Education and Information Technologies (2024) 29:1251–1277
https://doi.org/10.1007/s10639-022-11550-2

Review of the trends in the use of augmented reality technology for students with disabilities when learning physical education

Nur Azlina Mohamed Mokmin[1] · **Regania Pasca Rassy**[1]

Received: 29 March 2022 / Accepted: 20 December 2022 / Published online: 26 December 2022

Abstract

One of the most advanced reality technologies for education in recent years is augmented reality (AR). To create a fun learning atmosphere and to aid student learning, several subjects have begun incorporating modern technology into their teaching and learning procedures. In addition to being extensively tested and developed for typical students, AR has also been used successfully to help kids with learning disabilities (SLD). This study is focused on students with learning difficulties, looking at the changes in the usage of augmented reality (AR) technology in education over the previous few years, particularly in the area of physical education. Physical Education (PE) is frequently identified as one of the disciplines that is challenging for kids with learning disabilities to follow. This study makes use of a detailed analysis of an AR application in connection to this subject over the preceding five years because AR has the significant potential to be applied in the field of physical education. The development of this technology in physical education, the kind of AR technology employed, and the kinds of learning disability groups that the technology can help are demonstrated in a clear and understandable manner. The researcher's perspectives and the chance to advance this study will be helped by this.

Keywords Systematic review · Augmented Reality · Educational Augmented Reality · Physical Education · Sports · Students with Learning Disabilities

✉ Nur Azlina Mohamed Mokmin
nurazlina@usm.my

Regania Pasca Rassy
grachsy@gmail.com

[1] Centre for Instructional Technology & Multimedia, Universiti Sains Malaysia, USM Penang, Malaysia

1 Introduction

In this century, technology has become essential to human life, as evidenced by the numerous innovations produced due to the effects of new technological developments on society (Scherer et al., 2019). Technology has fundamentally changed how we communicate, socialize, and live our daily lives. Immersive technology, which combines enhanced simulations or wholly artificial settings to create meaningful and exciting learning, is one of the technological advancements that has gained popularity over time (Barto, 2021). This technology, when used in education, has been shown to be incredibly effective when teaching students. In fact, it has been shown to be more effective than traditional methods in many cases (Bowser et al., 2016; Kumar, 2020; Marín-Morales et al., 2019). With immersive technology, students can engage with the material in ways that they would not be able to otherwise (Mokmin & Ridzuan, 2022). In addition, they can learn in new and innovative ways that they may never have thought of before.

With different existing technologies, this has become a new idea and innovation in the education field. Over the past decade, there have been introduced multiple ways in which 'reality' can be experienced, rapidly evolving as a result of the rapid growth of technology (Mann et al., 2018). One of the immersive technologies in education that is expanding quickly and has significant potential is augmented reality (AR) (Cabero-Almenara & Roig-Vila, 2019). Some scholars refer to AR as the real-time use of technological equipment to combine digital and physical information (Maas & Hughes, 2020). More specifically, AR refers to the loading and merging of virtual objects, such as video, sound, photographs, text, 3D models, etc., with real-world views (Tekedere & Göker, 2016).

Several AR technologies have been developed over the years, such as Pokemon Go (Walker et al., 2017) and Hololens (Paigude, 2019), and they are widely used in everyday life by consumers and educators alike. With this technology, it is hoped that it can become one of the positive changes that provide opportunities and strategies in education to create an innovative and attractive educational environment for students in this era. AR regularly uses marker-based applications that rely on picture recognition. For instance, while location-based applications function without markers, an AR project has been developed that uses the user to identify the augmented object. This method uses a digital compass or global positioning system (GPS) to detect the user's location before replacing or combining real-world physical objects with augmented ones (Parekh et al., 2020). There's also projection-based augmented reality, often known as Spatial Augmented Reality (SAR) or projection mapping, which operates by projecting virtual data directly into an actual space (Ojer et al., 2020).

AR has been widely used to promote various supports in education and a more independent life (Akçayır & Akçayır, 2017). In this case, AR allows students to learn independently because this technology provides a good learning experience and level of satisfaction. Apart from education, AR applications have also been developed to make everyday life easier. Several studies have demonstrated that using AR in education boosts student motivation. The course content is presented

engagingly and innovatively, evoking interest and curiosity in the learning process (Cabero-Almenara & Roig-Vila, 2019).

In its use, AR requires supportive devices in the form of special AR devices, AR glasses, virtual retinal displays (VRD), and the most ubiquitous, mobile devices. Mobile devices are often used to support AR technology because, due to mobiles being easily accessible, this technology also allows access to and the dissemination of information about an individual's environment (Gómez-García et al., 2018). On the other hand, incorporating technology into the curriculum is becoming a necessity for effective teaching in the educational system because this particular educational technology tool offers countless possibilities that encourages students to learn in a meaningful way by bringing real-world situations into the classroom where they can engage in interaction and visualization (Lee, 2021).

This makes augmented reality (AR) particularly appealing and valuable in the field of education today, in part because it provides fresh learning experiences and integrates real-world things with virtual ones that can greatly aid the learning process (Guerrero et al., 2020) as well as resulting in increased engagement with any training activities (Cheng, 2017), and creating a pleasant learning environment (Sáez-López et al., 2020), all of which are outcomes of using AR in teaching and learning. Several subjects have started integrating AR into their learning activities to facilitate learning and make it more interesting, generally science subjects, such as biology, physics, chemistry, medicine, etc. (Ajit et al., 2022).

An essential component of a student's educational curriculum is physical education (PE). The course's content is mainly related to the human physique, and psychomotor learning taught during primary and secondary education (Tabuñar Fortunado, 2016). It can aid pupils in learning about discipline, collaboration, and physical fitness (Mokmin, 2020). Through learning, the course builds the abilities, know-how, attitudes, and values necessary to create and maintain an active and healthy lifestyle. Face-to-face instructions increase the students' self-assurance and capacity to take on challenges as individuals, groups, or as part of a team (WHO, 2010).

However, many schools do not provide sufficient resources to ensure that students with disabilities can participate in physical education classes, as stated by Bertills et al. (2019) and Demchenko et al. (2021). For many students, a lack of access to this type of instruction is a significant barrier to their academic success. This could lead to self-esteem issues and a lack of interest in school overall (Krause et al., 2020). Even though laws have been implemented to guarantee that disabled children have access to educational opportunities, many kids still encounter significant barriers to receiving these services (Haegele et al., 2018). International recognition has been given regarding the value of physical education (PE) in modern schooling (Yang et al., 2020). The challenge for schools is to provide inclusive programs that cater to all of their students' needs, regardless of their level of ability or status as having a disability.

People with disabilities may have ongoing physical, mental, intellectual, sensory, or other impairments that, combined with other factors, may prohibit them from participating completely and equally in society (Leonardi et al., 2006). Activities that meet these real-life criteria are extensively emphasized in the curriculum because kids with special education needs need real-life experiences to address

their challenging behaviors and build crucial fundamental skills (Cakir & Korkmaz, 2019). Integrating them into a regular physical education session is therefore even more difficult (Clemente, 2017). Due to the obstacles to physical activity that students with disabilities face at all levels of society, students with disabilities are less active than their non-disabled peers (Úbeda-Colomer et al., 2019).

Although it has been shown that technology can aid kids with impairments in their academic progress, most PE teachers still use traditional didactic teaching methods in their classrooms such as reading a book that explains a sports activity with several pictures. There is also practice time where the teacher will demonstrate and describe the action. Raising the standard of physical education is challenging since students frequently act without thinking (Zeller, 2017). This technology is still not being used to its full potential. AR in physical education can help pupils perform better by considering its numerous dimensions: it facilitates understanding the theoretical portion of the curriculum (Hsiao, 2013).

By implementing AR technology in the PE teaching and learning process, students can enhance their performance in various ways such as being introduced to virtual content in the classroom. Students can develop their digital abilities while contextualizing their studies and learning more about other fields (Arici et al., 2019). As a result, their academic performance and the classroom climate will improve (Fidan & Tuncel, 2019). Studies have shown that immersive technologies positively impact learning retention (Alzahrani, 2020) and that students who use these technologies motivation (Mokmin & Jamiat, 2021). However, several studies have been done to explore the use of AR by special ability students, like the study by Papakostas et al. (2021). The majority of the earlier research consists of modest pilot studies that weren't explicitly created to assess how AR affected children with physical limitations when learning physical education.

By incorporating AR technology into the special education curriculum, augmented reality environments will be able to provide kids with the real-life experiences that they require more readily and safely, especially in physical education subjects as one of the learning strategies. The study of the associated trends can provide an insight for educators on the application of AR in education which can simultaneously aid the students' learning and rehabilitation. The use of digital technologies has enabled teachers and trainers to provide students and patients with access to resources and information through applications that can augment their experience and facilitate the learning process of physical training. The knowledge of these trends can also give developers an insight into how people with disabilities can benefit from the technology and who can use it effectively in their daily lives.

2 Augmented reality in education

AR allows an individual to watch computer-generated information that enhances real-world items or environments (Garrett et al., 2018). Through the use of smartphones or eye devices, AR uses image recognition technology to identify places, images, markers, or things superimposed on the real world. The distinction between augmented reality and virtual reality is that augmented reality relies on the

integration of the digital (virtual) domain and physical (real) environment rather than attempting to build a totally digital world that people can interact with (Garrett et al., 2018). The three basic concepts that constitute AR are immersive, interactive, and participatory (Da Silva et al., 2017). The sense of being in one's surroundings is related to immersion. Nowadays, AR's application in multiple domains, especially in education, is on the rise.

Augmented reality has a lot of potential as a learning aid and it has already begun to influence education. The advancement of pedagogical techniques and augmented reality technologies may help pupils assimilate the learning material more quickly (Vuță, 2020). Physical education teachers claim that AR is an excellent tool for improving human mobility abilities and maintaining human health competence (Klochko et al., 2020). To ascertain the augmented reality (AR) developments in the sphere of education, (Sırakaya & Sırakaya, 2020) released a study that meticulously examined the studies that employed augmented reality (AR) to advance STEM education. Specifically, 42 papers from journals with indexes in the SSCI database were analyzed. The review concluded that the research growth rate in this area is not constant, although 2016 and 2018 showed an increase in journal publications, indicating that AR has gained popularity relative to the earlier years.

Although AR is famous as an additional learning material for science, several reviews on the trend of AR have also displayed ongoing trends over the years. A study on the evolution of technology trends from 2011 to 2021 done by Dubé and Wen (2022) shows that AR is one of the simulation technologies forecasted to have long-term effects on education. The review also added that advancements have been made regarding mobile providers implementing an operating system that has allowed AR to be developed for mobiles. AR has also generated the most publications, followed by virtual reality.

Another review by (Chiang et al., 2022) shows that AR has also been implemented in vocational training. Specifically, 80 relevant studies were chosen for the final analysis from the review's cross-referencing and abstract reading processes from two perspectives: the development of vocational skills (including application area, target audience, training objectives, and effects) and the use of augmented reality training technology (including AR applications, AR training systems, and devices). The results show that AR has been most frequently used in industrial training, medical training, industrial maintenance, and assembly.

In Table 1 below, we can see the results of a review of each article that shows the range of years of the paper that was included in the research, the number of papers that meet the criteria, and what fields of education use AR for learning from the selected paper.

The table above compares four of the recent articles that have reviewed the use of AR applications in educational settings. The first study by Saidin et al. (2015) found nine papers related to the research topic published between 2007 -2013. A subsequent survey by Sirkaya and Alsancak Sirkaya (2018) examined the trends found in the use of AR learning. The research found that 86 papers were included in the predetermined criteria and that all of the papers were published from 2011—2016. Garzón et al. (2019) conducted a comparable study, namely a systematic review and meta-analysis of augmented reality in educational contexts. From his research, it

Table 1 Comparison of the research trends on the use of AR applications in educational settings

Author/Year	Years of published papers	Amount of research	Educational field
(Saidin et al., 2015)	2007–2013	9	Medical education (3), Chemistry education (1), Mathematics (1), Biology (1), Physics (1), Astronomy (1), and History (1)
(Sirkaya & Alsancak Sirkaya, 2018)	2011–2016	86	Biology Education (17), Engineering Education (11), Medical Training (10), Other (10), Physics Education (6), Informal Education (6), Language Education (5), Chemistry Education (5), Mathematics Education (5), Special Education (4), Preschool Education (3), History Education (2), and Astronomy Education (2)
(Garzón et al., 2019)	2012–2018	61	Natural sciences, mathematics, and statistics (30), Arts and humanities (10), Social sciences, journalism, and information (7), Information and communication technologies (5), Engineering, manufacturing, and construction (4), Health and welfare (4), and education (1)
(Ajit et al., 2020)	2012–2020	18	Physics (6), Mathematics (3), Sciences (1), Chemistry (2), Astronomy (2), Natural Science (4)

was found that 61 relevant articles were published between 2012—2018. The final participant in a comparative trial was Ajit et al. (2020), who found 18 papers published in 2012—2020. The comparison articles above show that each article found there to be several fields of education that use AR in their learning. Table 2 below summarizes the educational fields that use AR in their learning process to see which areas use AR the most.

The table above shows which areas of education use AR technology the most in their learning process. From the summary of the four primary papers, it was found that the results in the field of Mathematics and Statistics were that the education sector used AR the most, with a total of 39 papers included. The second rank is occupied by Biology, with 18 included papers. The third rank is held by Engineering Education, Manufacturing, and Construction with 14 included papers. According to Table 2, the enthusiasm of the researchers and developers is regarded as excellent, as indicated by the many variations in the field of education that have begun to integrate this technology into their learning. Still, it can also be seen that these studies are not found in the field of physical education. In contrast, physical education is a subject where AR technology can be integrated as one of the learning strategies that can be applied. This is a new research field that has great potential in the future.

2.1 The trends of augmented reality in physical education

The trend of augmented reality in physical education is now becoming more prevalent in mainstream physical education curriculums worldwide. While there are

Table 2 The total number of studies using AR according to field of education

Educational Field	Total
Mathematics and Statistics	39
Biology	18
Engineering, Manufacturing and Construction	14
Medical Education and Medical Training	13
Physics	13
Arts and Humanities	10
Chemistry	8
Social Sciences, Journalism, and Information	7
Natural Sciences and Sciences	6
Informal Education	6
Astronomy	5
Information and Communication Technologies	5
Languages	5
Health and Welfare	4
Special Education	4
History	3
Preschool Education	3
Education	1

various benefits to incorporating AR into physical education, it is important to understand the risks and vulnerabilities of these technologies so then they can be addressed before widespread use. The majority of children learn about physical activity (PA), which is a crucial part of their overall health, in physical education (PE) classes at school (Cheung, 2019).

Chen et al. (2020) has used AR technology to demonstrate Tai-Chi movements to older adults. They created an app that uses specific Tai-Chi movements according to the practitioner's capacity for augmented reality-assisted training. The results show that the users successfully learned the fitness exercise and got positive outcomes for their exercises. Another AR fitness app developed by Nair et al. (2019) proved that AR can be used for fitness. Their AR app encourages users to increase their level of fitness activities at each level in the AR game app. These results prove that the AR technology can be integrated into a fitness app for better results. However, further searching on all databases shows that there are very few systematic reviews on the trends of AR in PE.

2.2 Students with special needs (SSN)

The numerous aspects of a child's growth that make them who they are include their personality, communication abilities (verbal and nonverbal), resilience, strength, capacity to understand and enjoy life, and their drive to learn. Because each child is unique in their talents, personalities, and life experiences, different disabilities will have distinct effects on each child (Mercier & Doolittle, 2013). There are numerous ways to define "students with special needs" (SSN). According to Rattenbury (2021), SSNs may result in physical issues, terminal illnesses, and learning difficulties. Some will also experience cognitive or psychological problems. The Nidirect UK (2021) study identifies SSNs as having exceptional educational needs that make learning more challenging than it is for other students their age. They may also have problems with communication, behavior, or schoolwork. Therefore, educators have developed Exceptional Education to meet the unique learning needs of these individuals. The Ministry of Women, Family and Community Development stipulates that there are specific disabilities, specifically seven types including vision, speech, physical, learning difficulties, mental, and various or multiple disabilities (Abdullah & Hanafi, 2017; Olufadewa et al., 2021).

According to Bryant et al. (2019), to facilitate the learning of students with special needs, the following key attributes should be included in their education:

1. Free appropriate public education
2. Less restrictive environment
3. Systematic identification procedures
4. Individualized education programs
5. Family involvement
6. Related Services
7. Access to the general education curriculum
8. Evidence-based practices

9. Frequent monitoring of progress.

Although it is hard for an educational system to facilitate all of the attributes mentioned, the effort to include the primary key attributes can contribute to inclusivity among SSNs. According to the Special Education department data, most of the SSNs in Malaysia are categorized as having a Learning Disability (LD) problem. Approximately 82% of the SSNs in 2020 are students with a LD. Learning disability refers to a level of intelligence that does not match the individual's biological age. This category includes advanced global development, Down Syndrome, and intellectual disability. This category also includes conditions that affect the individual's learning ability such as autism (autism spectrum disorder), attention deficit hyperactivity disorder (ADHD), and specific learning difficulties such as dyslexia, dysphagia, and writing disorders (Radzi et al., 2019). Referring to the previous explanation that the most significant percentage of SSNs in Malaysia are students with learning disabilities, this study will focus on SLDs to see if there are studies that have integrated AR technology into PE classes with SLDs as participants.

2.3 Augmented reality with learning disability students

For students with disabilities, AR technology can assist in various ways. We can see the reviews that AR can be used as a learning material that teaches diverse physical learning, performs self-care tasks, and retains information for a long time (Ariffin et al., 2022; Mokmin & Rassy, 2022). For people with disabilities, augmented reality (AR) is a potent tool because it may display context-sensitive digital content that is able to satisfy their individual needs at the time and provide timely learning (Walker et al., 2017). As special education learning materials developers, there is an urgent need to understand the innovative tools available and apply them to meet the learners' unique needs. For instance, teachers can add text tags to real-world items that the AR software can read to contextualize words. AR apps can read difficult terms aloud, display other information about academic topics, provide video instructions, provide detailed information about upcoming programs when engaged in multi-step activities, or provide tips to individuals to support independent living (Alzahrani, 2020; Billinghurst et al., 2014; Lai et al., 2019). If we consider the practical use of AR in education and a more user-friendly entertainment value design, AR can offer a variety of alternatives.

Learning disability is usually caused by a discrepancy in how a person's brain is "wired," to put it simply (Rachamalla & Rafi, 2016). It also has to do with the neurological problems that usually cause learning impairment. Students with learning disabilities (SLDs) are just as intelligent as their peers. However, they may struggle with reading, writing, spelling, reasoning, and organizing information if left on their own or taught conventionally (Rachamalla & Rafi, 2016). Specialized teaching techniques are needed for students with learning disabilities, communication problems, behavioral problems, or developmental concerns to improve their learning and skill acquisition (Cifuentes et al., 2016). LD children struggle to organize and comprehend visual and aural information during

learning. They usually have a lack of concentration, are hyperactive, and have difficulty in terms of making social and environmental adaptations. Each LD student has a unique character that we should consider when designing suitable learning materials for LD students (Radzi et al., 2019). Because individuals with learning difficulties frequently become unmotivated during the learning process, the motivation to learn might be a problem. Although PE provides SSN opportunities to develop their emotional and physical development, they tend to participate less than other students (Adams, 2016). Therefore, educators should consider the students' special needs and focus more on getting their concentration and providing an adaptable learning environment.

According to Yenioglu et al. (2021), for students with special needs, AR can be used as a teaching tool to help them learn, build their comfort and confidence, and strengthen their social, physical, and cognitive capabilities. Integrating AR for children with learning disabilities is one of the learning strategies that can be used to help. Physical activity is necessary for children with disabilities to develop properly, yet choosing an appropriate physical activity for children with impairments can be difficult when an attempt is made to integrate them into a regular physical education lesson (Clemente, 2017). Due to the many obstacles to physical activity that people with disabilities face at all levels of society, students with disabilities are less active than their able-bodied peers (Úbeda-Colomer et al., 2019). Using AR technology as part of the students' physical activities becomes a new strategy that can be investigated to re-encourage the spirit of children with disabilities to carry out physical activities and sports in the same way as their peers.

The systematic review technique can produce a summary of trends or a summary of certain research topics that are generally found in the articles collected over several years. This is very helpful for researchers who want to get an overview of research development in this field. This is demonstrated by the research conducted by Quintero et al. (2019) who conducted a systematic review of articles from 2009—2018 that summarized the state of employing augmented reality as a teaching tool that considers all student requirements, including those with disabilities. The application of AR in special education and inclusive schools is a common emphasis of the current systematic reviews but the breadth of this research is still broad. Therefore, a more thorough systematic examination of physical education for kids with learning difficulties will be carried out in this study. This can act as an inspiration for future research with the goal of this study being a guide, aiding researchers by providing an overview of the development of AR in PE with SLDs.

3 Methodology

The recommended reporting items for systematic reviews and the meta-analysis (PRISMA) review protocol, including a search strategy, selection criteria, and data acquisition and analysis processes, were used to conduct the systematic review process to accomplish this study's objectives (Liberati et al., 2009). The research questions (RQs) were:

(1) What was the trend of AR applications in physical education during the 2015—2021 period?
(2) What progress has been made in the study of employing augmented reality (AR) technology in the field of physical education with students who have learning disabilities (SLD) as the participants?
(3) What variables are used in the research of AR in the PE field with SLD?
(4) What kind of AR types are used in the PE field in relation to SLD?
(5) What categories of learning difficulty have been investigated in relation to the PE field's AR application?
(6) What are the differences and limitations of selected research?

To find empirical studies on augmented reality in physical education with children who have learning disabilities as the study sample, a thorough search was conducted. The studies selected were published between 2015 and 2021 and were identified using databases such as ERIC, PubMed, ScienceDirect, PsychINFO, Google Scholar, Elsevier, EBSCOhost Routledge (Taylor & Francis), SAGE, IEEExplore, and Springer. The following keyword search terms were used during the electronic scanning phase: ('Augmented Reality' OR 'Augmented Reality Technology' OR 'Augmented Reality system') in ('Physical Education' OR 'Sports' OR 'Sports Education') with ('Disabilities' OR 'Disability' OR 'Disabled' OR 'Disorder' OR 'Special needs') students. The selected studies were reviewed based on the title, abstract, method, and results to ensure its relevance. The literature review flow diagram is shown in Fig. 1 below which demonstrates the process starting from identification, through to screening, eligibility, and the included articles.

The search results of the online databases using the keywords mentioned above resulted in 71 articles. Three articles come from additional records identified through other sources or manual searching. When the scanning process was complete, the next step was to perform a PRISMA-based selection process. From the 71 articles that were found, screening was carried out. Four duplicate articles were found from the results of the first screening, then the articles were discarded, followed by a second screening process finding 63 excluded articles. These articles were excluded because they did not meet the criteria. After reading in more detail, 58 further articles did not meet the criteria that had been determined. Most articles used AR technology for learning in physical education or sports without involving disabled students as the research participants. This was the main problem encountered because research on this topic is still rarely studied. Therefore, it is challenging to find similar research. This also causes the results of the included articles to not to total much, even though the range of article publications has been expanded.

As many as five articles were not determined to be empirical studies. This is because there ere two categories of non-empirical method used to review the advancements in a particular field of research (e.g., systematic literature review, meta-analysis). Certain non-empirical techniques (such as critical studies and editor's introductions) rely on the author's authority or experience, personal observations, and reflections on current affairs (Dan, 2019). After going through the screening stage, it was found that four articles met the criteria and were therefore included in this study.

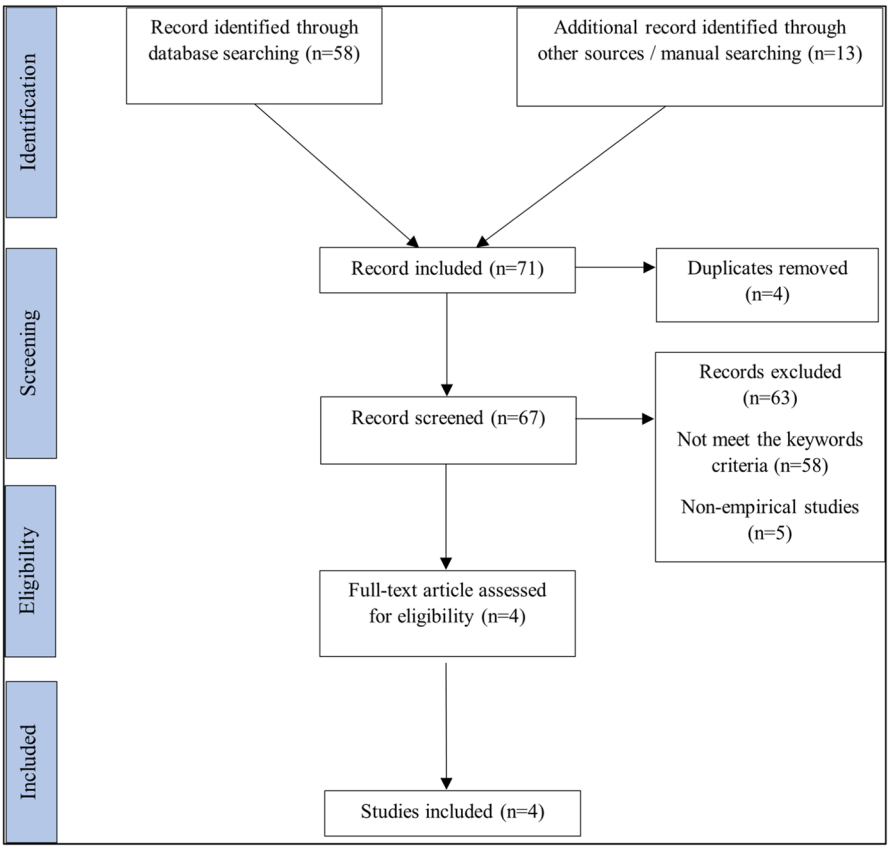

Fig. 1 Flow chart of the PRISMA-based selection process

3.1 Eligibility criteria

Exclusion and inclusion criteria were employed as part of reporting the systematic review and meta-analyses in accordance with the population, intervention, comparison, outcomes, and study (PICOS) design principles to find papers pertinent to this research (Methley et al., 2014). This study's exclusion and inclusion criteria have been described in Table 3 below.

After the screening process following the predetermined criterion, four articles met the requirements, whereas 47 articles did not meet the inclusion criteria because most of them used AR for physical education or sports field classes but did not include disabled students. Alternatively, they used AR as part of an interaction with disabled students but not in the physical education/sports field.

Table 3 Exclusion and inclusion criteria

Inclusion criteria	Exclusion criteria
It is a full-text article, and it is from an international peer-reviewed journal	Conference proceedings, book chapters, reports, letters, or papers with simple summaries
It used AR as the primary technology	AR technology is not the leading technology used in the study
It used AR technology in the physical education/ sports field	AR is implemented in another educational field (chemistry, physics, biology, etc.)
It included participants with special needs	The study uses more than one technology (virtual reality, mixed reality, etc.)
It was published between 2015 and 2021	
It was written in English	

4 Results and discussion

The outcomes of the five research questions will be presented in this section. First and foremost, the focus was on the most recent developments in AR technology in physical education to determine the current trends. The second research question determined the most recent outcome in AR technology in PE with disabled students. The third question helped the researcher to decide which variables are commonly employed in AR studies in physical education, followed by what types of AR are used in this field. The last question was to determine which disabled student groups were being examined.

4.1 Trends of AR technology in physical education from 2015–2021

From the 61 articles collected from 2015 – 2021, there were 14 articles found to be related to the application of AR in the PE field.

Figure 2 above shows that there were no papers published in 2015. Every year from 2016 to 2017, the number of published articles increased but in 2018 and 2019, compared to the previous year, fewer articles were published. Lastly, in 2020, there was a significant increase of seven published articles, followed by a reduction in 2021. We can deduce from the graph that while the interest of researchers in this topic is still low, research in this field began to gain traction in 2020, as indicated by the significant number of papers published in that year compared to the average number of published articles in the prior years. This trend answers the first research question, showing that a few researchers are aware of the many positive impacts resulting from the integration of this technology as demonstrated by the graph concerning the last five years of research in education.

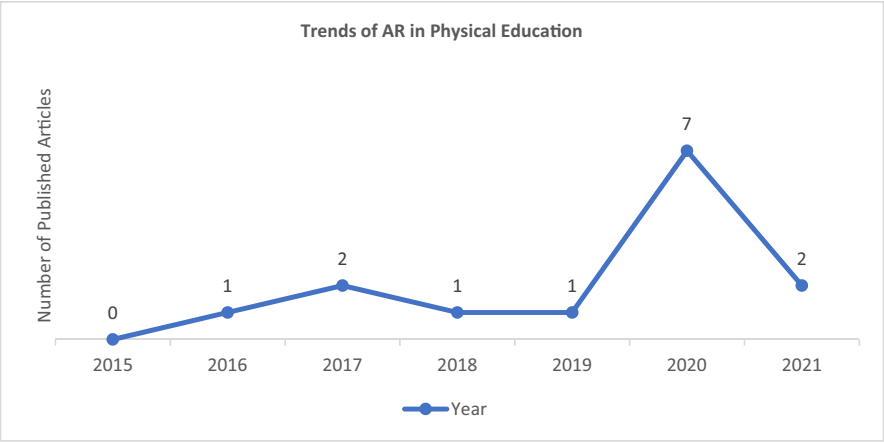

Fig. 2 Recent trends of AR in physical education

4.2 The development of research on the use of AR technology in the PE field with SLDS as participants

One of the qualifying requirements that has been established states that papers that might be submitted in the review must use augmented reality technology in the field of physical education or sports. The second research question sought to learn how the studies on the application of augmented reality technology, specifically in physical education, have developed using SLDs as participants. As shown in Fig. 2 above, 61 articles were successfully collected according to the specified keywords. After the analysis process, none of the articles found discuss the implementation of AR into PE classes with learning disability students as the participants. This shows that this field of research has great potential because no one has researched it yet. On the one hand, the four articles that were included in this study inclusive of the results of the analysis were engaged in sports and training with disabled children as shown in the table below.

From Table 4 above, we can see that the first article by Lin and Chang (2015), seeks to investigate how augmented reality (AR) games might help youngsters with disabilities get stronger physically. This is followed by the research conducted by Graf et al. (2019) that identified the potential of iGYM AR-based games to accommodate a variety of abilities and mobility aids in exergames. Using the same application, Lu et al. (2020) used it to create the final player detection and filtering technique for iGYM. Many tracking algorithms were assessed and their performance was compared. Lastly, the research conducted by Nebytova et al. (2021) proved AR technology's effectiveness when aiming to enhance learning in relation to the educational and training process of track and field athletics.

The results show that no research has been conducted more specifically in the PE field regarding the use of AR technology in relation to SLDs, even though many advantages have resulted from the use of AR in the PE field in reference to several studies that researchers have carried out. However, there were four studies on

Table 4 List of research studies included

Author (year of publication)	Purpose
(Lin & Chang, 2015)	Sought to enhance the body strength of children with disabilities using a body motion interactive game
(Graf et al., 2019)	Found ways that iGYM could be used in exergames to accommodate a range of abilities and mobility aids
(Lu et al., 2020)	To decide on the player recognition and filtering approach for iGYM, then to examine the performance of several tracking algorithms and evaluate them
(Nebytova et al., 2021)	Shows that augmented reality technology can improve the learning related to the coaching and instructional processes for track and field sports

physical activity, three of which aimed to help children with disabilities in reference to sports and other basic physical activities.

4.3 List of variables used in the research of ar in the PE studies

Research question number three aimed to determine what variables are used in the research on the implementation of AR technology in the PE field by focusing on students with learning disabilities as the participants.

As shown in Table 5 above, one study employed the physical play experiences of the participants as the dependent variable, one article used the health improvement of the participants, and two articles used body movement. Two articles used inclusive AR floor projection as an independent variable. One article used AR-based interactive games, and the last article used AR sports and game training. From some of the studies above, it can be seen that most of the research conducted in the sports field for SLDs has tried to examine the effects resulting from the use of AR on the SLDs' body movements and health improvements.

4.4 Types of AR technology used in the PE field with SLD

The three articles that are shown in Table 3 applied projection-based AR. This works by projecting artificial light onto an actual surface. The other technique that is often used is markerless AR. This does not require a marker to display specific 3D objects and also sometimes it allows the user to interact with it. One of the articles

Table 5 List of variables used in the research of AR in PE studies

Author	Dependent variable	Independent variable
(Lin & Chang, 2015)	Body movement	AR-based interactive game
(Graf et al., 2019)	Physical play experiences	Inclusive AR floor projection system
(Lu et al., 2020)	Body movement	Inclusive AR floor projection system
(Nebytova et al., 2021)	Health improvement	AR sports and game training method

used AR interactive games. It aimed to increase the motivation of children with developmental impairments to participate in physical activities by integrating a web camera that tracks movement and allows the participants to interact with the project physically. The two articles used floor projected AR in exergames to help students with a movement impairment to experience playing a hockey game like their peers. The last article used markerless AR in the form of AR interactive sports games to evaluate the training effect in the educational and training process in relation to track and field athletics.

We can conclude that all articles were developed in the field of physical activity which aims to help SLDs; more specifically, three of the articles researched the field of sports, and one of them was conducted in the field of simple physical activity. The findings above provide an answer to research question number 4, demonstrating that markerless and projection-based AR are the two most popular types of augmented reality. Markerless AR includes holding 3D content to a fixed point in space while overlaying it over a scene without requiring prior knowledge of the user's surroundings. This is in accordance with the target sample they tested, namely students with learning disabilities who then focused on seeing their body movements when using the application. This will significantly facilitate researchers and participants using the projection-based AR and markerless AR types.

4.5 List of disability groups that participate in the research of ar technology in the PE field

The four articles show that three types of disability were included in this research. One article included SLD with developmental disabilities as the participants consisting of three students, each of whom had different skills: developmental disabilities, cerebral palsy, and moderate multiple disabilities. The following article included SLD with hearing disorders in their research. Two articles tested SLD with mobility disabilities assisted by mobility aids. We can conclude that the research on AR used in physical activities with SLD, according to these four studies, found that the research on mobility disabilities dominates, followed by developmental disabilities that also affect movement. The reviews are essential to determining the type of AR and variables used in the studies. Most of the articles have made an attempt to see what effect the technology has on children with disabilities that interfere with their mobility.

4.6 The differences and limitations found in selected research

Table 6 summarizes the comparison between the four articles included in this study. The first study used an AR application to increase the body strength of children with developmental disabilities. This study found positive results for using AR applications for children's physical activity and motivation. As for the limitations of this study, researchers must adjust the content of AR applications for the four participants. This is somewhat less effective if a large number of participants faces further

Table 6 Comparison table for selected articles

Authors (year)	Research purpose	Results	Limitation	Proposed solution
(Lin & Chang, 2015)	To enhances the body strength of children with developmental disabilities. Using AR body motion interactive game	The results of this study indicate that the use of real-time technology to create a flexible, low-cost interactive basic program investigated for individuals diagnosed with developmental disabilities yielded significant results. This application has a positive effect on children's physical activity and motivation to carry out the physical activities they need for their body health	Because the application is free and flexible, the content of this application has been changed (image and sound) to suit the disabilities experienced by the participants. So, three participants got different content	It is better that the content presented is the same for all participants so all participants get the same treatment. On the other hand, maybe the author can look for participants with the same criteria, so there is no need to adjust the content for each participant because it will be ineffective if many participants follow a similar study in the future

Table 6 (continued)

Authors (year)	Research purpose	Results	Limitation	Proposed solution
(Graf et al., 2019)	Creating an interactive floor projection system designed to enable people with mobility disabilities to compete on par with, and in the same physical environment as, their peers without disabilities in playing exergames adaptive sports	The results showed that most of the participants that had previous experience with adaptive sports, stated that iGYM is not like other adaptive sports that require special equipment to be played adaptively. iGYM is adapted for everyone, even people without physical disabilities. Players love iGYM, which allows them to play with people with different abilities. Most of the players said they did not often engage in physical activity with people with different mobility before this study	Since this research takes the form of exergames 1 on 1 matches, there are uncontrollable factors that impact the players' gameplay, including personal preferences, social factors, the impact of some players' internal balancing to ensure fairness, and spectators' support for players who are playing against friends or family After the treatment session, participants are given more time to play without reducing the number of players on the field or increasing the pressure of observation. The gameplay seems to change as a result. It prompted multiplayer matches, participation using mobility aids other than wheelchairs (such as crutches), and the children players playing alongside their parents	In order to reduce pressure or other external factors that can affect players during the match, it is recommended to do some exercises before the match so that players get used to and can adjust to external factors that may affect the game Further research can be developed to enable the competition to be followed by people with movement disabilities with any mobility aids (not only wheelchairs)

Table 6 (continued)

Authors (year)	Research purpose	Results	Limitation	Proposed solution
(Lu et al., 2020)	A technical discussion of the player detection and tracking features of the iGYM system by evaluating two adaptive filtering-based tracking methods, Kalman Filter (KF), and Particle Filter (PF), to quantify the performance of each scheme for player tracking	Due to its real-time nature, the system faces difficulties in decreasing latency and resolving the discrepancy between the present and future frames. By utilizing a Kalman filter, iGYM balances complexity and accuracy. The real-time system was successfully tested using volunteers with various abilities	Particle filtering (PF) and Kalman filtering (KF) significantly increase accuracy compared to the detection-only algorithm, with PF generally outperforming KF somewhat better According to the data, the particle filter performs better when dealing with sudden maneuvering player movements that cause significant tracking mistakes. However, Both are comparable for regular movement. This study chooses a Kalman filter for real-time system field trials with actual users since its accuracy is identical to that of the particle filter for typical player motions	Because the research uses only Kalman Filter (KF) in the field trials, future research is recommended to try using Particle filtering (PF) to ensure an accurate comparison of the two algorithms

Table 6 (continued)

Authors (year)	Research purpose	Results	Limitation	Proposed solution
(Nebytova et al., 2021)	Proving that augmented reality technology can improve learning in track and field sports coaching and instructional processes	The findings show that augmented reality (AR) technology significantly impacts how well children are trained in the movement approach since AR can demonstrate it at any level of detail Athletes who are hearing impaired can see the reference components of various exercises in full detail with an equal degree of accuracy. They are able to compare techniques, recognize their mistakes, and get insight into all aspects, which in actual practice would be extremely difficult to achieve	The sports training of children with hearing impairment has benefited from AR technology. However, augmented reality technology hasn't been used as much as it should, though, so far. In particular, it relates to sports training	This is a potential future research opportunity for researchers and developers. The use of AR in sports and training areas for children with disabilities is minimal. Further research is suggested to start developing AR in this area

research in the future. In future research, it is suggested to find commensurate participants so that they do not need to adjust the content for each participant.

The second research created an AR interactive floor projection system to enable people with mobility disabilities to play exergames with people with no special needs. This study uses a peripersonal circle to detect participants' movements. The results show that some participants who have previously played adaptive sports think this application is easier to use because it does not require special equipment like other adaptive sports. Most participants felt this was their first experience exercising with disabled people. As for the shortcomings in this study, some participants felt that external factors affected players' gameplay during matches, which can be minimized by practicing before the actual games. This research is also limited to wheelchair users, and further research can develop this application so that movement disabilities can use it with other mobility aids.

The third study tries to improve the second study, where the study uses the same AR application but focuses on testing the most effective algorithms to reduce delays when detecting participant movement, namely Kalman Filtering (KF) and Particle filtering (PF). The results show that using both algorithms is proven to increase the accuracy of movement detection compared to detection-only algorithms. The two algorithms also have a slight difference. For basic movements, the two algorithms are comparable, but for sudden maneuvering player movements, PF is more effective. The shortcomings are that the algorithm used for real-time system field trials with actual users is only KF because the two algorithms are identical. Suggestions for further research to try PF as well to get accurate results for the difference in the use of the two algorithms.

The last study aims to prove whether AR technology can improve learning in track and field sports coaching and instructional processes in children with hearing impairment. The results show that AR significantly positively impacts student learning processes. As for the shortcomings found by this study, the lack of AR research in sports training areas caused the lack of references can be used. This is potential research that researchers and developers can develop in the future.

5 Discussion

A systematic review is a methodology of critically evaluating, summarizing, and seeking to reconcile evidence (Munn et al., 2018). It entails conducting a comprehensive search for all pertinent published and unpublished material on a topic (Siddaway et al., 2019). The use of AR in PE over the last six years was examined in this study using the systematic review approach. In the early stages, 61 articles were found following the examination of the online database search results, which were then analyzed. Only 14 articles addressed AR technology use in the PE profession were located. Still, the number of publications on this topic increased significantly in 2020. This demonstrates that this topic of study has started to draw the interest of various researchers and will only continue to expand. Even though technology has increasingly permeated both professional sports and our daily lives in recent years, the integration of the AR-based applications into PE is still

low. According to Yang et al. (2020), the usage of Bluetooth, network positioning, infrared rays, augmented reality (AR), virtual reality (VR), Bluetooth, the Internet of Things (IoT), and Bluetooth in physical education has not been studied; all of these technologies are worth investigating.

Overall, this study's findings have revealed that the recent developments in AR applications in relation to PE were unstable and largely consisted of a small number of applications. The movement showed that researchers are not yet aware of the positive impact of AR technology's integration in sports learning, nor has it found there to be research in this area when including SNS. When this was incorporated into the PE curriculum for kids with learning difficulties, it has a good impact. The papers also outlined the advantages of using AR in the world of sports. The technology can assist with interface interactions, providing physical play experiences and real-time feedback for various types of disabilities (Graf et al., 2019). Additional to that, the technology also effectively helped deaf children practice track and field athletics (Nebytova et al., 2021). However, from the 14 articles, four articles worked on the physical activity environment and involved SLD. Of the four articles included in this study, most used markerless AR to detect body movements as the dependent variable with inclusive AR floor projection as the independent variable. This study was mostly done using SLD with mobility disabilities, followed by developmental disabilities and hearing disorders.

6 Conclusion

In light of the benefits that augmented reality technology can offer regarding the learning process, it can be concluded that there is a dearth of studies on the use of physical education in education. By integrating this technology in the classroom, it can help increase the level of student motivation and development, especially for students with special needs. It can also help them learn safely and comfortably.

Most of the research conducted in this area, specifically integrating it with students with special needs, is still focused on students with limited mobility with the aim of helping them visually by trying to get their attention first. The child will unconsciously be aroused and do what is shown or demonstrated by the technology. This helps to train their movements so then these children are motivated to do the physical activities necessary for their health. It also allows the children with disabilities to experience playing sports which are otherwise difficult for them to do, unlike how the sports are for their peers. Overall, the effectiveness of using AR technology shows there to be positive dynamics. The accessibility of AR enables users to interact physically with technology to inspire youngsters with developmental challenges to engage in physical exercise. For future studies, it is hope that more reviews will be examine the trends associated with applying AR in the development of different subjects for students with disabilities. It is hoped that this research can be used as a reference for developers and educators to develop more AR tools for students with disabilities that can be implemented into the learning curriculum.

Acknowledgements The author is from Universiti Sains Malaysia and the funding and materials are supported by the university.

Funding This work was supported by the Ministry of Higher Education Malaysia for the Fundamental Research Grant Scheme with Project Code: FRGS/1/2021/SSI0/USM/02/10.

Data availability There is no supporting data.

Declarations

Ethics approval statement This study has been cleared by the ethics committee.

Patient consent statement/Permission to reproduce material from other sources/clinical trial registration Not related.

Competing interests No competing interest.

References

Abdullah, N., & Hanafi, H. (2017). The rights of persons with disabilities in Malaysia: The underlying reasons for ineffectiveness of persons with disabilities Act 2008. *International Journal for Studies on Children, Women, Elderly and Disabled, 1*(1), 127–134.

Adams, D. (2016). *The effectiveness of the buddy support system in special education in Malaysia*. (Doctoral Dissertation). http://studentsrepo.um.edu.my/id/eprint/6568

Ajit, G., Lucas, T., & Kanyan, R. (2020). A systematic review of augmented reality game-based Learning in STEM education. *Educational Technology Research and Development*. https://doi.org/10.1007/s11423-022-10122-y

Ajit, G., Lucas, T., & Kanyan, R. (2022). A systematic review of augmented reality game-based Learning in STEM education. *Estudios De Economica Applicada*. https://doi.org/10.1007/s11423-022-10122-y

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*. https://doi.org/10.1016/j.edurev.2016.11.002

Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. *Applied Sciences (Switzerland)*, *10*(16). https://doi.org/10.3390/app10165660

Arici, F., Yildirim, P., Caliklar, Ş, & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. *Computers and Education, 142*(March), 103647. https://doi.org/10.1016/j.compedu.2019.103647

Ariffin, U. H., Mokmin, N. A. M., & Akmal, M. A. (2022). Augmented Reality Technology in Physical Education: A Systematic Review in Instructional Design, and AR Implementation Option Over the Last 5 Years. *Advanced Journal of Technical and Vocational Education, 6*(1), 13–20. https://doi.org/10.26666/rmp.ajtve.2022.1.3

Mokmin, N. A. M., & Rassy, R. P. (2022). Augmented reality technology for learning physical education on students with learning disabilities: A systematic literature review. *International Journal of Special Education, 37*(1), 99–111. https://doi.org/10.52291/ijse.2022.37.30

Barto, A. (2021). *Immersive learning: What it is and how to use it*. Roundtable Learning. Retrieved December 30, 2021, from https://roundtablelearning.com/immersive-learning-what-it-is-and-how-to-use-it/

Bertills, K., Granlund, M., & Augustine, L. (2019). Inclusive teaching skills and student engagement in physical education. *Frontiers in Education, 4*(August), 1–13. https://doi.org/10.3389/feduc.2019.00074

Billinghurst, M., Clark, A., & Lee, G. (2014). A survey of augmented reality. *Foundations and Trends in Human-Computer Interaction, 8*(2–3), 73–272. https://doi.org/10.1561/1100000049

Bowser, A., Phillips, C., Johnson, D., Wyeth, P., Hides, L., Klarkowski, M., Valladares, E., Beneitez, N., Chiang, M.-H., Chen, T. K., Tseng, D.-Y., Lin, A., Li, K. C.-Y., Vicente, O., Vicente, S., Martin,

D., Florido, M. Á. R., Maynar, M., Palavalli, B. M., … Ren, X. (2016). Fitmersive Games : Fitness Gamification through Immersive VR. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, *46*(10), 3679–3682. https://doi.org/10.1145/2909132.2909287

Bryant, D., Bryant, B. R., & Smith, D. D. (2019). *Teaching students with special needs in inclusive classrooms* (2nd ed.). Sage Pulications Ltd.

Cabero-Almenara, J., & Roig-Vila, R. (2019). The motivation of technological scenarios in Augmented Reality (AR): Results of different experiments. *Applied Sciences (Switzerland)*, *9*(14). https://doi.org/10.3390/app9142907

Cakir, R., & Korkmaz, O. (2019). The effectiveness of augmented reality environments on individuals with special education needs. *Education and Information Technologies*, *24*(2). https://doi.org/10.1007/s10639-018-9848-6

Chen, P. J., Penn, I. W., Wei, S. H., Chuang, L. R., & Sung, W. H. (2020). Augmented reality-assisted training with selected Tai-Chi movements improves balance control and increases lower limb muscle strength in older adults: A prospective randomized trial. *Journal of Exercise Science and Fitness, 18*(3), 142–147. https://doi.org/10.1016/j.jesf.2020.05.003

Cheng, K. H. (2017). Reading an augmented reality book: An exploration of learners' cognitive load, motivation, and attitudes. *Australasian Journal of Educational Technology, 33*(4), 53–69. https://doi.org/10.14742/ajet.2820

Cheung, P. (2019). School-based physical activity opportunities in PE lessons and after-school hours: Are they associated with children's daily physical activity? *European Physical Education Review, 25*(1), 65–75. https://doi.org/10.1177/1356336X17705274

Chiang, F. K., Shang, X., & Qiao, L. (2022). Augmented reality in vocational training: A systematic review of research and applications. *Computers in Human Behavior, 129*(April 2021), 107125. https://doi.org/10.1016/j.chb.2021.107125

Cifuentes, S. C., García, S. G., Andrés-Sebastiá, M. P., Camba, J. D., & Contero, M. (2016). Augmented Reality experiences in therapeutic pedagogy: A study with special needs students. *Proceedings - IEEE 16th International Conference on Advanced Learning Technologies, ICALT 2016*. https://doi.org/10.1109/ICALT.2016.23

Clemente, I. (2017). Barriers and facilitators to participation in physical activity for children with disability. *Physiotherapy (United Kingdom), 97*, eS1131.

Da Silva, I. C. S., Klein, G., & Brandão, D. M. (2017). Segmented and detailed visualization of anatomical structures based on augmented reality for health education and knowledge discovery. *Advances in Science, Technology and Engineering Systems, 2*(3), 469–478. https://doi.org/10.25046/aj020360

Dan, V. (2019). Empirical and Non-Empirical Methods. In J. Matthes, C.S. Davis, and R.F. Potter (Eds.), *The international encyclopedia of communication research methods*. https://doi.org/10.1002/9781118901731.iecrm0083

Demchenko, I., Maksymchuk, B., Bilan, V., Maksymchuk, I., & Kalynovska, I. (2021). Training future physical education teachers for professional activities under the conditions of inclusive education. *Brain. Broad Research in Artificial Intelligence and Neuroscience, 12*(3), 191–213. https://doi.org/10.18662/brain/12.3/227

Dubé, A. K., & Wen, R. (2022). Identification and evaluation of technology trends in K-12 education from 2011 to 2021. *Education and Information Technologies, 27*(2), 1929–1958. https://doi.org/10.1007/s10639-021-10689-8

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers and Education, 142*(September 2018), 103635. https://doi.org/10.1016/j.compedu.2019.103635

Garrett, B. M., Anthony, J., & Jackson, C. (2018). Using mobile augmented reality to enhance health professional practice education. *Current Issues in Emerging ELearning, 4*(1), 10. https://scholarworks.umb.edu/ciee. Retrieved October 19, 2020, from https://scholarworks.umb.edu/ciee/vol4/iss1/10

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality, 23*(4), 447–459. https://doi.org/10.1007/s10055-019-00379-9

Gómez-García, M., Trujillo-Torres, J. M., Aznar-Díaz, I., & Cáceres-Reche, M. P. (2018). *Augment reality and virtual reality for the improvement of spatial competences in Physical Education*. https://doi.org/10.14198/jhse.2018.13.proc2.03

Graf, R., Benawri, P., Whitesall, A. E., Carichner, D., Li, Z., Nebeling, M., & Kim, H. S. (2019). Igym: An interactive floor projection system for inclusive exergame environments. *CHI PLAY 2019*

- *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 31–43. https://doi.org/10.1145/3311350.3347161

Guerrero, A. J., García, S. A., Parejo, M. R. N., Soto, M. N. C., & García, G. G. (2020). Augmented Reality as a Resource for Improving Learning in the Physical Education Classroom. *International journal of environmental research and public health, 17*(10), 3637. https://doi.org/10.3390/ijerph17103637

Haegele, J., Zhu, X., & Davis, S. (2018). Barriers and facilitators of physical education participation for students with disabilities: An exploratory study. *International Journal of Inclusive Education, 22*(2), 130–141. https://doi.org/10.1080/13603116.2017.1362046

Hsiao, K. F. (2013). Using augmented reality for students health - Case of combining educational learning with standard fitness. *Multimedia Tools and Applications, 64*(2), 407–421. https://doi.org/10.1007/s11042-011-0985-9

Klochko, O. V., Fedorets, V. M., Uchitel, A. D., & Hnatyuk, V. V. (2020). Methodological aspects of using augmented reality for improvement of the health preserving competence of a Physical Education teacher. *CEUR Workshop Proceedings, 2731*, 108–128.

Krause, J. M., O'Neil, K., & Jones, E. (2020). Technology in physical education teacher education: A call to action. *Quest, 72*(3), 241–259. https://doi.org/10.1080/00336297.2019.1685553

Kumar, J. (2020). *Everything you need to know about immersive learning*. Elearning Industry. https://doi.org/10.1016/j.jpeds.2014.07.019

Lai, A. F., Chen, C. H., & Lee, G. Y. (2019). An augmented reality-based learning approach to enhancing students' science reading performances from the perspective of the cognitive load theory. *British Journal of Educational Technology, 50*(1), 232–247. https://doi.org/10.1111/bjet.12716

Lee, I. J. (2021). Kinect-for-windows with augmented reality in an interactive roleplay system for children with an autism spectrum disorder. *Interactive Learning Environments, 29*(4), 688–704. https://doi.org/10.1080/10494820.2019.1710851

Leonardi, M., Bickenbach, J., Ustun, T. B., Kostanjsek, N., & Chatterji, S. (2006). The definition of disability: what is in a name? In *Lancet* (Vol. 368, Issue 9543). https://doi.org/10.1016/S0140-6736(06)69498-1

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ (Clinical Research Ed.)*. https://doi.org/10.1136/bmj.b2700

Lin, C. Y., & Chang, Y. M. (2015). Interactive augmented reality using Scratch 2.0 to improve physical activities for children with developmental disabilities. *Research in Developmental Disabilities, 37*, 1–8. https://doi.org/10.1016/j.ridd.2014.10.016

Lu, P., Lim, J., Graf, R., & Kim, H. S. (2020). IGYM: An Inclusive Augmented Reality Exergame for People of All Abilities. *IEEE Workshop on Signal Processing Systems, SiPS: Design and Implementation*, *2020-Octob*, 1–6. https://doi.org/10.1109/SiPS50750.2020.9195226

Maas, M. J., & Hughes, J. M. (2020). Virtual, augmented and mixed reality in K–12 education: A review of the literature. *Technology, Pedagogy and Education, 29*(2), 231–249. https://doi.org/10.1080/1475939X.2020.1737210

Mann, S., Furness, T., Yuan, Y., Iorio, J., & Wang, Z. (2018). *All Reality: Virtual, Augmented, Mixed (X), Mediated (X,Y), and Multimediated Reality*. arXiv.https://doi.org/10.48550/arXiv.1804.08386

Marín-Morales, J., Higuera-Trujillo, J. L., Greco, A., Guixeres, J., Llinares, C., Gentili, C., Scilingo, E. P., Alcañiz, M., & Valenza, G. (2019). Real vs. immersive-virtual emotional experience: Analysis of psycho-physiological patterns in a free exploration of an art museum. *PLoS ONE, 14*(10), 1–24. https://doi.org/10.1371/journal.pone.0223881

Mercier, K., & Doolittle, S. (2013). Assessing student achievement in physical education for teacher evaluation. *Journal of Physical Education, Recreation & Dance, 84*(3), 38–42. https://doi.org/10.1080/07303084.2013.767721

Methley, A. M., Campbell, S., Chew-Graham, C., McNally, R., & Cheraghi-Sohi, S. (2014). PICO, PICOS and SPIDER: A comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. In *BMC Health Services Research*. https://doi.org/10.1186/s12913-014-0579-0

Mokmin, N. A. M. (2020). The effectiveness of a personalized virtual fitness trainer in teaching physical education by applying the artificial intelligent algorithm. *International Journal of Human Movement and Sports Sciences, 8*(5), 258–264. https://doi.org/10.13189/saj.2020.080514

Mokmin, N. A. M., & Jamiat, N. (2021). The effectiveness of a virtual fitness trainer app in motivating and engaging students for fitness activity by applying motor learning theory. *Education and Information Technologies, 26*(2), 1847–1864. https://doi.org/10.1007/s10639-020-10337-7

Mokmin, N. A. M., & Ridzuan, N. N. I. (2022). Applying artificial intelligence algorithm through immersive technology for physical education. *Advanced Journal of Technical and Vocational Education, 6*(1), 1–5. https://doi.org/10.26666/rmp.ajtve.2022.1.1

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(1), 1–7. https://doi.org/10.1186/s12874-018-0611-x

Nair, Y. N. I., Azman, F., Rahim, F. A., & Cheng, L. K. (2019). Endure: Augmented reality fitness mobile application. *2019 IEEE 4th International Conference on Computer and Communication Systems, ICCCS 2019*, 419–424. https://doi.org/10.1109/CCOMS.2019.8821640

Nebytova, L. A., Katrenko, M. V, Savin, D. I., & Zhuravleva, Y. I. (2021). *Augmented reality in the training process of children with hearing disorders*. Distance Learning Technologies 2019. Vol-2834. 330–339. https://ceur-ws.org/Vol-2834/Paper28.pdf

Nidirect UK. (2021). *Northern Ireland Government Website*. https://www.nidirect.gov.uk/articles/children-special-educational-needs

Ojer, M., Alvarez, H., Serrano, I., Saiz, F. A., Barandiaran, I., Aguinaga, D., Querejeta, L., & Alejandro, D. (2020). Projection-based augmented reality assistance for manual electronic component assembly processes. *Applied Sciences (Switzerland)*, *10*(3). https://doi.org/10.3390/app10030796

Olufadewa, I. I., Oladele, R., Oduguwa, I., & Adesina, M. (2021). Historical perspective and classification of disability. *Yenagoa Medical Journal*, *3*(1).

Paigude, P. S. (2019). A survey on the effectiveness of hololens and augmented reality in education. *International Journal for Research in Applied Science and Engineering Technology, 7*(1), 293–296. https://doi.org/10.22214/ijraset.2019.1050

Papakostas, C., Troussas, C., Krouska, A., & Sgouropoulou, C. (2021). Exploration of augmented reality in spatial abilities training: A systematic literature review for the last decade. *Informatics in Education, 20*(1), 107–130. https://doi.org/10.15388/infedu.2021.06

Parekh, P., Patel, S., Patel, N., & Shah, M. (2020). Systematic review and meta-analysis of augmented reality in medicine, retail, and games. *Visual Computing for Industry, Biomedicine, and Art*, *3*(1). https://doi.org/10.1186/s42492-020-00057-7

Quintero, J., Baldiris, S., Rubira, R., Cerón, J., & Velez, G. (2019). Augmented reality in educational inclusion. A systematic review on the last decade. *Frontiers in Psychology, 10*(AUG), 1–14. https://doi.org/10.3389/fpsyg.2019.01835

Rachamalla, S. A., & Rafi, Dr. M. (2016). Learning disabilities: Characteristics and instructional approaches. *International Journal of Humanities, Social Sciences and Education*, *3*(4). https://doi.org/10.20431/2349-0381.0304013

Radzi, C. W. J. M., Jenatabadi, H. S., Alanzi, A. R. A., Mokhtar, M. I., Mamat, M. Z., & Abdullah, N. A. (2019). Analysis of obesity among malaysian university students: A combination study with the application of Bayesian structural equation modelling and pearson correlation. *International Journal of Environmental Research and Public Health*, *16*(3). https://doi.org/10.3390/ijerph16030492

Rattenbury, R. M. (2021). What is a special need child? *The Classical Review, 41*(2), 53–55. https://doi.org/10.1017/S0009840X00039548

Sáez-López, J. M., Cózar-Gutiérrez, R., González-Calero, J. A., & Carrasco, C. J. G. (2020). Augmented reality in higher education: An evaluation program in initial teacher training. *Education Sciences*, *10*(2). https://doi.org/10.3390/educsci10020026

Saidin, N. F., Halim, N. D. A., & Yahaya, N. (2015). A review of research on augmented reality in education: Advantages and applications. *International Education Studies, 8*(13), 1–8. https://doi.org/10.5539/ies.v8n13p1

Scherer, R., Siddiq, F., & Tondeur, J. (2019). The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education. *Computers and Education, 128*(September), 13–35. https://doi.org/10.1016/j.compedu.2018.09.009

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. In *Annual Review of Psychology* (Vol. 70, Issue January). https://doi.org/10.1146/annurev-psych-010418-102803

Sırakaya, M., & Sırakaya, D. (2020). Augmented reality in STEM education: A systematic review. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2020.1722713

Sirkaya, M., & AlsancakSirkaya, D. (2018). Trends in educational augmented reality studies: A systematic review. *Malaysian Online Journal of Educational Technology, 6*(2), 60–74. https://doi.org/10.17220/mojet.2018.02.005

TabuñarFortunado, I. (2016). An overview to game theory, physical education and sports, its thirteen essentials and categories. *Education Journal, 5*(5), 92. https://doi.org/10.11648/j.edu.20160505.12

Tekedere, H., & Göker, H. (2016). Examining the effectiveness of augmented reality applications in education: A meta-analysis. *International Journal of Environmental and Science Education, 1*(16), 9469-9481. https://files.eric.ed.gov/fulltext/EJ1118774.pdf

Úbeda-Colomer, J., Devís-Devís, J., & Sit, C. H. P. (2019). Barriers to physical activity in university students with disabilities: Differences by sociodemographic variables. *Disability and Health Journal, 12*(2), 278–286. https://doi.org/10.1016/j.dhjo.2018.11.005

Vuță, D. R. (2020). Augmented reality technologies in education - a literature review. *Bulletin of the Transilvania University of Brasov Series V Economic Sciences, 13(62)*(2), 35–46. https://doi.org/10.31926/but.es.2020.13.62.2.4

Walker, Z., McMahon, D. D., Rosenblatt, K., & Arner, T. (2017). Beyond Pokémon: Augmented reality is a universal design for learning tool. *SAGE Open*, *7*(4). https://doi.org/10.1177/2158244017737815

WHO. (2010). Global Recommndation on Physical Activity for Health. In *World Health Organization 2010*.

Yang, Q. F., Hwang, G. J., & Sung, H. Y. (2020). Trends and research issues of mobile learning studies in physical education: A review of academic journal publications. *Interactive Learning Environments, 28*(4), 419–437. https://doi.org/10.1080/10494820.2018.1533478

Yenioglu, B. Y., Ergulec, F., & Yenioglu, S. (2021). Augmented reality for learning in special education: A systematic literature review. *Interactive Learning Environments, 0*(0), 1–17. https://doi.org/10.1080/10494820.2021.1976802

Zeller, J. (2017). Reflective practice in the ballet class: bringing progressive pedagogy to the classical tradition. In *Journal of Dance Education* (Vol. 17, Issue 3, pp. 99–105). https://doi.org/10.1080/15290824.2017.1326052