commonly accessed through the use of various devices and platforms. AR applications are developed using the available tools and platforms, such as Unity, Unreal Engine, AR Core, HP Reveal and others. Moreover, well-known technology corporations such as Google, Facebook, Apple, Amazon and Microsoft have made significant contributions to the process of developing AR services and tools [3,4], including Wearable Devices (Handheld), Heads Up Displays (HUD) and Holographic Displays (Microsoft HoloLens), which are mainly conceived for Mixed Reality MR, Tablets and Mobile Devices (smartphones). In other words, this technology requires specific hardware with a camera to be operated [5]. Milgram and Kishino [6] presented a model describing a mixture of digital objects from the real environment into the virtual environment, which determined the edges of the MR continuum. The term Extended Reality (XR) has been recently conceived and is beginning to be used among researchers as a unified platform. XR is an umbrella term that embraces the spectrum from AR to Virtual Reality (VR) and throughout Mixed Reality (MX) (please see Figure 1 [7]). The ongoing research trend in XR is how to develop collaborative systems in terms of design and user experience (UX) to support multi-users [8].

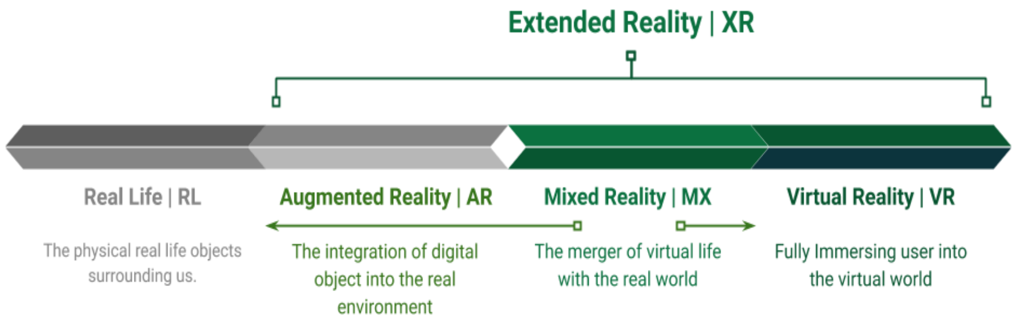

Figure 1. Extended reality spectrum.

AR can assist people with special needs in the sustainable development of a wide range of different applications, such as improving skill acquisition, learning performance, rehabilitation and training individuals to solve difficult tasks and to be more independent in daily life [9]. AR technology can be used as an assistive technology and an instructional tool to support learners with special needs in a sustainable learning environment, each according to his or her disability [10]. However, AR adoption comes with several challenges and barriers. One of the key technical challenges is the object recognition of the AR application, as there must be a perfect match between real and virtual objects to ensure accuracy. [11]. Another challenge comes from hardware limitations—for example, low-quality cameras affecting the AR application's robust tracking performance [12]. For people with special needs, their individual needs must be taken into account, which means that each application must be designed according to a specific context [13]. Furthermore, there are some problems in processing the information that extends reality. Boletsis [14] shows that there are many interaction differences among the three evaluated VR locomotion techniques (teleportation, walking-in-place and controller/joystick), as each of them has its weaknesses and strengths. In addition, Keil [15] argues for the need to standardize AR object placement, as the AR hardware is still in the development phase. Furthermore, Lokka [16] emphasizes the need to reduce the redundant and irrelevant parts of the applied content, avoiding cognitive load to provide an optimal design that has a better recall accuracy, especially for the elderly segment. It is worth mentioning that, as a result of the relative complexity of AR technologies before 2010, their adoption was limited [17]. Nevertheless, in the last 10 years, they has begun to be implemented more extensively due to their enhanced cost-effectiveness, to the availability of simple hardware and to the improvements made to smartphone devices [18] in terms of quality, quantity and the use of high-speed internet. Sirakaya [19] stated that this ease of access and use has led to a noticeable increase in the number of mobile applications and systems that utilize this emerging technology. Therefore, AR and its applications have become available to a wide range of users [20]. In addition, they might enrich the current style of tele-education by providing collaborative and continuous education tools [21] and enhancing telerehabilitation, which is the use of ICT to assist patients remotely in the rehabilitation process [22].

1.1. Disabilities

People with special needs are listed under different disability categories. There are different types of disability in terms of causes, consequences or the effects they produce—for instance: Physical Disabilities [23], Autism Spectrum Disorder (ASD) [24], Intellectual Disabilities [25], Down Syndrome (DS) [26], Cognitive Impairments [9] or Mental Disorders [27]. Generally, there is no specific definition of disability, but it can be defined as the passive consequence of an individual's interaction with their physical and social environment [28]. It was previously believed that a disability stems from psychological or medical limitations, so it is inside the individual. According to Näslund [29], although it is hard to see a clear boundary between disability and impairment, they are both relational rather than dichotomous. Hence, there is a relationship between impairment (intrinsic factor) and the environment (extrinsic factor). This relational model evolved from the previous discussions concerning the concept of disability. It can be seen that the number of people with one type of disability exceeds one billion (15% of the world population) worldwide, and this figure is continuously increasing [30]. For most people with special needs, it is quite challenging to integrate normally within a society lacking a realistic comprehension of their essential challenges. According to the World Health Organization (WHO) [28], people with special needs experience health conditions that make them less able than their peers to access a proper education system or work opportunities, which makes them more vulnerable to poverty. Thus, there is an imperious demand to focus on this segment of society to expand the range of services provided to them, especially for skill development, education and rehabilitation. It is important to investigate their needs by finding sustainable approaches and evidence-based solutions for the acquisition of daily life skills and for sustainable learning for living independently. Environmental factors are one of the causes of disability and, therefore, play a significant role in the rehabilitation process. Evidence revealed that the majority of people with special needs are less likely to engage with their environment, and this is especially valid for cognitively impaired individuals. [30]. Human cognition has been addressed by many research domains, since humans have dissimilar approaches to storing, retrieving and processing graphical information based on different cognitive contents and the environment [31]. Human cognition is the mental status or action (process) of knowledge acquisition based on known facts and the apprehension of the world through experience, thought and the senses [32]. According to recent studies on human cognition, the implementation of AR can have an impact on the expansion of human cognition via the proposed interactive interfaces [33]. Different aspects of intellectual and human cognition—such as cognitive load, attention, perception, emotion, evaluation, memory and knowledge formation—can be considered in the AR/MR user evaluation process to gain an inclusive understanding of their impact and enhance their effectiveness [34]. Baker-Ericzén [35] suggests that people with special needs can sustainably develop their cognitive abilities and social skills by implementing intervention programs.

1.2. AR for People with Special Needs

AR technology has been applied to various important sectors in addition to education, such as healthcare, cultural, heritage and military sectors [36]. Krannich [37] noted that learning has shifted from the classroom to real-life domains such as the workplace, using technology for individuals with special needs. Special education can benefit from the features provided by AR systems to deal with a variety of different cases, each of which has its specificities [38]. AR as an intervention can be used for skill acquisition in different life circumstances and occurrences that individuals with special needs may encounter, to control the environment and become more independent in the community. Baragash [39] categorized the learning acquisition domain for those with special needs into four main aspects, namely: enriching the learning environment, enhancing social and communication skills, assisting individuals who have physical and motor disabilities and supporting individuals in their daily life tasks. In addition, Porter [40] presented a slightly wider range of skills that need to be addressed, which are vision impairment, motor skills, daily living skills, hearing impairment, communication skills and cognitive skills.

Recently, this topic has received considerable attention from researchers and practitioners. Moreover, in order to acquire a broader idea on how to implement AR in special education, a comprehensive review of the published SLRs is relevant to the topic of this study. According to Alalwan [41], it is important to understand more about learners and the process of selecting a suitable technology setting. Several scientific studies have systematically reviewed and investigated the impact of this interactive technology on helping people with special needs. For instance, Khowaja [42] and Adnan [43] systematically reviewed evidence-related studies that deal with AR App. as an intervention to improve autistic children's skill acquisition. A study by Cavalcanti [44] focused on the approaches generally used to assess the usability of AR rehabilitation systems. Another study by Blattgerste [9] investigated the impact of AR on cognitively impaired people. Furthermore, Garzón [20] has conducted a meta-analysis to study trends of AR in educational settings and their influence on special needs systems. Thus, previous literature reviews spotlighted and assessed the approaches and practices for the usage of AR on a specific disability category. Nevertheless, none of the existing literature reviews systematically analyzed the use of AR as an assistive technology for people with special needs within the wide range of disability categories corresponding to the five main domain skills proposed in this study. Therefore, further research in needed in the utilization of AR for the development of sustainable skills by people with special needs.

1.3. The Aim of the Study

The purpose of this study is to review prior studies in order to investigate the best ways of implementing AR technologies for sustainable skill development to assist people with special needs. This systematic literature review focuses on the existing studies concerning the use of Augmented Reality (AR) technology to improve and develop skills for people with special needs regardless of their disability category or level and their age group. This study tries to answer the following research questions after systematically analyzing the literature:

RQ1: What is the distribution of publications over time?
RQ2: What is the geographical and demographic distribution of the studies?
RQ3: What study design and methodologies have been implemented?
RQ4: Which types of disabilities have been covered in the reviewed studies?
RQ5: Which AR technology/approaches have been used?
RQ6: Which AR domain fields were most used for sustainable skill development?

2. Methodology

This study conducted a systematic literature review (SLR) according to the framework proposed by Kitchenham [45], which suggests the development of a protocol that guides the researcher through the overall review process. The developed protocol helped the researchers minimize the risk of possible bias.

2.1. Search Strategy

The search process was based on the search terms that are relevant to the main theme of this study, which is the use of Augmented Reality technology to assist individuals with special needs. The keywords "Special needs" and the synonyms shown in Table 1 were discussed with two experts in special education. They were used to obtain the relevant literature published in five high-impact electronic databases—Web of Science, Scopus, ScienceDirect, IEEE and ERIC—between 2010 and 2020. The process was conducted by independent reviewers to decrease the likelihood of biases or unintended errors.

Table 1. Keywords search query.

	Keyword	Synonyms
MAIN	"Augmented reality"	"AR"
AND	"Special needs"	"Special education" OR "Disabilities" OR "Learning difficulties" OR "Disabled" OR "Intellectual disabilities" OR "Cognitive impairments" OR "attention deficith hyperactivity disorder" OR "Autism spectrum disorder" OR "Autism" OR "Mental disorder" OR "disorder" OR "Physical disability" OR "Down Syndrome"

2.2. Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were considered in the study selection process to obtain relevant studies that fell within the scope of this study [46]. The inclusion criteria were carefully set by the reviewers to ensure a successful selection process. The selected papers had to be review articles published in English and fully available in the selected databases, as shown in Table 2. Any publication that did not meet these requirements was excluded from the review.

Table 2. Inclusion and Exclusion Criteria.

Criteria for Inclusion	Criteria for Exclusion
• Only articles written in the English language.	• The article is written in another language.
• Only peer-review articles	• Not a peer-reviewed article.
• Full text is available online	• Full text was not in open access.
• Available within the 5 selected databases	• Duplicated between the databases
• Articles with the research topic	• Articles with topics unrelated to the study's main theme.
• Research that was published between 2010 and 2020.	• The research aim of the paper is not defined clearly.

2.3. Selection Procedures

For the primary study selection process, the PRISMA diagram was implemented (Figure 2). The term PRISMA refers to "preferred reporting items for systematic literature review and meta-analysis" [47], (p. 1). From the database search, a total of four hundred and fifty-five (n = 455) articles were found, as follows: Web of Science (n = 115), Scopus (n = 75), ScienceDirect (n = 198), IEEE (n = 20) and ERIC (n = 47). Before the screening of the articles, all the selected articles underwent a checking process to be certain that no duplicated articles were obtained across the databases. Ninety duplicate articles (n = 90) were detected. The researchers performed the screening process individually to read the titles and abstracts of the three hundred sixty-five (n = 365) articles. Then, they engaged in discussions and cross-checks to assess whether the articles should be included in the review study. The screening process led to the rejection of a total of (n = 154) research papers, as they were not related to the research topic. Additionally, more research papers (n = 55) were excluded for various reasons: e.g., they were not peer-reviewed articles, there was no open access to the full-length paper, and they were not written in English.

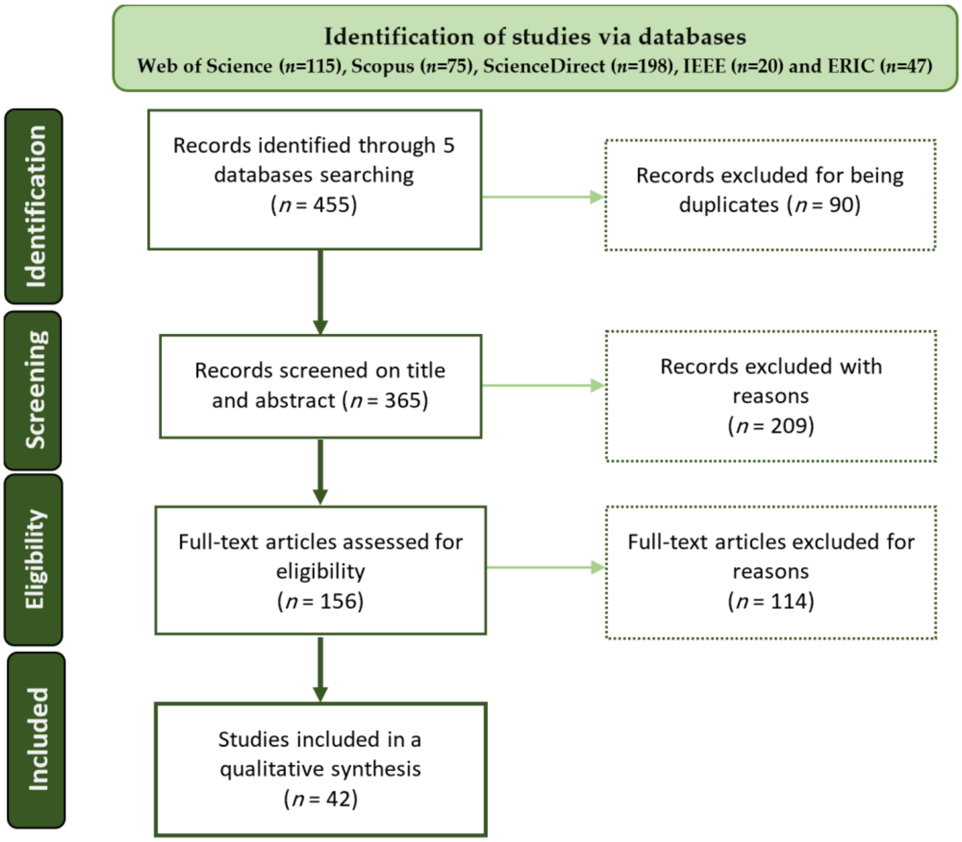

Figure 2. PRISMA flow diagram describing the selection process.

Afterwards, the process of reading the full articles was performed separately by the researchers for the remaining articles (*n* = 156). One hundred and eight (*n* = 108) articles were excluded because they were not relevant to the research questions and were considered not to be significant for this review. It is worth mentioning that all the collected datasets were managed using the online Google Sheet, in which the full version sheet can be accessed by a sharable link (https://docs.google.com/spreadsheets/d/1Wj2vht8Jh4DO6WzFv5laa0s33y5QcnMa9hLT0Dvjv-s/edit#gid=1386834576, accessed on 6 August 2021).

The included articles were required to address the used of AR technology by people with special needs. Therefore, in the final stage, a total of forty-eight (*n* = 48) original articles were considered to meet the inclusion criteria and cover the aim of this review study (Figure 2).

2.4. Quality Assessment

The quality appraisal (QA) procedure included the investigation of the quality of the selected studies relevant to the main research topic, to assist the analyses and synthesis process [48]. All authors carefully monitored the planned review progress and the task allocation to maintain the elevated quality of the SLR. Although the selected studies were high-quality papers, a critical assessment procedure has been performed following the guidance of Kitchenham [45]. The primary studies have been quantitatively assessed for their quality using the questions below and ranking them as low, medium or high [49]. For this purpose, the following questions were developed for the quality appraisal:

QA1: Do the research topics include the implementation of AR in special education?
QA2: Is the study clear in terms of the context?
QA3: Are there accurate details on how the AR technology is implemented?
QA4: Is the research methodology adequately performed?
QA5: Are the study findings relevant to the purpose of this SLR?

A primary study was assigned 1 if it met the quality criterion. Correspondingly, it was assigned 0.5 if it partially met the quality criterion or 0 if it did not meet the quality criterion at all. The study was considered to have a high quality for any total score above 3 and low quality for any total score below 1. With any total score between 3 and 1, the study was considered to have medium quality.

Based on the quality criteria, a total of 36 articles were categorized as high-quality studies, and 6 articles were considered to be of medium quality. However, 6 articles were ignored, since they had a quality score of less than 3, as shown in Table 3. (The full table of QA is available online at: https://docs.google.com/spreadsheets/d/1Wj2vht8Jh4DO6WzFv5laa0s33y5QcnMa9hLT0Dvjv-s/edit#gid=502326786, accessed on 6 August 2021). Ultimately, a list of 42 articles remained and was added to the EndNoteX9 bibliography and reference management system, used to allow for an easier collaboration and multitasking among researchers, and to monitor the activities and changes from the selection to the data extraction stage. Moreover, an education specialist was consulted to evaluate the methodology chosen for this study, in order to eliminate any bias in the methodology procedures. It was confirmed that the methodology aligned with the aim of the study.

Table 3. Quality appraisal table.

Primary Study ID	QA1	QA2	QA3	QA4	QA5	Total Score
PS1	1	1	1	1	1	5
PS2	1	1	1	1	1	5
PS3	1	1	1	1	1	5
PS4	1	1	0.5	1	1	4.5
PS5	1	0.5	0.5	0.5	1	3.5

2.5. Data Extraction

The articles that met the quality assessment criteria underwent the data extraction process, which was performed by the researchers. Data extraction is an important process and must be relevant to the domain of the research topic [50]. The data extraction process was conducted according to a list of elements shown in Table 4, developed for this study to standardize this process. Then, the content of all the primary studies retrieved was carefully reviewed to be summarized and then synthesized using the online link of the Google sheet. The framework for coding has been identified as follows:

Table 4. Data extraction from.

Data Item	Description
PS ID	The primary study identification
Reference	Author name(s) and year of publication
Region/Country	Specify where the study was conducted (Author's country)
Study objectives	The main aim of the study
Study design (Methodology)	Determine the study approach
Learning strategies	Describe which learning strategies have been targeted
Field of the Education (Discipline)	The field of education in which the AR has been created
Type of skill	Which learning domain has been used
AR Technology/Tool	Which AR tool has been used as an intervention
Type of the disability	Which disability type has been addressed
Sample	Participants' age group and numbers
Results	Present the main finding
Recommendations	What are the study limitations and future work

2.6. Data Analysis

The data analysis was performed after the data were extracted from the retrieved articles. This has been done by conducting a qualitative and quantitative synthesis and constructing a clear descriptive summary of the included studies to be presented in the form of a data extraction summary, as shown in Table 5. These data were analyzed according to demographic and methodological aspects based on the utilization of AR technology for individuals with special needs and the main research theme, to answer the predetermined questions.

3. Results

3.1. Publication Distribution by Time Frame

Altogether, the entire set of selected publications dealt with the use of AR technology in the skill development and rehabilitation of people with special needs. As shown in Figure 3, few studies were conducted at the start of this decade. After this time, the subject began to receive attention from researchers and saw a two-fold increase during the period chosen for this review, until it reached a peak of 7 studies in 2016. However, there was a dramatic decline in 2017, when only one study was conducted. From this time onward, there was a noticeable increase in the number of studies per year, until it reached 9 in 2020, which is a relatively small amount of research on such a contemporary topic. It is worth noting that this emerging technology should receive further attention from researchers, especially since AR technology is continuously developing.

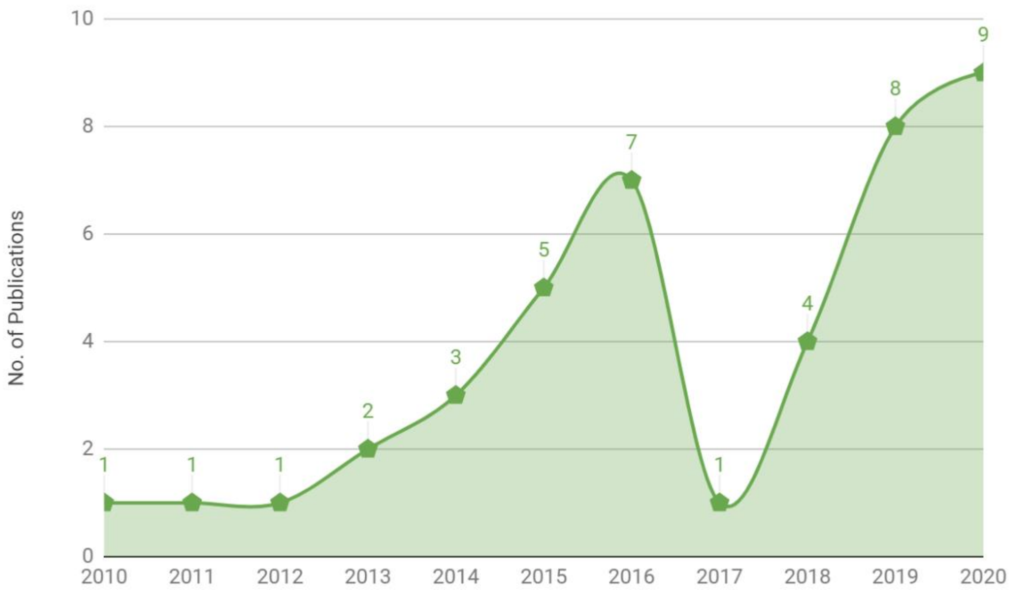

Figure 3. The distribution of publications over time (n = 42).

3.2. Geographical Distribution of the Publications

The studies included in this review were performed in thirteen different countries, as can be seen in Figure 4. Almost all researches were produced in developed countries, and there was no contribution from developing countries. The USA contributed the most, with 12 articles. Additionally, Spain and Taiwan recorded 8 studies, followed by Italy, KSA, Turkey and Malaysia, with just 2 studies. On the other hand, Brazil, the UK, Germany, Israel, México, and Belgium only contributed with 1 article each. It is revealing that the majority of the reviewed studies were conducted in developed countries, and that a greater focus has been given to the participation of these countries.

Figure 4. The distribution of studies over the different countries.

3.3. Demographic Distribution of Study Populations

Individuals with special needs suffer from different types of disabilities and have different severity rates. Moreover, the ability to withstand and respond to stimuli differs from one person to another and from one age group to another [51]. Table 5 presents the participants in the selected publications, which were from both genders. A total of 45% participants were male, and 42.5% were female. The remaining studies (12.5%) did not report the gender of the participants [52–55]. Furthermore, the recruited studies' population were not limited to any age group and had a broad range of sample sizes. The ages ranged from 1 to 97 years old, and the sample sizes ranged from 2 to 69. An increased focus should be given to children, since they cannot help themselves and need more support compared to older people with disabilities. In addition, children will be more engaged in AR technology, as it contains multimedia and game elements [56].

3.4. Study Design and Methodology

It has been observed that the single-subject study design structure was largely adopted to change individuals' behaviors. This approach has either single baselines [57–64] or multiple baselines [10,65–70] with the intervention phase for the same group. The single-subject design was implemented to investigate the change in an individual's behaviors within a small group [57]. In some of the reviewed studies, pre-post experimental research that employed control and treatment (intervention) and maintenance phases has been implemented [53,56]. The experiments' timeframe varied across the studies, as can be seen from Table 5. Nonetheless, other studies used methods such as surveys [71–73], observation [74], case studies [75,76] and comparison [51].

3.5. Distribution of Different Disability Categories

All the primary studies that have been reviewed included participants diagnosed with a wide range of disabilities. Some of the disability cases are intractable cases that are not curable, but the new technology can be applied to assist the patients in their tasks. This might help them to control their environment and become more self-reliant and independent [77]. The individuals suffer from different types of disabilities. The disability categories that have been covered by the study, which can be seen in Table 5, include Autism Spectrum Disorder (ASD) [53,54,64,65,72,78,79], Intellectual Disabilities (ID) [10,58,59,70,80], Learning Disabilities (LD) [57,76], Attention Deficit Hyperactivity Disorder (ADHD) [55,75,81], Cognitive

Impairments and Disorders (CI) [52,69,82], Physical and Motor Disabilities (PD) [51,60,62], Hearing Impairments (HI) [71], Neurodevelopmental Disorders (ND) and Down Syndrome (DS) [83], Small Animal Phobias (SAP) [61,63,84,85], Short Term Memory (STM) [86,87] and Mental Ability (MA) [88], as shown in Figure 5.

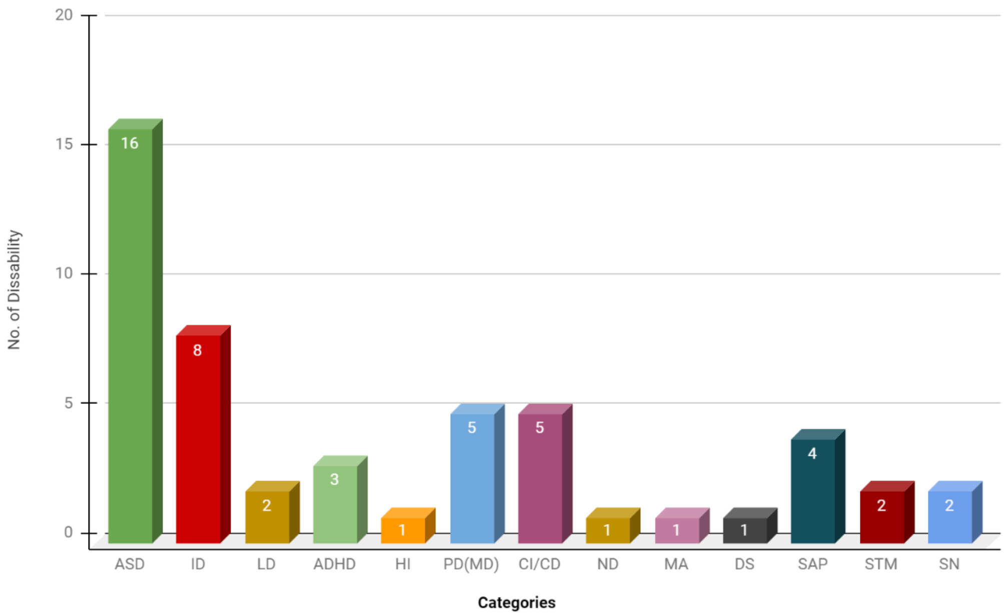

Figure 5. The different disability categories. ASD: Autism Spectrum Disorder; ID: Intellectual Disabilities; LD: Learning Disabilities; ADHD: Attention Deficit Hyperactivity Disorder; HI: Hearing Impairments; SN: Special Needs; CI: Cognitive Impairments; PD: Physical Disabilities; ND: Neurodevelopmental Disorders; DS: Down Syndrome; SAP: Small Animal Phobias; STM: Short-Term Memory; CD: Cognitive Disorders (Disabilities); MA: Mental Ability.

3.6. AR Technology Interventions and Approaches

The reviewed studies have shown that various AR technology tools and techniques have been implemented for intervention training or skill acquisition, as shown in Figure 6. Some of the reviewed studies build AR simulations using 3D digital objects [51,54,65,77,83], and AR video-based applications [10,79]. Moreover, the game-based concept was very common [58,60,72,75], especially when the targeted population were children. Furthermore, some studies implemented the concept of serious games ([63] and [56]), and the hardware devices used were diverse, including wearable and handheld gadgets. For example, wearable devices included a wearable Brain-Computer Interface (BCI) [55,81], which can be worn on the head, while other studies used hand-held devices [51]. Additionally, monitors and webcam devices were implemented by [60,68,69,74,84,89], and other studies implemented projection devices [78,82,85].

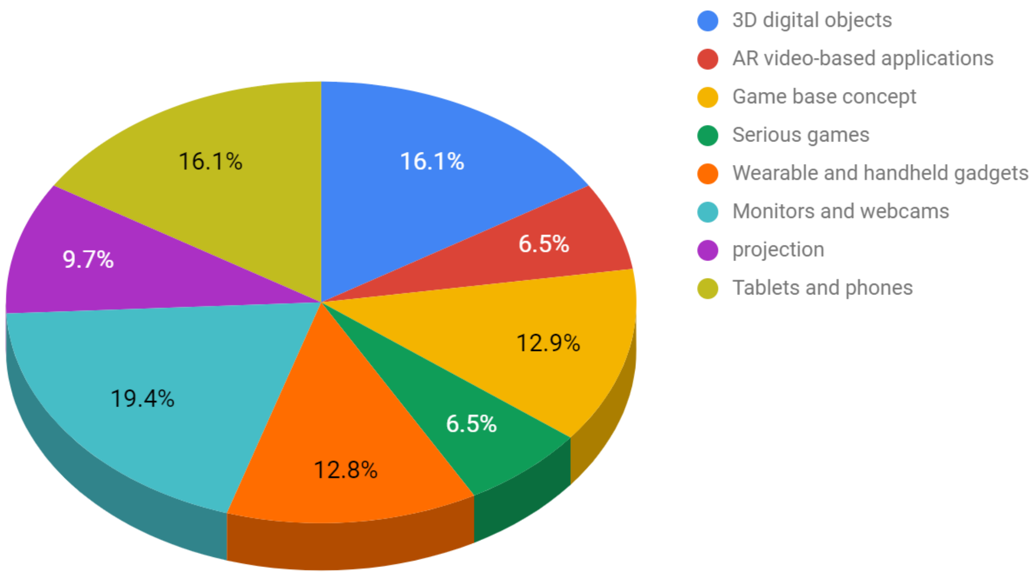

Figure 6. Technologies implemented in the reviewed studies.

Smartphones and tablets are powerful devices for running different AR systems due to their small sizes and low prices [51]. AR technology is mainly being used for therapy exposure or as an assistive tool [63]. The reviewed articles revealed the use of tablets and phones [59,70,71,73,80]. Mobile technology is a promising market, and it has the potential for an even greater development. In addition, it can be operated across platforms and has multilingual capabilities. Furthermore, the platforms used to build AR systems from the reviewed articles included HP Reveal [10,70], Unity with Vuforia [73,77,86], and Aurasma [57].

3.7. Domain Skills for Reviewed Studies

In general, five main skill acquisition domains for individuals with disabilities were highlighted by the reviewed articles. As can be seen from Figure 7, the majority of the studies (36.4%) focused on everyday tasks [54,57,71,73,76,78,80,83]. The learning domain was the second-largest percentage among the listed domains (30.3%), explored by [51–53,56,58,59,70,77,79,87]. These two domains were followed by the social skills domain [65,67,72,74,81], which had a percentage of 21.2%. The remaining two domains, the physical skills domain [60,62] and the workplace domain [69], recorded a modest percentage (6.1%) compared to the other domains, as shown in Figure 7 and Table 5.

There was an improvement in skills for individuals with special needs and performance after the intervention, and they were capable of performing independently with the assistance of AR [53,58,70]. A reviewed study by [79] found that AR help people in maintaining the skills required to independently brush their teeth. Another study [59,90] indicated that the navigation skills of the participants were improved. Moreover, Schall Jr [34] demonstrated that AR cuing enhanced the detection of target objects with low visibility to improve driving safety. By the same token, AR might lead to increased motivation and engagement, especially in the case of children with special needs. A reviewed study by Cakir [77] found that AR teaching material is effective in increasing the experiences of special needs children, and that students were motivated to participate in class when AR had been implemented. It has been observed that by using AR, participants earned an important Math learning skill immediately after the intervention [7,58]. In the same context, the findings of Antão [78] indicate that ASD achieved a better performance in terms of reaction time when playing AR game-based applications to acquire new science vocabulary [80]. The results of the study by [73] revealed that ASD children were able to develop their phonics literacy via the help of an AR application.

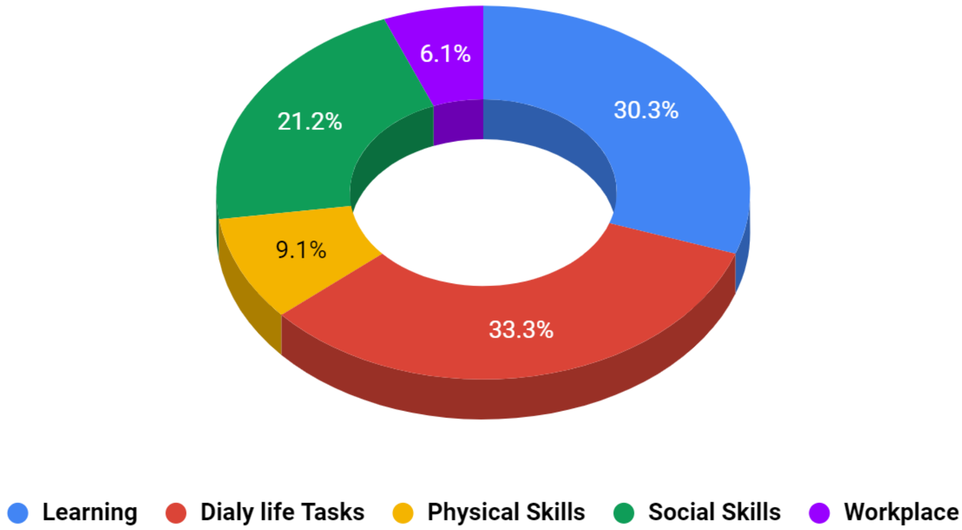

Figure 7. Skills acquisition domain.

4. Discussion

This systematic review focused on the existing literature on the application of AR technology to support sustainable skill acquisition and skill development by people with special needs. The effectiveness of AR technology can be achieved by providing an expressive collaboration between learners and their teachers or trainers. It can also be provided through a passionate motivation toward learning contents, which in turn creates a sustainable learning environment. There should be a sustainable framework for learning approaches and rehabilitation practices that can be beneficial to people with special needs.

The results indicate that AR technology has received increasing attention in recent years by specialists and practitioners, and it might even increase more. The reason could be the ease of use of AR tools [51] or the existence of several platforms that made the development of AR systems relatively simpler [71]. Although there is great potential in this technology, no technology exists without limitations and challenges. Furthermore, the geographical distribution of the scientific research was volatile, as the research conducted in developing countries was shown to be much less abundant compared to that in the developed countries. For instance, 28.5% of the reviewed studies were performed in the USA. This might be because the technological infrastructure is more advanced in developed countries. These results were expected, due to the availability of research tools and suitable experiment environments in developed countries. Furthermore, the demographic distribution of the participants in the reviewed studies was largely balanced between the two genders, and the age groups of the participants were varied. However, it is important to assist children with special needs, compared to young peers, as the former need more attention to develop and sustain their skills and to be more independent [77]. It has been observed that most elderly participants were tested for physical impairments or special memory, but, most of the participating children suffered from ASD, as shown in Table 5. This could have resulted from the primitiveness of AR hardware which is still at the development stage, leading the researchers and developers to focus on one disability category rather than another. Apart from that, different research models can be adopted in special needs studies. In this regard, the single-subject design for multiple or single designs of baseline was the most implemented methodology, because research concerning the changes in skills and behavior seeks to monitor the participants for the entire experiment period [10]. It is also important to focus on other aspects of AR use, such as the effects on human cognition.

The number of people with special needs is increasing significantly around the world every year. This is why more studies are needed dealing with people with special needs. According to the Nation's Report Card that was produced by the U.S. Department of

Education in 2015, there is a disparity in learning for people with learning disabilities, and only 8% showed an upper intermediate performance [57]. In addition, the National Center for Education of the USA claimed that between 2017 and 2018 6% of students (3–21 years old) were diagnosed with intellectual disabilities and enrolled in special education [10]. In Europe, ASD is common and prevalent, with a median rate of 10/10000, while in the USA it occurs in 1 out of every 68 children [78]. This is line with the results of this study, where most of the reviewed disabilities were from ASD categories. Additionally, according to Arpaia [55], most recent studies have reported that ADHD in the USA has increased by 10%, which also aligns with the result of this study, where it is the second most reported category.

It has been found from the results that different tools, packages and approaches have been implemented to develop an AR system for different uses. Most systems implemented AR technology using digital objects in the real world. It is important that the developed assistive tool be cost-effective and have a high performance. It has been observed that AR applications need to have a standardized design for interfaces and objects, and also reduce the redundant and irrelevant content. Furthermore, cutting-edge technologies such as computer vision and machine learning can be integrated and exploited to be combined with AR technology [82]. Moreover, there is a great need to develop AR applications to run perfectly on both mobile operating systems, IOs and Android platforms [77].

The two main fields or domains that have been under the focus of researchers were "learning" and "daily life skills", since AR technology can be implemented straightforwardly and results can be obtained easily. It is evident that in other domains—such as social skills, which has been studied by Lee [65]—individuals have improved their skills in important ways. People with special needs can gain the desired social skills and body gestures in the maintenance stage and retain them in the intervention stage of the experiment through a sustainable training program. Further, the results of a study by Chen [68] stated that AR assisted the participants in their experiment in terms of learning social skills and enabled them to understand different social signs. Moreover, it was observed by [56,62,82] that the use of AR technology is a sustainable and safe approach to increase physical activity at home through dance for people with Physical Disabilities (PD). However, less attention has been paid to the workplace. This might be due to the fact that AR is a relatively new technology, that has recently entered the industry and workplace. Thus, it was concluded that AR technology might have a future potential in helping and training operations in industrial setting and the workplace. This will increase the workers' efficiency, by reducing the cognitive load and the working time [48].

AR is considered a relatively modern technology and can be applied in multiple fields. Thus, this topic is considered to be a broad field. Therefore, there is a need for further research on the state-of-the-art to maximize the range of beneficiaries, especially as regards children with special needs, since not enough studies have been found on their sustainable skill development. Based on what was presented, the majority of research has been conducted on ASD and ID. Thus, there is a gap in the literature regarding the reviewed studies that focus on developing and investigating AR applications for some disability categories rather than others. For instance, there was only one study on hearing impairments. Furthermore, more research is needed on implementing AR for people with special needs in the workplace domain and to support the physical skills domain. Furthermore, it is important to re-examine the use of the unifying platform XR (AR, VR and MR), but not much has been done in this regard. Moreover, fewer studies are performed on collaborative AR, especially in the field of tele-education and telerehabilitation for people with special needs and in connection with the global pandemic situation.

Table 5. General Description of the Studies. (The full version of the table available: https://docs.google.com/spreadsheets/d/1Wj2vht8Jh4DO6WzFv5laa0s33y5QcnMa9hLT0Dvjv-s/edit#gid=797428243, accessed on 6 August 2021).

PSID	Ref.	Disability	Skill Domain	Sample	Technology/Tool	Research Methodology/Model
PS1	[10]	ID	Math Skills	3♀ Adults (21–24 year)	An AR video prompting (VP) Using iPad with HP-Reveal	Single-subject design for multiple designs of baseline
PS2	[57]	LD	Mathematics	4♀/3♂ Middle School Students (7–8 grade)	A Video-Based Instruction Using iPad with the Aurasma app	Single-case design
PS3	[65]	ASD	Social Skills (Communication)	3♀ & ♂ Children (7–9 years)	Kinect Skeletal Tracking with 3-D virtual characters	Single-subjects design through multiple-baseline (Wizard of Oz experiment)
PS4	[78]	ASD	Learning Alphabet Letters and Numbers	(5♀/43♂ ASD) & (15♀/33♂ TD)	Webcam and Projection-Based AR computer game "MoviLetrando"	Reaction time (RT) performance before and after the training for the Control group (TD)
PS5	[75]	ADHD	Cognitive Behavioral Therapy (CBT)	♀ & ♂ Children	AR Technology based Simulation game	Case Study (Treatment-Program)
PS6	[58]	ID	Daily life task (using ATM)	1♀/2♂ junior high school students (9 grade)	AR tech. "Let's go banking" game on iPad and iPhone, with simulation	Single baseline design
PS7	[81]	ADHD & ASD	Social Communication/Attention	1♀/6♂ high school students (14–18 years)	Wearable Empowered Brain glasses—AR game base	Correlation relative to (ABC–H)
PS8	[71]	HI	Literacy Development (User Requirement)	10♀/4♂ parents for questionnaire (av. 43 years)&7♀ interviews) and 14♀children from (1,2,5 grad)	Mobile AR app. (ArSL)	3 methods have been used: questionnaires for parents, observations with students and interviews with their teachers.
PS9	[77]	SN	Independent Tasks	4♀ & ♂ students & 6♀ & ♂ Teachers	AR teaching assistance with Cinema 4D (Unity 3D, Vuforia programs)	Design-based research (Mixed Method)
PS10	[72]	ASD	Social Skills	1♀/10♂ Student (2–6 years)	AR game, Quiver Vision for Android smartphones (v 3.15).	The quantitative quasi-experiment study pretest-posttest (control & intervention group)

Table 5. *Cont.*

PSID	Ref.	Disability	Skill Domain	Sample	Technology/Tool	Research Methodology/Model
PS11	[74]	SN	Stimulate cognitive, problem solving & social skills	13♀/12♂ Pre-School (4–5 years)	"Giok the alien" AR App., physical cube, TV and smart device	Observation
PS12	[66]	ADS	Social skills (Cues)	1♀/2♂ Children (8–9 years)	AR with concept map (CM) Technique (Social Stories TM)	Multiple-baselines with Single-subject research
PS13	[59]	ID	Navigation Skills	1♀/2♂ Postsecondary Students (22–25 years)	iPhone app. Waypoint	Single-subject case designs (ABAB)
PS14	[76]	LD	Mathematics	22♀ & ♂ primary school students (6–12 years)	Tabletop System	Pilot Case Study (experiment)
PS15	[56]	CI & PD (MD)	Daily life activities	3♀/8♂ Patients (32–86 years)	AR Serious game "SIERRA", TV and HP Camera	Experiment (control group)
PS16	[79]	ASD	Brush teeth	3♂ Elementary Students (6–7 years)	Marker-based AR picture prompt to trigger a video model clip using iPod	Baseline and maintenance phases occurred in the SNE classroom and bathroom for a 5-step teeth brushing activity.
PS17	[67]	ASD	Nonverbal Facial Cues	1♀/5♂ Adolescents (11–13 years)	AR Based Video Modeling Storybook (ARVMS) with PC & a tablet, using Vuforia	Single-subject with multiple baseline design across subjects
PS18	[80]	ASD & ID	Teaching Science Vocabulary	3♀ ID & 1♂ ASD College Students	Aurasma Mobile app. using iPads	Multiple-probe across-behaviors/skills design
PS19	[91]	ID	Digital Navigation Aids	2♀/4♂ College Students (18–24 years)	AR, G. Maps on Mobile and paper map	Adapted alternating treatment design
PS20	[89]	ASD	Mental representation of pretense (Deficits/delays in symbolic thinking)	2♀/10♂ Children (4–7 years)	AR system with monitor and webcam	A within-subject experiment

Table 5. *Cont.*

PSID	Ref.	Disability	Skill Domain	Sample	Technology/Tool	Research Methodology/Model
PS21	[60]	PD	Enhance body motion (strength)	2♀/1♂ Children (3–6 years)	Scratch 2.0 AR interactive game using laptop and webcam	Single-case research (ABAB)
PS22	[68]	ASD	Emotional expression & social skills	1♀/2♂ Adolescents (10–13 years)	AR-based self-facial modeling (ARSFM) using monitor and webcam	Multiple baseline design
PS23	[90]	ASD & ID	Navigation decision (independently)	3♀ID & 1♂ ASD College Students (21–24 years)	AR, G. Maps on Mobile and paper map	Adapted alternating treatments design (Single-subject study)
PS24	[69]	CI	Vocational task prompting for job	1♀/2♂ employee (20–25 years)	AR Coach system using monitor and webcam	Multiple baseline design
PS25	[52]	CI	Improving driving safety	20 Elderly licensed drivers (65–85 years)	AR Cue	Experimental (factorial design)
PS26	[53]	ASD	Basic Living Skills BLS	4 children & 5 SpeEdu teachers	AR Animation and (Static graphic)	Pre-post experimental research design (control & treatment group)
PS27	[73]	ASD	Phonics-based Literacy	10♀ & ♂ Children (8–10 years)	AR Android app. and Flashcard using Vuforia Unity	A survey by interviewing lecturers and observation
PS28	[83]	ND, (ASD, DS & ID)	Theory of Mind skills (learning)	6♀/24♂ Students (7–14 years) (3♀/14♂ A) (3♂ DS) (3♀/7♂ ID)	AR 2D & 3D Touch Screen using Unity and 2D paper	Comparing the 3 environments
PS29	[61]	SAP	Treating AD	4♀ Patients (M = 41.50 years)	AR Projective (P-ARET)	A single-case study
PS30	[86]	STM	Spatial STM	35♀/41♂ preschool (5–6 years) & Primary school (7–8 years) healthy children	AR Spatial Memory App (ARSM) for Android and IOs using Unity and Vuforia	Testing the spatial short-term memory in Real Settings
PS31	[57]	ASD	Interactive, concentration and motivation	14 Children (3–7 years) & 7 Teachers	Mobile AR (MOBIS) using digital contents and physical objects	Field Study (pre-post deployment)
PS32	[84]	SAP	Treating AD	6♀ (21–41 years)	AR system (NX-Ultra camera and a Logitech QuickCam Pro 4000)	Nonconcurrent multiple baseline design

Table 5. *Cont.*

PSID	Ref.	Disability	Skill Domain	Sample	Technology/Tool	Research Methodology/Model
PS33	[62]	PD	Motor functions (improving symptoms) and non-motor functions (mood, quality of life)	4♀/3♂ Individuals (M = 69 years)	AR smart Glasses	A single-group pilot feasibility study
PS34	[63]	SAP	Treating AD	1♀ (A 25-year-old)	AR Serious game on Mobile	A single case study
PS35	[85]	SAP	Evaluation of the collaboration between clients & therapists	20♀ Clients (M = 26.4 years)	AR Exposure Therapy (ARET) system	ARET group and IVET group
PS36	[87]	STM	Visuospatial (VSTM)	42♀/55♂ children (5–9 years) & 7♀/8♂ Young Adult (25–30 years)	AR Visuospatial Memory (ARSM) system	ARSM task located in the real-world setting
PS37	[82]	CD/PD (MD)	Cognitive support	20♀/24♂ Company assembly operators (22–58 years)	Top-mounted video projection, AR tech.	An exploratory study (experiment)
PS38	[51]	CD/PD	Independence (Route planning)	13♀/9♂ (M = 69.5) Older Adults and 13♀/9♂ young (25–40 years)	Handheld AR system using mobile	Comparison of 2 groups
PS39	[88]	MA	Reduces cognitive load (improve spatial direction)	17♀/11♂ Elderly (>65 years) (14 3D) & (14 2D)	AR with 3D Holography (AR-3DH)	ABA-designed pre- and post-tests to compare 2 groups
PS40	[55]	ADHD	Rehabilitation	4 Children (6–8 years)	A remote-controlled by AR glasses with Wearable BCI*	Experiment (Clinical case study)
PS41	[70]	ID	Independent Daily Living Skills	1♀/2♂ young adults (19–36 years)	AR Mobile App. using iPad with HP Reveal	Multiple-baseline and behavior design
PS42	[64]	ASD	Attention and Social Educational	1♂ Student (A 13-year-old)	Empowered Brain with smart glasses, smartphones/tablets and a web-based data portal	A single-subject study

5. Conclusions

In the last decade, the use of AR technology for people with special needs has been studied by researchers. However, minimal research has been conducted on the use of AR technology for sustainable skill development by people with special needs. Therefore, to obtain a deeper understanding of this issue, this study has conducted a systematic review of the existing literature on the use of AR technology for disability categories. The results of the SLR designate the current trends and procedures for sustainable skill development that can be addressed by using evidence-based practices. Additionally, more experimental studies need to be conducted to examine the sustainable use of AR tools on children with physical disabilities and to assist them in the workplace. This review is intended as a guide for practitioners, software/app. developers and researchers who are interested in implementing AR technology in special education. This SLR is expected to reveal avenues for further research.

Based on the findings, it is recommended that further studies be performed and develop tools that use AR technology for children in order to make their life easier and assist them to be more independent and socially active. It is also recommended that researchers focus on those disability categories that are less represented in the literature, such as Hearing Impairments (HI), Neurodevelopmental Disorders (ND), Mental Ability (MA), Down Syndrome (DS) and Learning Disabilities (LD). In addition, the AR content should be subject to more research in future studies.

This study, like other SLRs, has some limitations that should be addressed. The first limitation was the time period, which was bounded by the articles that were selected. Secondly, this review was limited to publications that met the chosen inclusion criteria only. Thirdly, this review only included peer-reviewed articles that were published in full text. Lastly, the search process was restricted to the five selected databases. Future studies should include articles that have been published in other languages and in other scientific databases. Moreover, future studies may include other categories of published work, such as book chapters.

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