A Meta Analysis on Augmented Reality Application for Individuals with Intellectual Disability

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***Abstract*—There is a growing interest in utilizing technology tools such as augmented reality to support individuals with disability in general and intellectual disabilities in particular. Therefore, the purpose of this study is to assess the effectiveness of augmented reality technology in improving positive outcomes of individual with intellectual disabilities. Following Arksey and O'Malley and Kitchenham guideline, a meta-analysis of the overall effect of augmented reality on individuals with intellectual disabilities was conducted. Twenty-two studies were considered to explore the effect of augmented reality technology on the outcomes of individuals with intellectual disabilities. The result of the majority of the studies indicated that augmented reality technology was effective in improving positive outcomes among individuals with intellectual disabilities. Hence, the study offers the benefits of utilizing augmented reality technology in special needs setting and could be a successful technology among individuals with intellectual disabilities.**

***Index Terms*—Technology, augmented reality, intellectual disabilities, meta-analysis.**

I. Introduction

Throughout the past decades, disabled individuals have increasingly made a notable integration into normal society [1]. Intellectually disabled individuals face several challenges in the performance of tasks in their day-to-day lives, and their opportunities to make choices are confined in terms of their living arrangements and independence. As a consequence, they find it difficult to make social connections, understand information (written, oral or social), and to develop adaptive behaviors (practical, social and conceptual skills) owing to certain limitations [2]-[3].

Nevertheless, the environment of special needs individuals requires specific communication strategies and tools involved in learning and acquisition of skills to ensure effective learning of students with intellectual disabilities and communication, behavioral and developmental disorders [1], [4]. More recently, the development of digital technology has been resulted in the creation of several options and alternatives for special needs individuals and with it, learning and teaching have been transformed [5]. Specifically, augmented reality AR is a promising technology that has been, time and again, used to develop individuals' skills and success among normal and disabled populations [6]. In fact, it has been noted to drastically change individual-animated objects interaction and engagement [7], particularly those individuals, who suffer from learning disabilities, reduced vision, autism and deafness [8], [9]. Literature generally promotes the use of communication tools, including AR as an effective technology device used for instruction delivery for intellectually disabled individuals in order to boost the integration of such individuals into mainstream schools and to enhance their academic, communication, leisure, employment and life management skills (e.g., [1]-[3], [10]-[12].

Generally speaking, augmented reality (AR) is capable of integrating and superimposing actual objects with information and virtual objects [13]. AR also delimits the user's sense of sight and extends sense of hearing, smell and touch [13], facilitating the processes of educational inclusion [11].

AR is represented through several actions and processes entailed in individual learning engagement and interaction [12]. [14] evidenced the AR technology effectiveness in enhancing the day-to-day skills among intellectually disabled individuals, while [3] supported the effectiveness of AR in enhancing the intellectually disabled individuals' independence skills. AR can improve intellectually disabled individual's decision-making [10] and can improve their science achievement in light of science vocabulary acquisition [10]. According to [15], AR is effective in enhancing the intellectually disabled individuals' navigation skills, and [16] found it to be capable of enhancing the vocational tasks performance of the same population type. A review of literature on the AR application on intellectual disabilities domain indicated its potential advantages.

In the face of the current increasing diagnosed individuals with intellectual disabilities, it has become a necessity to intensify search for methods to allow them to effectively and efficiently learn, for a complete social integration [1], [3]. The high level of demand for tools and methods to service special needs students has urged teachers, engineers, researchers and practitioners to look into techniques development involving AR to enable special needs' learning and enrich teaching experiences. In this regard, [17] found

Manuscript received April 14, 2022; revised May 6, 2022.

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that AR studies have not been widely conducted when compared to studies concerning other educational technologies [18], stressing the importance of having studies delving into the investigation of the level to which AR influences special needs individuals in their quest to acquire different life skills [19]. Coupled with this is the need to analyze the potential of AR to help disabled students [19], including those intellectually disabled.

Despite the numerous adopted teaching approaches to enhance students' learning (those with and without disabilities), AR technology literature remains limited to inconclusive findings regarding to the top effective intervention [20]. Added to this, AR has been tested in the disabled individual's realm, those with autism and those who are deaf e.g., [8], [9], [21], but only a few have tested it on those that are intellectually disabled. Hence, in this study, literature on the topic is reviewed, specifically 22 major studies obtained from different databases. Such review primarily aims to present an analysis outcome of literature concerning AR and students with intellectual disabilities and to furnish the strengths and weaknesses, conclusions, and challenges when it comes to this context. The AR technology administration into the realm of intellectual disabilities requires the resolution of the following main questions;

1) What is the effect of AR on the outcomes of intellectually disabled individuals?
2) What is the top common age level within which AR technology was conducted in the context of intellectually disabled individuals?
3) What are the advantages, limitations and challenges of AR when it comes to intellectually disabled individuals and the suggested trends in the AR use in such context?

II. Literature Review

A. Augmented Reality in General Special Education

There is notable extensive examination and use of AR applications in facilitating and integrating disabled individuals into the community they reside in [22]. AR applications are effectively adopted in mixed environments, enabling the combination of actual and virtual objects [8] and providing for different features of immersion, interaction and involvement in social services provided for disabled individuals (i.e., social living and physical and learning services) [17].

On the most basic level, [23] referred to disabled individuals as those suffering from long-term physical, mental, intellectual or sensory impairments, which prevent them from interaction and participation in society with the rest of their peers that are devoid of disabilities (p.1220). A thorough review of literature shows that AR used in special needs supports learning and self-determination, self-management, guidance in self-instruction and in resolving complex tasks in different environments [18].

Added to the above, literature also shows the value of AR in enhancing the learning of special needs students (e.g., [24]. In related studies, [25] promoted the AR's potential to display educational content to intellectually disabled students, while [15] evidenced its role in enhancing learning experience in light of navigation skills of intellectually disabled students in their quest to examine AR. Moreover, [26] study regarding the use of AR application as a reading assistant tool among students with reduced vision, found it to be effective in enhancing their vision. Also, [3] focused on daily living skills development through the use of AR among intellectually disabled adults. The authors found intervention activities to be effective in increasing the daily living skills of students, including independence skill.

In fact, literature also evidenced that AR teaching material is suitable and useful when used in developing cognitively impaired individuals. For instance, [27] found that participants' target response was increased, their vocational job skills improved during the intervention phases, allowing them to maintain such skills even following the intervention. AR was also showed to be invaluable in the context of ASD students, specifically on how to emote feelings and status, how to be aware of different situations, social situations, how to focus on learning, communication skills and how to enhance motivation and skills of interaction [8], [9].

B. Augmented Reality an Intellectual Disability

AR refers to a technology that combines the physical with the digital content to improve the real-world learning environment, via the superimposition of information concerning the immediate environment of the user, using cameras on mobile devices, while at the same time, inserting information using digital sources (videos and audio) [2], [10], [28]. It is a system that has the following major characteristics; 1) combining the real with virtual world, interaction in real time, aligning real objects/places and digital information using 3D technology [28]. In relation to the above, the Cognitive Theory of Multimedia Learning (CTML) offers a clear explanation for the AR potential effectiveness in the learning environment by stating that people learn expediently from words and pictures as opposed to learning from words only [29]. This principle is leveraged by AR by overlaying printed text, audio, videos, and other virtual content [28]. AR is capable of functioning as an assistive technology (AT) and instructional technology (IT) or both, based on the Universal Design for Learning (UDL) principles, enabling disabled students to learn effectively [10]. Moreover, AR teaches academic skills to students with intellectual disabilities in an authentic manner that is authentic, involving the creation of mobile learning environment that guides the learning via mobile devices and technologies [10]. Using AR can minimize the students' dependence on their teachers' assistance, shifting them towards increased independent learning, which is deemed to be a critical skill to acquire, particularly when students are preparing for a career [30].

III. Method

The present study followed a systematic review of relevant studies that has 4 phases. This technique was adopted from prior studies by [31], [32]. The 4-phases are as follows;

1) Planning the review – the first phase involves the determination of trends in educational studies for the years spanning from 2011 to 2020. The study conducted

an extensive and thorough systematic review to determine AR studies trends in intellectual disabilities settings, by examining studies from several databases such as (i.e., ERIC, EBSCOhost, and ScienceDirect, Scopus, Elsevier and ISI). To capture a broader range of potentially eligible studies, the researchers employed the "Augmented reality, augmented reality instruction, augmented reality technology" search terms as the key words primarily used to search the above studies.

2) Criteria for Studies Inclusion– in the environment of intellectual disabilities entities, AR has currently been the topic of focus although research on it remains few and far between in literature [33], [34]. Specific criteria in connection to research questions were reported and the exclusion and inclusion conditions for the studies examined were enumerated in [31], [32] study, for the years from 2010 to 2020, studies chosen based on journals, demonstrated methods or research topics, studies that indicate the populations that have been included in the AR studies, studies reported data analysis and findings, as well as studies that report limitations, pros and cons of AR and conclusions.
3) Criteria of Studies Exclusion – several criteria were defined to exclude some studies from this review such as: studies that did not mention the term augmented reality, studies conducted in special needs context or general disabilities, and studies that are conducted in the contexts of AR but not published in the above-mentioned databases such as (i.e., ERIC, EBSCOhost, and ScienceDirect, Scopus, Elsevier and ISI).
4) Study Selection – there were 22 articles culled from the databases and they were all deemed to be appropriate for the purpose of the study on the basis of assessment of clear outcomes, technology description, number of individuals reports, variables, statistics and outcomes. The studies were divided based on author's name, journal (identity), grade level, variables, and special needs (study content), and the findings and results (study data). Finally, the results were obtained by considering the research questions mentioned above.

IV. Results and Discussion

First, concerning the question about AR outcomes, Table I contains the results obtained from the coding process of data in the environment of special education. The table contains AR use, purpose and outcomes. The studies' findings presented in summarized form in Table I indicate that AR technology resulted in enhancing various students' skills, particularly students suffering from intellectual disabilities. Majority of the studies found AR technology to be successful in enhancing the learning outcomes and different life skills (emotional and personal) [1], [3], [14], [16], [35], [36].

TABLE I: A Summary of the 22 Studies Found Applying AR for Individual with Special Needs

	Variable Positive Outcome	Age	Type of AR	Domain
Benda and Uman and Smejkalova 2015	platform for display educational materials in the field of horticulture	Adult	Exploration type	Culture
Bridges, Robinson, Stewart, won & Mutua 2020	increase daily and independence skills	Adult	Exploration type	Life skills
Cacciatore 2018	Teach Transition-Related Math Skills	21-24	Exploration type	Science
Chang, Kang, & Huang 2013	Improve student perception and vocational job skills	21-25	Unspecified	Life
Kang and Chang 2019	Improved sudents learning and motivation	4th grade	Unspecified	Life
Colpani and Homem 2015	Assisting learning process	Children	Game	Science
Covaci, Kramer, Augusto, Rus and Braun 2015	helping disabled people in developing basic knowledge in everyday tasks.	Mean age 26	Exploratory type	Science
McMahon 2014	Improve the Academic Achievement and Independence	18-22	Exploratory type	Science
McMahon, Cihak, Wright, & Bell, 2015	increase knowledge	18-22	Exploratory type	Science
McMahon, Cihak, & Gibbons 2013	was effective in identifying possible food allergens	18-22	Exploratory type	Life
Smith, Cihak, Kim, McMahon, and Wright 2017	improve navigation skills	18-22	Unspecified	Life
Cate, David, Byungkeon, Don, & Rachel, 2017	improve navigation skills	18-22	Unspecified	Life
Tenemaza, Antonio, Ramirez, Vela, &Rosero, 2016	Help people in their daily life	Old people	Unspecified	Life
McMahon, Cihak, Wright, & Bell 2016	results indicate that all students acquired definition and labeling knowledge for the new science vocabulary terms.	Postsecondary Education Students	Exploratory type	Science
McMahon, Cihak, Wright, 2015	Results indicated that students traveled more successfully using augmented reality compared to Google Maps and a paper map	20-24 years	Exploratory type	Life
McMahon, Cihak,	All participants readily identified possible food	Participants	Exploratory type	Life

Gibbons, Fussell, Mathison, Tennessee 2013	allergens	ranged in age from 19 to 23 years.		
McMahon, Smith, Cihak, Wright, & Gibbons 2015	The results indicated that the augmented reality navigation application was functionally the most effective condition.	18-24	Exploratory type	Life
Heyn, Baumgardner, McLachlan, & Bodine, 2014	All participants reported increased levels of engagement, enjoyment, and immersion involving the MR exercise environment as well as positive feedback recommending this type of exercise approach to peers with similar disabilities.	23-57 (3 male and 3 females)	Exploratory type	Social
Reardon, Wright, Cihak, & Parker 2016	Improved performance vocational skills	ages 19-29	Unspecified	Life
Reardon, Zhnag, Wrght, Lynne, & Parker, 2018	AR instruction allowed the students to learn the skills to mastery, and improved geometry performance.	ages 18–34	Exploratory type	Science
Rossi, Davenio, Morelli, &Grigioni, 2020	Useful tool to provide more independence to Patients during actual daily living activities and it will be able to notify users about a potentially dangerous situations, by providing cues in real time.	Adult	Exploratory type	Life
Vullamparthi, Nelaturu, Mallaya, Chandrasekhar 2013	The ap facilitates functional reading among children	4-10	Exploratory type	Extype

This finding may be attributed to the purpose behind the development of individual intellectual ability, the exposure to the required skills in life, and thus, AR was utilized to facilitate engagement in learning positive behaviors and skills in actual life circumstances. Moreover, the result may be attributed to the advantages provided by AR technology including, provision of information, to intellectually disabled individuals. According to [18], AR provided devices that enable the provision of information of the environment to intellectually disabled individuals of which such individuals may not be able to access some other way. In the same way, [35] revealed that AR is capable of achieving a cognitive prosthesis action, with AR facilitating the cognitive accessibility of intellectually disabled individuals of the environment.

Based on literature, using AR among intellectually disabled individuals can promote their engagement and enhance their cognitive experience. The authors stated that the experience outcomes showed increased independence of users, information access, life quality, acquisition of vocational life skills, daily life skills, and tackling every-day life adeptly. Also, Meanwhile, [16] revealed the capability of AR to enhance the performance of vocational skills among intellectually disabled individuals, while other studies evidenced its role in increasing daily life skills learning, and independence skills acquisition among the same demographic group [3], [14].

Moving on to the question concerning the educational level (school, higher education, special center for intellectual disabilities) of AR studies participants, Table 2 presents the results. Based on the table, majority of the studies focused on post-secondary students (59.09%), with the purpose behind the studies being to encourage students learning, clarify topics, and assisting their learning experiences, motivation, engagement and performance through the AR features. The reason behind the focus on post-secondary setting may be attributed to the specialized cost devices required for using AR technology, the long implementation period, and the need for AR experts, which higher education of special needs can afford. The result may be linked to the school and social environment that reinforces the social relations and interactions that motivate the leveraging of AR learning benefits. The next majority group focused on rehabilitation centers (22.72%), and lastly, 9.09% of the studies that determined the positive AR technology impact on intellectually disabled students focused on schools and in other contexts. Limited available studies found may also be related to the specialized cost devices that AR technology requires that many institutions are unable to afford. Added to the above explanation, the majority of AR technology and devices are developed for a distinct skill, and they may not all be suitable for intellectually disabled individuals, and they may not be accessible to children and other individuals without resolving interaction aspects first. Another reason behind the result may also be the lack of specialized teacher's training in schools. As for the rest of the studies that focused on elderly people with learning difficulties, their access to new technology is generally limited. In this regard, [36] revealed that older people with difficulties in learning new skills also face difficulties in accessing new technology solutions. This curtails their ability for acquiring conceptual knowledge required for interface interaction. Only a few studies were carried out to determine the AR potential in the context of schools and as such, further studies are required to focus on highlighting the benefits of AR and on examining it in various levels and contexts. Moving on to the domains, AR in intellectual disabilities is conducted on various domains such as 12 studies on personal and social life (54.55%), 9 studies in the domain of science (41%), and 1 study (4.45%) in the domain of culture. The domains of life and science were the preferred ones in previous studies. Since science and life skills are ideal domains based on the review on AR in intellectual disabilities setting, the potential of AR could be further extended to other domains such as education, health and other domains. Moving on to AR types, the most type of AR used in intellectual disabilities was exploratory based learning. The results showed that 22 studies 15 studies utilized AR exploratory based-learning [1], [10] 7 studies were unspecified [14], and 1 study used simulation-based game [37]. Two types of AR technology implemented in intellectual disabilities setting are discovered in the literature, which include AR an explanatory based-learning and

simulation-based game. It would be interesting to explore more types of AR that can be developed to be implemented in intellectual disabilities settings.

Moving on to the question concerning the advantages, limitations and challenges of AR in its application on intellectual disabilities context, and the suggested trends in its use, on the basis of the result, several uses of AR listed include, assisting in the learning process among intellectual disabilities, enhancing perception and vocational job skills, enhancing math skills, enhancing academic achievement and independence [1], [27], [37] increasing knowledge [10], and determining health food and daily skills in life [35], [38] and increasing science vocabulary knowledge [10].

Studies of this caliber like [39] and [14], revealed that AR leads to enhanced fundamental knowledge in daily tasks and performance of daily life skills. The result may be attributed to the general premise that technology (like AR) is effective and useful for special needs and for intellectually disabled individuals. It provides individuals with the ability to control prompts and coupled with the AR technology environment, contributes to enhanced and efficient learning tasks engagement, and eventually enhanced experiences of learning. Still another benefit of AR mentioned in literature by [10] is its support towards users' decision-making, their independence and their control of learning [6]. This may be attributed to the role of AR technology in helping intellectually disabled individuals during tasks activities completion. AR also allows visualizing the decision-making pictures. More specifically, AR experience provides users with a view to context-relevant prompts in real life circumstances, supporting their decision-making process, which in turn, leads to positive outcomes.

Generally speaking, individual with special needs can benefit from the use of AR technology, with AR teaching materials providing enrichment to education and towards interesting learning, boosting students' interests and providing them a view of actual life events. In this regard, [22] revealed that AR is suitable and useful in special education development. It brings real-life experiences to students to increase their social interaction and their collaboration with their peers and teachers. They also added that AR technology makes it possible to learn and apply social skills and social interaction, both qualitatively and quantitatively. On the whole, AR is an effective tool to use to help learning and skills development (academic, social and physical) among special needs individuals. Literature on AR advocates its contribution to enhanced motivation and positive physical activities coupled with heightened cognitive learning among down syndrome children [1], [6], [14], [22], [36], [37]. In other words, AR technology is a promising tool in the field of special education and results indicate that future studies should extend the study on the above topics.

With regards to the AR limitations, the major limitations that literature dedicated to intellectual disability enumerates are as follows; AR has to be developed in a way that suits the students' ability as opposed to solely their needs [1], [10]. Prior studies mentioned above revealed that AR effectiveness is based on the students' level, which means the students also differ in their disabilities. Studies also focused on limited participants, which brings up the question of whether AR is effective when applied on large-sized participants [3], [15]. Because of the relative novelty of AR technology, only little is known about its operations and potential and whether the required intervention objects can contribute to AR efficiency [1]. Therefore, limitations originate from the purpose and the time period of activities [1], [3]. AR application development has to take into consideration the users' perception and needs to furnish relevant information [16], [25]. Another limitation relates to the user's skills and abilities to use it owing to its novelty, and thus, it needs to be used frequently [16], [25]. Another limitation is related to methods of data collection, as the studies reported that questionnaires were the most used method. It is great to include some other reliable evaluation for individual with intellectual disabilities such as observation and case study method. Another limitation is methodology that most studies focused on students with autism, therefore, it is necessary to expand and diversify research to cover other settings related to intellectual disabilities. A limitation identified in the studies is the need to expand research in developing the use of AR technology to various groups of individuals with disabilities and not to be oriented to a specific disability such as autism. Few studies define truly diverse samples of individuals with intellectual disabilities. Another limitation related to previous studies that most of the studies outcomes were reported based on the short-term evaluation effect, and no study reported its outcomes over time or for long term impact.

Moving on to the AR technology challenges, the findings showed that the design of AR activities is one of the major challenges [16], [25]. The results may be related to the challenge of the design of activities that require specialized devices. In this regard, [40] and [17] contended the need to integrate AR system to other hardware and software devices to resolve issues of interfacing and to maintain stability. Another challenge is logistics – this takes the form of limited resources, locations and the related factors [1], [10]. Therefore, AR design should be connected to actual world location and features that are relevant to other contexts. Moreover, AR features also pose another challenge as highlighted by [16] and [25], which could be addressed and tackled through the provision of user support and suitable design of the learning environment. Additionally, designers of AR learning environment have to take the gap into consideration and request support from their instructors.

Prior studies also forwarded the learning form used in AR as another challenge (e.g., [14], considering the system is a multi-task technology that is not easy to interact with. Other studies like [16] and [15] also mentioned the AR system design as a challenge because of the lack of the availability of experts, the details involved, the abilities of individuals and the used devices. In other words, AR technology should be developed towards meeting the needs of the individual and it should have enough versatility to allow intellectually disabled individuals to easily complete the tasks and activities.

V. Limitations and Suggestions

This meta-analysis study has some limitations, with the first being the number of studies obtained from the data

sources for review. The studies had different objectives and as such, their findings may not be applicable to all intellectual disability situations and settings. The second limitation is the focus of the reviewed studies on improving the individuals' specific skills, particularly individuals suffering from intellectual disabilities. In this regard, future studies may concentrate on skills improvement for knowledge improvement, and thus, future studies may adopt this avenue of investigation. The majority of the reviewed studies had limited participants to their experiments, which requires future studies to conduct the experiments on large-sized samples involving different types of disabilities and various levels. Lastly, prior studies examined the effectiveness of AR with intellectual disabilities from samples that have similar age categories, necessitating studies to be conducted to compare the influence of AR on samples with different ages, gender and settings.

VI. Conclusions and Implications

This study conducted a review of studies concerning the effectiveness of AR technology in the context of intellectually disabled individuals. The findings showed the majority of prior studies supported positive outcomes and the potential of AR to meet the needs of this demographic. They also showed that AR enhances the social interaction among intellectually disabled individuals, their motivation, and their participation in social and day-to-day tasks and activities. Overall, AR technology can be effectively utilized to assist intellectually disabled individuals in learning and acquiring skills to meet their needs and in motivating them to take part in societal activities for a stable and normal social life.

Although, the importance of AR technology usage in special needs settings has been reported in the past studies, its application in intellectual disabilities contexts has been scarce and exploratory. A relatively small body of the studies identified in this study review suggests more investigations in this setting is needed. Additionally, the scope of research on AR-supported individuals with intellectual disabilities should be further expanded. Other intellectual disability contexts other than autism deserve further investigation. Replicate studies in different intellectual disability contexts can further boost the validity of the research results.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All the researchers contributed to the paper.

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