Accessibility of Educational Games and Game-Based Approaches to People with Learning and Physical Disabilities: A Systematic Literature Review

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Abstract

Games and game-based approaches to education have become a part of most online and offline learning. They are thought to engage students and facilitate effective learning. These technologies, nonetheless, are often inaccessible to people with disabilities such as learning, auditory, visual, or cognitive impairments. In this paper, I ask: what is the state of the art of academic research on accessibility of game-based education to people with disabilities? What needs research and development to make sure no student is left behind? This literature study of research published between 2016 and 2020 (66 manuscripts) shows that researchers are directing relatively less attention towards motor and auditory accessibility. Research investigating the use of accessible solutions by people with and without disabilities simultaneously, in the same setting is needed. Emerging technology, such as AR & VR need attention and the range of stakeholders involved in this research needs expansion.

Keywords: educational games, gamification, serious games, learning difficulties, accessibility, disability.

1. Introduction

According to relatively recent estimates from the World Health Organization (WHO), there are approximately 1 billion individuals living with a disability globally, i.e., impairments that impact daily living (WHO, 2022). This number is increasing due to aging, accidents, wars, and many other causes. It is also a conservative estimate, given how people with disabilities often prefer not to disclose their disabilities - due to fears of social stigmatization and exclusion (Baltzar et al., 2023) - as well as due to individuals lacking formal diagnosis despite having a disability.

Disabilities differ across several categories: cognitive, developmental, neuropsychiatric, visual, auditory, motor, or mobility disabilities (WHO, 2022) that can create different access barriers. Ideally, educational tools, whether digital or physical, should be usable and accessible by a wide range of people with a wide range of abilities and disabilities. When educational tools are inaccessible, learners with disabilities are especially likely to experience learning barriers, exclusion, and potentially a lower quality of education compared to their peers.

The social model of disability has long emphasized that disability is socially constructed (Haegele & Hodge, 2016). Frameworks of technobabbleism show the exclusionary danger of ability/ableist assumptions that designers can implicitly have when developing technology (Shew, 2020). For example, if all schoolbooks were printed in large, clear fonts & colors from the get-go, and were available in brail, learners with visual disabilities would not experience a visual barrier to their use of schoolbooks. However, the assumption, which many designers can have, that these accessible designers are not needed, is what makes accessible designers rarely available or an afterthought.

The curb cut effect (Heydarian, 2020) has long demonstrated that accessible designs are the most usable designs and come to the benefit everyone in society. For example, accessibly printed schoolbooks can improve the reading experience of students, teachers, and parents with and without disabilities since large prints can be more comfortable to read. Regardless these needs and potential benefits from accessibility, it is rarely implemented and individuals with disabilities especially struggle in physical, digital, formal, and informal educational spaces, facilitated by game tools or not. This lack of accessibility can be due to many reasons, such as lack of resources, or overworked educational staff. In this paper, however, we ask: *what are we doing (as researchers) to examine and facilitate the accessibility of game-based education to everyone, especially people with disabilities? What is the state of the art of said research and what needs more attention?* The answers are provided through a systematic literature review.

Previous literature reviews examined the accessibility of separate game-based approaches to education, e.g., games in schools (Lynch et al., 2022), for people with cognitive impairments (Cinquin et al., 2019), or gamified tools for learners with ASD

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(Camargo et al., 2019) and cognitive disabilities (de Franca et al., 2019). Given that the lines between, for example gamification, serious game, or educational game can be blurry (Landers et al., 2018), the aim of this literature study is to expand on previous work by conducting a holistic, integrative literature review of research on several game-based approaches and disabilities simultaneously so as to integrate research lines, and provide overall conclusions on the field.

2. Methodology

To conduct the literature review, I followed a summarization of knowledge systematic literature review approach (Paré et al., 2015), in combination with thematic analysis (Grant & Booth, 2009). The combined approach allows for systematic analysis of the literature under study according to themes of interest. The literature search was performed in Jan 2021, starting with exploratory searches to determine possible keywords to be used. A timeframe of five years, 2016-2020 inclusive (and Jan 2021) was set to examine the most recent literature at the time of starting this research. This ensured a relatively manageable and recent pool of literature to review and allowed for a relatively reasonable publishing timeframe. Forward and backwards references were not included in the review for the same reasons. I used SCOPUS as the search database since it is a technology-oriented database where most accessibility journals and conference are indexed. This decision comes with limitations noted later in the manuscript. The employed search query was:

(TITLE-ABS-KEY (accessibility) AND TITLE-ABS-KEY (gam*)) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016))

The use of an asterisk " * " in the query is to account for all variations of the word "gam" such as: games, gamification, serious games, etc. While scholars can argue for differences between these approaches, they all are game-based approaches to education that often crosspollinate each other. Focusing on one approach (e.g., gamification and not serious games), would be reductionist especial given that the goal from this literature review is to develop a holistic picture of the literature, rather than analyze the details of as approach or another.

The search query yielded 1,156 initial results. These hits were screened according to the following criteria: the manuscript's 1) language was English, Arabic, or Finnish. Notable, however, no manuscripts in Finnish or Arabic were found. 2) focus was the accessibility of any game-based technology and a disability. 3) focus was education. 4) full text was available through university libraries, online repositories, or by contacting the authors of the manuscripts. The screening process is summarized in Figure 1.

Initial screening was based on the title and abstract of the reviewed papers. I was lenient during screening and decided on whether to finally include a paper or not based on full-text reads of the manuscripts, which I conducted next to extract variables of interest. Screening, coding, and analysis of the manuscripts were conducted by the sole author of this study. Initial findings were presented, without publishing, at university seminars and the feedback received refined the analysis and reporting process.

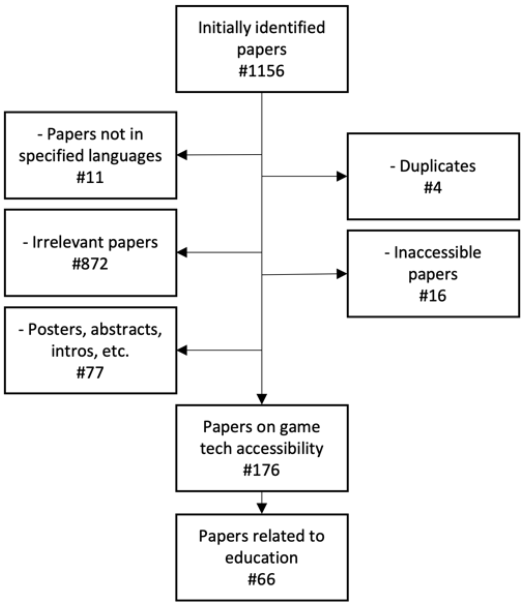


Fig. 1. Summary of the screening process

3. Findings

The selected 66 manuscripts were coded iteratively according to 25+ themes and variables of interest the full rendition of which is not possible within this manuscript. Coding is described in the coming sections along with key findings.

3.1. Educational game-based technology throughout the years

I started coding game-based approaches with a pre-defined set of codes that included digital, serious, mobile games, and gamification. Audio games emerged and were added to the codes. I did not impose a standardized definitions of these terms on the literature

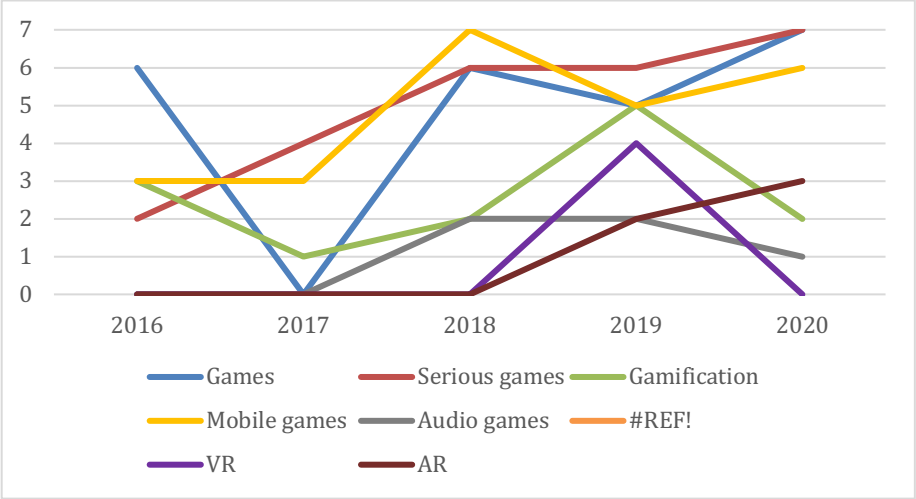
but coded them as they appeared. For example, if an author used the word "gamification", I classified the research as such. This is due to the general lack of standardized definitions for these socially constructed terms, blurring the boundaries between game-based approaches (Landers et al., 2018). Figure 2 presents the popularity of game-based approaches that appeared in the literature by year. Some research was classified under several approaches if the authors of said research used more than one term in describing it.

3.2. Platforms popularity over the years

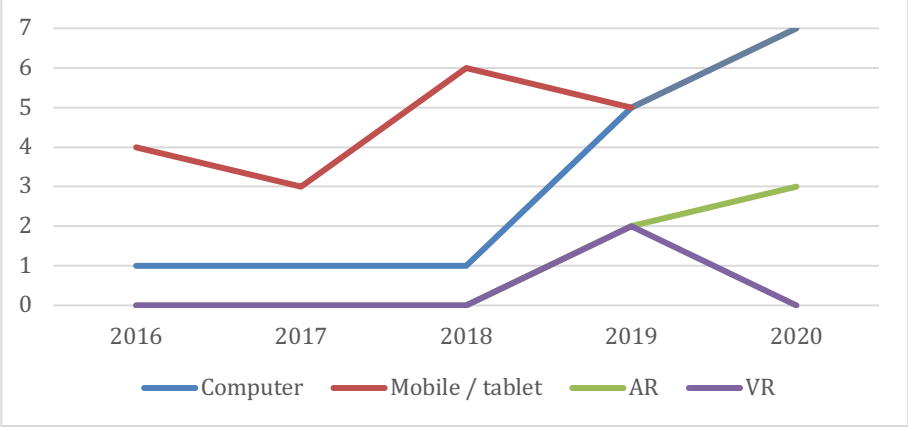
In terms of the platforms researched, I coded them with a predefined set of codes that included mobile, tablet, computer, AR, and VR. No additional codes emerged, however, the codes for mobile and tablet were merged as they appeared in conjunction with each other. The code computer was initially broken down to Windows and Mac but were then combined as authors of the reviewed literature did not always specify the operating system that they were examining. AR refers to virtual overlays on reality through mobile cameras. VR refers to immersive experiences through head-mounted display. Notably, these 2 terms were standardized in the literature and there were no cases of mismatched operationalizations. Figure 3 presents changes in platform popularity over the years.

3.3. Disabilities examined and stakeholders involved

I started coding disabilities with the pre-defined categories of visual, auditory, motor, and cognitive and emotional disabilities. Cognitive and emotional were merged as I struggled to find the find line distinguishing them based on the operationalizations found in the literature. Disabilities within a singular category are not the same, e.g., color blindness is different from low vision, or blindness although all three are visual disabilities. Hence, I coded sub-categories in an emergent fashion based on the specific terms or



¨Figure 2. Game-based terminologies / technologies appearing in the reviewed literature by year.



¨Figure 3. Platforms the accessibility pf which is researched/ by year.

Table 1 Disabilities and stakeholders in game-based education accessibility research

	Children (< 18)		Adults		Caregivers	Educators
	A*	B**	A*	B**		
	Visual disabilities					
Blind	**5 papers** (Correa et al., 2018; Kane et al., 2018; Lozano et al., 2018; Mikulowski, 2018; Neto et al., 2019, 2020)	**2 papers** (Neto et al., 2019, 2020)	**5 papers** (Andrade et al., 2019; Herskovitz et al., 2020; Leporini & Palmucci, 2018; Neto et al., 2019, 2020)	**2 papers** (Neto et al., 2019, 2020)	---	**1 paper** (Ulisses et al., 2018)
Low vision	**5 papers** (Kane et al., 2018; Neto et al., 2019, 2020; Othman et al., 2019; Regal et al., 2020)	**2 papers** (Neto et al., 2019, 2020)	**5 papers** (Andrade et al., 2019; Herskovitz et al., 2020; Neto et al., 2019, 2020; Regal et al., 2020)	**2 papers** (Neto et al., 2019, 2020)	---	**2 papers** (Othman et al., 2019; Regal et al., 2020)
Color blindness	**2 papers** (Neto et al., 2019, 2020)				---	---
	Auditory disabilities					
Deaf	**1 paper** (Beckett et al., 2016)		**1 paper** (Chebka & Essalmi, 2015)	**2 papers** (Alvarez-Robles et al., 2020; Chebka & Essalmi, 2015)	**1 paper** (Beckett et al., 2016)	**2 papers** (Beckett et al., 2016; Ulisses et al., 2018)
	Motor disabilities					
Cerebral Palsy	**2 papers** (Beckett et al., 2016; Kang et al., 2021)	**1 paper** (Beckett et al., 2016)	---	---	**2 papers** (Beckett et al., 2016; Kang et al., 2021)	**2 papers** (Beckett et al., 2016; Kang et al., 2021)
	Cognitive / emotional disabilities					
Autism spectrum	**2 papers** (Kamaruzaman et al., 2016; Kang et al., 2021)	---	---	---	**3 papers** (Kamaruzaman et al., 2016; Kang et al., 2021; Martins et al., 2020)	**2 papers** (Kamaruzaman et al., 2016; Kang et al., 2021)
Dyslexia	**1 paper** (T. Rocha et al., 2019)	---	---	---	---	---
Neurodiv ergence	---	---	**1 paper** (Gotfrid, 2016)	---		---
Down syndrome	**1 paper** (Vieira et al., 2018)	---	2 **papers** (Buzzi et al., 2016; Vieira et al., 2018)	---	**1 paper** (Vieira et al., 2018)	---
Learning difficult-ies	**2 papers** (El Hammoumi et al., 2018; T. Rocha et al., 2019)	**1 paper** (El Hammoumi et al., 2018)	---	---	---	---
* A = stakeholders with disabilities, ** B = stakeholders without disabilities						

conditions appearing in the literature. Table 1 presents the reviewed accessibility research by disability category and subcategory.

I also was interested in examining whether people with said disabilities directly participated in research and who else - in addition them -participated in. I coded stakeholders involved in the examined research starting with the least pre-defined set of codes: people with disabilities, people without disabilities, and educators. The first two categories were then broken down into the six categories of adults/adolescents/children with and without disabilities. Children were research participants younger than 18 years old or as otherwise determined by the authors of the manuscripts, depending on local

regulations. Participants 11-18 years old were sometimes referred to as adolescents. Caregivers were also added as a coding category and it included parents, guardians, personal assistants, and any other such non-medical, non-educational personnel who appeared in the research.

3.4. Research objectives of the literature

Table 2 presents a summary of the research objectives of the reviewed literature. I did not have initial codes for this theme, but the codes emerged through full reads of the manuscripts, with close attention to statements such as "the aim of this research is" or "this research contributes". Initially identified coding categories were further refined through a second iterations of coding. Some research appears in more than one category in table 2 if the authors of said research had more than one objective.

The most popular research objective in the reviewed literature was to design and evaluate an accessibility related artefact. A second significant portion of the research focused on proposing accessibility related design guidelines or design methods. Research also examined the accessibility of existing solutions, proposed designs without evaluating them, and a few conducted reviews of previous literature. Little research investigated the needs and perspectives of stakeholders with disabilities, co-design, and co-development with people with disabilities, accessibility strategies organically employed by participants with disabilities, nor the development process required to make accessible educational games.

4. Discussion and future directions

Technology popularity: I observed a lack of consensus amongst researchers in defining game-based technology as noted by previous literature reviews. Hence, I find that a narrowed focus on a singular terminology/approach does not necessarily create a resilient distinction between implementations, but merely limits the creative space and design traditions available to draw from. We find that examining game-based technology in a singular domain holistically can allow for crosspollination and application of, for example, findings on serious games accessibility to mobile games.

Table 2 Research objectives of the reviewed literature

Research objectives	Papers	Total
Design and evaluate a splution	(Bar-El et al., 2018; Buzzi et al., 2016; Chebka & Essalmi, 2015; Correa et al., 2018; De Biase et al., 2018; de Souza Sombrio et al., 2016; El Hammoumi et al., 2018; Fernández et al., 2019; Gotfrid, 2016; Herskovitz et al., 2020; Jaramillo-Alcázar et al., 2018a, 2018b, 2020; Kamaruzaman et al., 2016; Kane et al., 2018; Levy & Gandy, 2019; Lozano et al., 2018; Mikulowski, 2018; Neto et al., 2019, 2020; Othman et al., 2020; Regal et al., 2020; T. Rocha et al., 2019; Spyridonis et al., 2017; Spyridonis & Daylamani-Zad, 2019, 2021; Vieira et al., 2018)	27
Develop accessibility design guidelines / methods	(Alvarez-Robles et al., 2020; Baalsrud Hauge et al., 2018; Beckett et al., 2016; Bouaine et al., 2020; Escudeiro et al., n.d.; Garcez et al., 2020; Jaramillo-Alcázar, Luján-Mora, et al., 2017; Jaramillo-Alcázar, Salvador-Ullauri, et al., 2017; Jaramillo-Alcázar et al., 2020; Jaramillo-Alcázar & Luján-Mora, 2017, 2018; Kane et al., 2018; Leporini & Palmucci, 2018; Mahdi et al., 2020; Salvador-Ullauri, Acosta-Vargas, Gonzalez, et al., 2020; Smith & Abrams, 2019; Vieira et al., 2018; Westin & Dupire, 2016a)	18
Analyze the accessibility of existing solutions	(Bernardo et al., 2016; Coelho et al., n.d.; Herskovitz et al., 2020; Jaramillo-Alcázar, Luján-Mora, et al., 2017; Jaramillo-Alcázar, Salvador-Ullauri, et al., 2017; Jaramillo-Alcázar & Luján-Mora, 2017, 2018; Salvador-Ullauri, Acosta-Vargas, Gonzalez, et al., 2020; Salvador-Ullauri, Acosta-Vargas, & Luján-Mora, 2020b, 2020a; Torres-Carazo et al., 2016)	11
Design a solution without evaluation	(Baalsrud Hauge et al., 2018; Dudaković et al., 2018; Ferreira et al., 2016; Pereira et al., 2020; E. Rocha & Escudeiro, 2018; Salvador-Ullauri et al., 2017; Sombrio et al., 2016; Ulisses et al., 2018; Zulkifli et al., 2019)	9
Review literature	(Camargo et al., 2019; Cinquin et al., 2019; Coelho et al., n.d.; Salvador-Ullauri, Acosta-Vargas, & Luján-Mora, 2020b; Sousa, 2020; Valencia et al., 2019)	6
Investigate the needs/ experiences of people with disabilities	(Andrade et al., 2019; Cairns et al., 2019; Leporini & Palmucci, 2018; Martins et al., 2020; Othman et al., 2019)	5
Examine co-design and co-development	(Beckett et al., 2016; Kang et al., 2021; Regal et al., 2020)	3
Investigate the development process	(Muratet & Garbarini, 2020; Westin & Dupire, 2016b)	2

In this pool of literature, the terms "game", "serious games" and "mobile games" were the most popular. That may be due to how games are what this is all about. Mobile games are a natural extension of games and serious games are highly anchored in the education domain. The popularity of most terms, however, appears to fluctuate over the years except for serious games that maintains an up-curve. Gamification, in general, has been gaining in popularity in education (Aura et al., 2022; Landers et al., 2018), yet research on its accessibility appears to falter in popularity. Perhaps serious attention needs not be paid to this presumed dearth of literature as it is possible that a significant portion of the research was missed due to the limitations of this study. It can be argued that researchers are using the terms most popular at the time of publication to frame their research, hence the spike in gamification accessibility research when the term was popular. The down curve after could be just a reflection of the term going out of fashion as some researchers and practitioners became critical of it. But the accessibility research continues anyway under different labels. Alternatively, this dearth of literature can show that an emerging approach to game-based education is in need of accessibility research. The same fluctuation in VR research popularity, perhaps reflects how VR generally did not meet the hype that initially surrounded it and so educators may have come to pay less attention to it after the hype. Nonetheless, the dearth of VR accessibility research may indicate that the emergent use of VR education is in need of more attention.

Platform popularity: Figure 2 shows that in the reviewed literature, the accessibility of tablets and mobile phones is examined the most. This reflects the general popularity of these devices in society and with people with disabilities (Andrade et al., 2019). Tablets, especially occupy a sweet accessibility spot as they are portable but have big screens. Hence, people with visual disabilities have a bigger screen to work with, which they also can get close to as they want without a keyboard obstructing the way. Touch screens are not necessarily accessible to people with motor disabilities (Jaramillo-Alcázar, Salvador-Ullauri, et al., 2017) but tablets can often be connected to switch devices that allow access without touch if the app running on the tablet allows it. The bigger screen also makes it easier to press on bigger targets. In comparison, mobile phones especially have major accessibility challenges that are not always solvable (Jaramillo-Alcázar, Luján-Mora, et al., 2017; Jaramillo-Alcázar & Luján-Mora, 2017).

Emerging platforms, such as AR and VR, appear to have received limited research attention. This is especially problematic with the potential resurgence of AR and VR under the branding of the "metaverse" and after the release of Apple's Vision Pro. VR technologies can be inaccessible to people with vision impairment who, as a simplest example, may be using glasses that do not fit under most head-mounted displays on the market, let alone that the fidelity of VR experiences can be very low and can cause significant eye fatigue and cybersickness. VR can also be inaccessible to wheelchair users (Gerling et al., 2020) or learners with motor disabilities if the use of controllers is required. Notably, there is research on wheelchair accessible VR and haptics that can bypass these limitations (Gerling et al., 2016, 2020), however, I saw little of this research in the educational domain although many of the examined AR and VR technologies required body movements. AR often require learners with disabilities to use a small mobile phone on the go, which can be hard to work with as discussed (Hurd & Kurniawan, 2019). It can also subject them to increased dangers, relatively more than their peers without disabilities, if they are to roam outdoors while playing (Salen Tekinbaş, 2017). Understanding AR and VR games and the limits of reality can be challenging for people with some cognitive disabilities (Cinquin et al., 2019) but such games can also aid with learning social cues and emotional expressions (El Hammoumi et al., 2018).

Disabilities researched: In the reviewed literature, the range of disabilities investigated appears relatively limited, with some disabilities receiving more attention than others. For example, I found six sub-categories of cognitive disabilities investigated in the literature, but such nuanced investigation of other disabilities was limited. Perhaps this reflects how cognitive disabilities garner increased attention in education. By that token, it is important to note that vision or hearing disabilities, when not accommodated properly, can cause learners to fall behind and present with similar cognitive and behavioral limitations. Nuanced investigations of sub-categories of all disabilities are essential to ensure the development of the right solutions for all learners.

Stakeholders: Table 1 highlights that the reviewed research is heavily conducted directly with people with disabilities, as it should. Nonetheless, the lack of research with people without disabilities, using the same technologies in the same settings, can highlight a lack of consideration of the social, political and relational dynamics of disability (Kafer, 2013) that affect how game technology is used in social contexts (Hassan & Baltzar, 2022). When accessible solutions are evaluated only with people with disabilities, we may be developing technologies that are exclusionary to people without disabilities, indirectly creating divides between learners in the same classroom (Andrade et al., 2019). Similarly, without contrasting the experiences of people with and without disabilities, we hardly can identify disability unique experiences that may need research attention. Finally, such research with people with and

without disabilities can contribute solutions that promote social interaction and natural learning of social skills (Hassan & Baltzar, 2022; Ulisses et al., 2018).

In this pool of literature, little research was conducted with adults with motor and cognitive disabilities. Perhaps this reflects how learning can be especially difficult with a cognitive or a motor disability that impedes writing and understanding. Adults with such disabilities may have come to avoid any education more than necessary beyond basic education as children. This may be the case, but it does not necessarily explain why research has taken a resignation from these research directions. Perhaps this reflects anecdotal evidence showing that organizations for people with cognitive and motor disabilities are less organized and hence their members less reachable for research. It also appears that designers and developers were not present in this research. It is also important to involve more stakeholders in accessibility research. Able stakeholders (e.g., parents, teachers) should not speak for/ overshadow learners with disabilities. But the scope of accessibility research can increase through the inclusion of more stakeholders. For example, research with developers can help resolve key barriers to implementing accessibility more widely.

Research objectives: the objectives of the literature varied. The majority did not start with explicitly delineating the needs of learners with disabilities, which raises questions as to who or what determines researchers' understanding of these needs. This is also reflected by the lack of co-design and co-development research. Notably, I see little research examining and documenting ad-hoc solutions that educators and people with disabilities are anecdotally known to utilize in classroom to facilitate accessibility. I encourage the documentation of these solutions as it is likely that they are affordable and easy to implement. Much of the assistive technology used in gaming and education tend to fail these two criteria. I further encourage granting learners with disabilities agency in determining their needs through genuine, rather than token-istic research participation and co-design.

5. Limitations

This literature review is inherently limited by the query, keywords, and database employed in the literature search. Scopus is limited with its technology and academic focus. The search query was limited to publications within 2016 to 2020, inclusive (and Jan 2021). Even within these boundaries, it is inevitable that I failed to identify relevant research or made human errors in screening and coding. I encourage future researchers to investigate a larger timeframe, using more databases, different search strings, and in contexts other than education.

Conclusion

Game-based technologies have become a part of most learning contexts, online and offline. As with any technology, we must ensure that it is accessible to as many people, as possible. To examine the state of research on accessibility of game-based technologies in education, I conducted a literature review (66 manuscripts). The findings show disparities in research attention directed towards different disability categories, sub-categories, stakeholders, and game-based approaches. More research is needed with adults with motor and cognitive disabilities, disabilities sub-categories, emerging technologies such as AR, VR, and gamification.

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