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# The Potential of Serious Games to Foster Learning among Children and Adolescents with Disabilities: A Systematic Review

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# THE POTENTIAL OF SERIOUS GAMES TO FOSTER LEARNING AMONG CHILDREN AND ADOLESCENTS WITH DISABILITIES: A SYSTEMATIC REVIEW

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**Abstract:** *Serious Games for children and adolescents with disabilities can enhance their learning and respond to their needs in an inclusive educational setting. The aim of this systematic review is to analyze the potential of Serious Games for children and young people with disabilities, thereby providing an overview of effective Serious Games for schools and practitioners in the field of inclusive education. For this purpose, a systematic review of empirical literature found in the database Education Resources Information Centre (ERIC) was conducted, applying a qualitative content analysis. Findings from the 21 reviewed quantitative and qualitative studies indicate that Serious Games provide effective support for achieving learning objectives in certain school subjects and facilitate optimal conditions for learning. We found that Serious Games have strong potential and can make an important contribution to the inclusion of children and adolescents with disabilities in school.*

**Keywords:** *serious games, children and adolescents with disabilities, inclusion, systematic review*

## Introduction

Worldwide, education systems aim to provide an effective education for children, adolescents and adults based on Article 26.1. of the Universal Declaration of Human Rights "Everyone has the right to education. […]" (United Nations, 1948, p. 6). Since the adoption of the UN-Convention on the Rights of Persons with Disabilities (CRPD), which has been ratified by 182 states worldwide, inclusion has entered the spotlight of educational discourse. Consequently, countries have shown increased interest in the idea and practice of inclusive education (UNESCO, 2008; Makarova, 2017). Beyond general human rights, which describe the recognition of the dignity and equal and inalienable rights of all members of the human community as the basis of freedom, justice and peace in the world (United Nations, 1948), all signing states committed themselves to providing effective and individualized support measures in their educational system. The aim is to maximize the academic and social development of all people, consequently enabling their full inclusion in society (OHCHR, 2020).

According to Article 24 of the CRPD all "States Parties recognize the right of persons with disabilities to education" (OHCHR, 2020). The signatory parties have shown their commitment to ensuring that all people, whether with disabilities or not, have a right to equal educational opportunities without discrimination as well as "full development of [their] potential and sense of

dignity and self-worth" (OHCHR, 2020). To consummate these rights, countries must ensure that all necessary steps are taken to guarantee all people full access to equal education in an inclusive education system (OHCHR, 2020). Due to these global developments, educational systems of those countries that have ratified the CRPD are challenged to implement reforms that foster inclusive education, and teachers are challenged to find ways to individually address the different needs of children in their classes (Kraglund-Gauthier, Young, & Kell, 2014).

Following these developments, an education system of the future needs to be fully inclusive. To reach this goal of full inclusion at the school level, innovative didactic methods are needed that meet all learners' needs. One possibility is the use of *Serious Games*, which have been specifically developed to support the learning of specific target groups (Breitlauch, 2012). A range of *Serious Games* has been developed recently, aiming *to foster the learning of young people with disabilities*. The present article focuses on the potential of these *Serious Games*. It presents findings of the systematic literature review of quantitative and qualitative research on *Serious Games* and shows to what extent *Serious Games* as specially designed games can support the learning of children and adolescents with disabilities to promote inclusive education.

## What is a Disability?

As stated by the World Health Organization (WHO), "disability is complex, dynamic, multidimensional, and contested [and it is considered as an] umbrella term for impairments, activity limitations and participation restrictions, referring to the negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors)" (WHO, 2011, p. 3). A disability may relate to three different areas: 1) Problems in body function or alterations in body structure (impairments), 2) difficulties in executing activities (activity limitations), and 3) problems with involvement in any area of life (participation restrictions) (WHO, 2011, p. 5).

However, from the perspective of the Preamble to the CRPD, disability does not represent an attribute of a person. Instead, disability "results from the interaction between persons with impairments and attitudinal and environmental barriers that hinder their full and effective participation in society on an equal basis with others" (WHO, 2011, p. 4). In an educational context, disability is not an individual condition, but is a result of educational systems' failure to accommodate the needs of children and adolescents with different needs, which turns an individual's characteristic into a handicap for learning in mainstream education. Consequently, the social model of disability distinguishes "between a biological, underlying condition or way of being […] and disability rooted substantially in inaccessible social and political infrastructures […]" (Kapp, Gillespie-Lynch, Sherman, & Hutman, 2012, p. 60).

Thus, in order to enable equal educational opportunities of all children and adolescents with or without different needs schools must promote inclusive education.

## What is Inclusive Education?

Inclusive education refers to an approach and view that urges schools "to welcome and value everyone, regardless of differences" (Renzaglia, Karvonen, Drasgow, & Stoxen, 2003, p. 140). A

vivid explanation of inclusive education is provided by the policy recommendations of the Australian Government Department of Education:

> Inclusive education involves embracing human diversity and welcoming all children and adults as equal members of an educational community. This involves valuing and supporting the full participation of all people together within mainstream educational settings. Inclusive education requires recognizing and upholding the rights of all children and adults and understanding human diversity as a rich resource and an everyday part of all human environments and interactions. Inclusive education is an approach to education free from discriminatory beliefs, attitudes and practices, including free from ableism. Inclusive education requires putting inclusive values into action to ensure all children and adults belong, participate and flourish (Cologon, 2013, p. 6).

Parallels to Cologon's (2013) definition that inclusive education is free from discriminatory beliefs, attitudes, and practices while ensuring that all people can belong, participate, and flourish can also be seen in UNESCO's terminology of inclusive education. Specifically, UNESCO describes inclusion in an educational context as an evolving concept that involves the transformation of schools and other centers of learning to accommodate all learners. An inclusive education involves all students independent of their personal characteristics or abilities (UNESCO, 2008). In an inclusive education concept, all barriers for participation of every learner must be removed. "It presumes that the aim of inclusive education is to eliminate social exclusion resulting from attitudes and responses to diversity in race, social class, ethnicity, religion, gender and ability" (UNESCO, 2008, p. 5). In that context, a vast repertoire of learning strategies to respond precisely to learners' diversities is required in order to respond to the expectations and needs of heterogeneous students to provide effective learning opportunities (UNESCO, 2008).

If inclusive education is being implemented worldwide, as mentioned above, schools' student bodies will become increasingly heterogeneous. This heterogeneity brings new challenges to education. Students bring with them very different cognitive and physical prerequisites, which in turn lead to increased demands on the teachers. Therefore, didactic methods are needed that provide learning gains to all students. One possible approach to supporting a heterogeneous student body with a wide range of different needs in school is the use of certain *Serious Games* in an inclusive educational setting.

### What is a *Serious Game*?

A precise definition of the term *Serious Games* is complex because the term *"Serious Games"* covers a wide range of attributes. First, a Serious Game represents a series of activities in which one or more players are involved. As a game, it is voluntary and enjoyable. Furthermore, it involves rules, specific goals, and ways to achieve these goals through moves or actions (Caillois, 1961; Dempsey, Haynes, Lucassen, & Casey, 2002). *Serious Games* are, moreover, usually played on a computer and create an entertaining mental contest. Despite providing entertainment, the primary purpose of *Serious Games* is learning rather than entertaining (Zyda, 2005; Klopfer, Osterweil, & Salen, 2009; Gotterbarn, 2013). *Serious Games* are driven by educational goals of fostering learning in a variety of domains (Zyda, 2005). Moreover, they also aim to support attitude and behavior change, such

as discouraging smoking or encouraging recycling (Bogost, 2007; Boyle, Connolly, & Hainey, 2011).

*Serious Games* are generally developed by experts explicitly for one specific target group and its needs in order to enable effective learning. The integration of concrete learning objectives and the consideration of media-didactic models are of great importance in the development of *Serious Games* (Breitlauch, 2012).

## ***Serious Games*** **in Education**

*Serious Games* are developed for specific target groups (Breitlauch, 2012), and numerous *Serious Games* have been developed to support young people with disabilities. This suggests that they have a great learning potential for children and people with disabilities and thus can enrich inclusive education.

Recent studies show that *Serious Games* have been used for different purposes in schools all over the world: to raise learning motivation and also to foster students' language and mathematical skills, to help students learn about history, ethics or science (Wastiau, Kearney, & Van den Berghe, 2009; Vu & Feinstein, 2007), to reduce school phobia (Wastiau et al., 2009), or to sensitize students to dangers on the Internet (Iten & Petko, 2016). The potential of *Serious Games* is also constantly exploited in professional training (Pourabdollahian, Taisch, & Kerga, 2012; Cain & Piascik, 2015; Le Compte, Elizondo, & Watson, 2015; Wilson, Calongne, & Henderson, 2015), especially in commercially oriented companies (Dicheva, Dichev, Agre, & Angelova, 2015). Research also shows that certain *Serious Games* are used for both addiction and disease prevention (Willmott, Taylor, Russell-Bennett, & Drennan, 2019; Winksell, Sabben, Akelo, Ondeng'e, Odero, & Mudhune, 2019).

*Serious Games* aim to convey learning content in a playful way. They create playful challenges that lead to increased learning motivation (Breitlauch, 2012), a key factor in current pedagogical research. To increase learning motivation, the following requirements must be met: first, playing the Serious Game should be fun. Therefore, it requires an appealing mode of play adapted to the target group. Second, the game needs to be adapted to both the explicit needs and the abilities of the target group. Third, the learners should be made aware that they are not playing the game just for fun, but also for learning (Martens, Diener, & Malo, 2008; Derbali & Frasson, 2012; Breitlauch, 2012; Erhel & Jamet, 2013; Chen & Law, 2016; Iten & Petko, 2016; Yang, Chun, & Chiag, 2018). Many researchers assume that the increase in motivation triggered by learning with *Serious Games* supports the learners in acquiring school or academic skills and expertise (Boyle et al., 2011; Chu & Chang, 2013; Cheng, Lin, She, & Kuo, 2017; Vu & Feinstein, 2017; Yang et al., 2018). However, findings on whether increased motivation leads to better learning outcomes are inconclusive. A meta-analysis of the effects of computer gaming and interactive simulations in schools confirms that increased motivation can improve learning outcomes (Vogel, Vogel, Cannon-Bowers, Bowers, Muse, & Wright, 2006). In a subsequent meta-analysis, the literature about cognitive and motivational effects of *Serious Games* was reviewed again. While *Serious Games* were found to be more effective in terms of learning and retention, they were not more motivating than conventional teaching methods (Wouters, Van Nimwegen, Van Oostendorp, & Van Der Spek, 2013). However, the two more recent meta-analyses indicate that learning with *Serious Games* has a

positive impact on learning outcomes in terms of extending expertise in science (Zhonggen, 2019; Riopel et al., 2020). Zhonggen (2019) found that both students and teachers were more motivated when using *Serious Games* for science learning.

Although, it is unclear whether using *Serious Games* in educational contexts leads to increased learning motivation, they have the potential to foster the acquisition of certain types of expertise or skills. For example, *Serious Games* have been successfully integrated in educational settings to improve mathematics skills such as analyzing statistics (Wronowski et al., 2020) at higher educational levels or to promote younger learners' calculating competences with fractions (Cyr, Charland, Riopel, & Bruyère, 2019) or arithmetic polynomial operations (Barros, Carvalho, & Salgueiro, 2019). Additionally, *Serious Games* have been used for language learning, for instance to help students learn vocabulary effectively and sustainably (Abrams & Walsh, 2014; Alyaz, Spaniel-Weise, & Gursoy, 2017). Regarding Science Learning, the use of *Serious Games* leads to major gains in learning expertise (Riopel et al., 2020; Tsai & Tsai, 2020), as well as knowledge retention (Riopel et al., 2020).

However, *Serious Games* have not only been effectively integrated into an educational context to foster the acquisition of specific expertise, but also to help students individually, e.g., by reducing individual barriers. For example, learning with *Serious Games* has helped young learners who suffered from didaskaleinophobia (fear of going to school) to collaborate with other students as part of a group (Wastiau et al., 2009). Furthermore, they have also been used to support students with poor organization skills and lack of discipline to develop leadership skills (Wastiau et al., 2009). Moreover, *Serious Games* have been effectively used in schools to change students' behavior in bullying situations. Even though the serious game did not lead to active support for the victims in bullying situations, it transformed students' passive non-helping attitude to an internalized conviction that they should help the victim (Kolić-Vehovec, Smojver-Ažić, Martinac Dorčić, & Rončević Zubković, 2020).

## Focus of the Current Study

To summarize the theoretical and empirical framework of the current study, it can be concluded that *Serious Games* represent an alternative to conventional teaching methods, and they have a positive impact on learning. Research on *Serious Games* has demonstrated that *Serious Games* they can be used effectively in school to foster learners' acquisition of expertise, to increase their motivation to learn, and to promote a positive change in behavior. The present systematic literature review explores the potential of *Serious Games* to foster learning for a specific group of learners; namely, children and adolescents with disabilities.

Research on *Serious Games* that effectively promote the learning of people with disabilities has already been conducted, but on a modest scale. There are three reviews, the findings of which are used again in the course of the present study. In the first review, Lämsä, Hämäläinen, Aro, Koskimaa, and Äyrämö (2018), the potential of *Serious Games* for people with learning disabilities was discussed. The authors found that certain *Serious Games* effectively support people with learning disabilities in the acquisition of language and mathematics skills. The second review by Tsikinas and Xinogalos (2019) focused on studies on the effects of *Serious Games* for people with intellectual disabilities or autism spectrum disorders. They emphasized an improvement of social,

communication, and cognitive skills through playing *Serious Games*. Finally, in the third review Stančin, Hoić-Božić, and Skočić-Mihić (2020) found that *Serious Games* can have a positive impact on children and adolescents with intellectual learning disabilities in the field of mathematics.

In order to gain a more comprehensive view of *Serious Games* in an inclusive education system, the current study provides a systematic review of research on *Serious Games* developed for people with disabilities to promote their learning in school. In contrast to existing reviews, our focus goes beyond specific school subjects and also includes the support of conditions and behavior that fosters learning. Hence, this study integrates the findings of previous research by addressing the following question: Which *Serious Games* effectively support children and adolescents with disabilities learning in an inclusive education context?

## Methods

### *Content Analysis*

This study analyses the potential of *Serious Games* for children and adolescents with disabilities, applying the method of qualitative content analysis, a method that allows a systematic means of categorizing and summarizing issues of interest addressed in different studies (Mayring & Fenzl, 2014). The qualitative content analysis was carried out using the MaxQDA software package. A category system was created for this study; specifically, deductively given categories were applied and further enriched by inductive category application. All coding was performed by the first author.

### *Definition of Search Terms*

Our search aimed to capture two concepts: *Serious Games* and *Disability*.

*Serious Games* appear in digital format and are played on a computer device. Therefore, the search terms *Serious Game*, *Digital Game* and *Computer Game* and different combinations (e.g., *Digital Serious Game*) were used in the systematic literature search. However, the term *Game-based Learning* was excluded for the literature search because it forms a sub-category of *Serious Games* (Hainey, Connolly, Stansfield, & Boyle, 2011). Although, the term *Game-based Learning* is sometimes used synonymously with *Serious Game*, it does not describe a specific game but rather a *learning approach* in which learning is effectively accomplished by means of a learning game (Boyle et al., 2011). We therefore did not include *Game-based Learning* as a search term.

Disability is defined by the WHO "as an umbrella term for impairments, activity limitations and participation restrictions. Disability is the interaction between individuals with a health condition (e.g., cerebral palsy, Down syndrome and depression) and personal and environmental factors" (WHO, 2011, p. 4). Due to the diversity of the term disability, our review included both physical impairment (problems in body function or alterations in body structure) as well as cognitive/mental impairment which complicate everyday life (e.g., learning, participation, executing activities, employment, etc.). To ensure that the systematic search initially covers as many forms of disability as possible, the keywords *disability*, *disabled* and *disabilities* were used as search terms.

*Source Selection*

To conduct a review of qualitative and quantitative empirical research in the field of educational science, the database *Education Resources Information Centre (ERIC)* was selected for the systematic search. ERIC is the world's largest education database and applies quality criteria for selecting articles for inclusion in its database (completeness, integrity, substantive merit, utility/importance, education research). Articles eligible for review (a) were written in the English language and (b) not published before January 2016. In order to take rapid technological change into account, only articles from the past five years were included in this systematic review. Accordingly, January 2016 to September 2020 was selected as the time period for the systematic search. Furthermore, to ensure the quality of research chosen for analysis, (c) only articles published in peer-reviewed journals were considered. Additional inclusion criteria for the systematic search were that (d) articles or papers included qualitative or quantitative research emphasizing certain *Serious Games* especially developed for children or adolescents (4 until 19 years) with disabilities as well as indicating effective learning with *Serious Games*. Articles that did not meet the criteria were excluded from the review.

In the first step, the database ERIC was searched with the keywords *computer game*, *digital game*, *serious game*, *serious computer game*, *computer serious game*, *digital serious game* and *serious digital game* in combination with the keywords *disability*, *disabled* and *disabilities*. The search yielded 801 hits. Next, the 801 articles titles and descriptors/subject headings were screened for the keywords *computer game*, *digital game* and *serious game* and similar terms that correspond to the taxonomy of *Serious Games* as well as terms that could represent the name of a certain Serious Game. After screening titles and descriptors/subject headings, 35 articles and 6 dissertations were selected for further screening. Subsequently, the abstracts of the total 41 remaining articles or papers were screened according to the following criteria: The article or paper emphasizes or provides evidence that (a) certain *Serious Games* are being addressed (b) especially developed for children or adolescents with physical and/or cognitive impairment (c) to support their learning. Further, the article or paper had to refer to (d) *Serious Games* for children or adolescents (4 until 19 years) with disabilities. Finally, the article or paper had to underline how *Serious Games* support school-relevant learning or skill acquisition, i.e. it should include (e) quantitative or qualitative research. After abstract screening, 21 articles matching the criteria were selected for the systematic review.

In a second step, the 21 chosen articles were coded according to a refined category system with MaxQDA software (see Table 1, in the Appendix). This category system was deductively developed based on the theoretical and empirical framework of the study and was then inductively enriched through the coding process. In order to examine the studies' background, the methods sections of the articles were coded to describe the samples, including the country where the research took place. The methods sections of articles were also coded to describe the methodological design of the study (e.g., sample, construct, data analysis method). The result sections of the articles were coded for text segments that reported significant and non-significant effects of *Serious Games*, from which the learning potential for children and adolescents with disabilities can be derived.

In the third step, using the MaxQDA overview of retrieved segments (see Table 1), the distribution of the codes for the categories Serious Game and Research Approach was examined. The 21

reviewed articles reported learning effects of 26 different *Serious Games* for children or adolescents with disabilities. Of the total 21 articles, 10 present findings on how *Serious Games* can foster conditions for effective learning, and 15 articles present *Serious Games* that promote the acquisition of expertise or skills in certain school subjects: in mathematics (7 articles), in language learning (7 articles), and in Science, Technology, Engineering, and Mathematics (STEM) (1 article). Furthermore, 17 articles refer to *Serious Games* specially designed for children (four up to 12 years) with disabilities, whereas one refers to adolescents with disabilities (13 until 19 years) and three emphasized both children and adolescents with disabilities. Moreover, 19 articles reported *Serious Games* for children or adolescents with cognitive disabilities, while two were related to *Serious Games* for children or adolescents with physical disabilities. Twelve articles presented quantitative research on *Serious Games*' effectiveness, while five presented qualitative research, and one reported findings from mixed-methods research (quantitative and qualitative). Finally, three of the selected articles were literature reviews. The first review focused on the effects of *Serious Games* on people with intellectual disabilities or autism spectrum disorders. The second review focused on *Serious Games* that enhance the basic reading and mathematics skills of people with different learning disabilities. Finally, the third review focused on the use of certain *Serious Games* for students with intellectual disabilities. Of the 26 *Serious Games* reviewed, only six had been included in the three existing literature reviews. The remaining 20 *Serious Games* thus represent a considerable extension of knowledge over the three previous reviews.

*Data Analysis*

Using the MaxQDA coding query tool, intersections of the target code categories Serious Game and Research Approach were extracted from the results sections across 21 selected articles to analyze the effects of specific *Serious Games*. Each extracted text segment contained references to the effects in relation to the learning goals of the *Serious Games*, which were specially developed for children or adolescents with disabilities. The text segments varied in length, where the minimum text segment consisted of a few words and the maximum text segment of an entire paragraph. The content of the extracted text segments was analyzed and interpreted according to the category system.

*Background of Analyzed Studies*

Of the 21 reviewed articles, the three previous literature reviews were from Finland, Greece and Croatia. They reported on effective use of *Serious Games* for children or adolescents with disabilities in Brazil, Canada, the United States, Algeria, Finland, France, and the United Kingdom. The 18 additional studies included in the present review were conducted in Europe (Cyprus, Croatia, Finland, France, Ireland, Italy, Macedonia, Poland, United Kingdom), Asia (Iran and the Asia-Pacific region), Africa (Algeria, Morocco), America (United States of America), and Australia. Sample size varied: of the selected studies, five were conducted with fewer than 10 participants, four studies with 10-20 participants, four studies included 30-40 participants, another two studies were conducted with 40-50 participants. Finally, the largest number of participants were found in a study with 60 participants.

## Results

In what follows, the results of this study regarding the effectiveness of *Serious Games* for children and adolescents with disabilities will be presented and summarized in an overview (see Table 2, in the Appendix). For this purpose, the *Serious Games* presented in the selected articles and papers were divided into subgroups according to their application. The following subgroups were created: Support for Learning, STEM-Learning, and Language-Learning.

### *Effective Support for Learning through Serious Games*

*Serious Games* may support learning through processes such as increasing motivation to learn, increasing self-efficacy, reducing anxiety, improving memory performance, or encouraging behavior conducive to learning.

A virtual reality storytelling tool, called *Wildcard* was developed by Gelsomini, Garzotto, Montesano, and Occhiuto (2016). The article describes a system that uses wearable smart phones as enabling technology (e.g., with Google Cardboard) to support children with intellectual and developmental disorders (IDD) in creating, personalizing, and realizing interactive stories. By using the Serious Game *Story360* in combination with the *Wildcard* system, the children follow an avatar with their eyes to proceed in the narration, resulting in an immersive story where the user determines the tale's advancement. If the playing child stops looking at the avatar, it ultimately stops moving and the storytelling will be paused. To analyze its effectiveness, the researchers observed eight individual therapeutic sessions, in which five children used the *Wildcard* system with *Story360*. Of the five participants, two children had minor forms of IDD, two were medium-functioning autistic children, and one child had a psychomotor impairment. First findings from behavioral observations of five children playing the game showed that children accepted wearing the device, interacted with the virtual world, and increasingly followed the avatar with their eyes, which the authors interpreted as increased attention. Therapists further observed that the children enjoyed playing the game (Gelsomini et al., 2016).

The virtual environment also plays an important role with the six *Serious Games Letters' Store, Twins, Guess the Missing, Match-it-up, Dragon's Words,* and *Sentences*. They were developed for children with either dyslexia or dysgraphia to support their reading and writing skills in the Arabic language (El Kah & Lakhouaja, 2018). Besides fostering language skills, the researchers intended to provide the children with a safe environment in which to face their deficits and learning weakness through playing. In a quasi-experimental study, 46 primary school pupils were divided into either a treatment or a control group to measure the learning achievements of the children before and after the use of this set of games. The authors found that playing the *Serious Games* led to a significant ($p<.05$) improvement in reading and spelling skills. The authors assume that the effects on language acquisition arose because the *Serious Games* had a positive effect on children's short-term and visual memory performance and the participants showed high motivation values while playing the *Serious Games* (El Kah & Lakhouaja, 2018).

Khamparia, Pandey, and Mishra (2020) integrated the Serious Game *SmartLearn* in an elementary school in an Asia-Pacific region to enhance the learning performance of children with neuromuscular disabilities in basic science-related courses. *SmartLearn* includes different puzzle

tasks, in which game fragments have to be recognized and moved in the correct order to suitable locations. It was integrated into the classroom to promote children's motivation to learn, reduce anxiety as well as cognitive stress, and to strengthen self-efficacy. The researchers conducted a quasi-experimental study including 30 children with neuromuscular disabilities who were allocated to either a treatment or control group, in order to analyze the effectiveness of *SmartLearn*. The results showed that children who played the Serious Game *SmartLearn* showed significantly ($p$<.05) better output in terms of reducing their anxiety level, increasing learning motivation, and enhancing self-efficacy (Khamparia et al., 2020).

Furthermore, the two Kinect-based *Serious Games Unboxit* and *Melody tree* were developed to improve visual memory and visual-spatial working memory as well as enhancing children's attention, concentration and processing speed (Kosmas, Ioannou, & Retalis, 2018). *Unboxit* is a typical flash cards game. Players need to focus on finding pairs of objects that are hidden in boxes. To select an object, the player holds his/her hand motionless for a few seconds directly over the object. *Melody tree* is a Serious Game focused on sounds. In this game, the playing children focus on finding pairs of sounds that are hidden in melody keys. Again, to select an object, a player places her/his hand over the object and keeps it motionless for a few seconds (Kosmas et al., 2018). The two *Serious Games* were tested over a five-month period with 31 elementary school children with cognitive disabilities. A mixed methods design was chosen to evaluate the *Serious Games*' effectiveness, where children completed memory tests before and after the intervention period, and teachers were asked to note their observations and reflections upon each game session. The results of the study showed that the two *Serious Games* led to significant ($p$<.05) increases in self-confidence, joy, enthusiasm, calmness, engagement, and motivation to participate (Kosmas et al., 2018).

Three *Serious Games Barrage Task App*, *Vocabulary App,* and *Imitation App* were developed to increase the academic skills of children with autism spectrum disorders (ASDs) and/or other developmental disabilities. The *Serious Games*' specific goals were to increase players' vocabulary expertise as well as to foster their ability to focus and imitate (Esposito et al., 2017). When playing *Barrage Task App*, children were asked to tap different stimuli (e.g., fish or farm animals). In order not to miss any animal, players needed to avoid distractions during the playing period. The Serious Game also offered multiple choices about what scenery the child preferred. The second app, *Vocabulary App*, dealt with the identification of words initiated by certain sounds. The word searched for was represented by a sound and the players had to select the matching word from a field of at least three images. Finally, the *Imitation App*, was characterized by the imitation of actions with objects (e.g., moving a toy car) and the subsequent answering of questions (e.g., "Where is the car?"). To answer the question, players must tap on the object the *Serious Game* asks for (Esposito et al., 2017). The quantitative study investigating effects of the three games included 15 children with an average age of four years and lasted 4 weeks. An increase in attention and improved receptive identification of objects was demonstrated *Serious Games*; however, these effects remained statistically insignificant. During the sessions, the participating children showed considerable motivation (Esposito et al., 2017).

Another Serious Game for children with autism is *Ucime Emocii* (Learning Emotions). Vasilevska Petrovska and Trajkovski (2019) tested whether *Ucime Emocii* (Learning Emotions) improves the

recognition and understanding of facial expressions of children with autism. For this purpose, the web application *Ucime Emocii* includes four basic emotions (sadness, happiness, fear, and anger) explored through photographs, pictograms and illustrations of social context. Players learn to recognize emotions through puzzle-like tasks in which images with facial expressions must be assigned to the terms "sadness", "happiness", "fear", and "anger" (Vasilevska Petrovska & Trajkovski, 2019). In a quasi-experimental study, 32 children and adolescents aged 7 to15 years with and without autism spectrum conditions were allocated to either the treatment or the control group to investigate the effectiveness of *Ucime Emocii*. It was found that the participants in the treatment group scored significantly ($p$<.001) higher than their control equivalents in the Emotion Comprehension Test measuring emotion recognition from facial expressions (i.e., photographs) and from graphical representations of facial expressions (i.e., pictograms). However, emotion comprehension impairments were present regardless of intellectual functioning among the autistic participants. The authors concluded that intellectual ability may act as a moderator in the learning process (Vasilevska Petrovska & Trajkovski, 2019).

Additionally, the *Serious Games MEGA BLOKS®* and *MEDIUS* were developed for children and adolescents with autism spectrum disorders to foster cognitive stimulation and interactive gaming. While playing the 3D graphics application *MEGA BLOKS®* children need to move and place colorful blocks in the correct position. On a screen the children are shown two-dimensional shapes. Using an interactive game board, they then recreate this figure with game pieces. If the form is correctly reproduced, the player reaches the next level (Barajas, Al Osman, & Shirmohammadi, 2017). The results of a quasi-experimental study, including nine children and adolescents aged 6 to 15 years showed that *MEGA BLOKS®* led to a significant improvement of autistic children's social interaction ($p$=.005) and collaborative play time ($p$=0.004), but evidence of better performance based on the increased number of completed minigames remained insignificant). *MEDIUS* teaches autistic children different geometric shapes and supports them in differentiating between forms and colors (Daouadji Amina & Fatima, 2018). In a behavioral observation with ten children between 5 and 13 years, the researchers used a computer system with a camera that detected if players turned their head left or right, up or down. The computer system would then consider that the child was no longer concentrating and would automatically stop the counter. The authors concluded that MEDIUS increased the amount of time children and adolescents with autism spectrum disorders spent paying attention and concentrating. The Serious Game helped them to stay focused until the end of a learning session. (Daouadji Amina & Fatima, 2018). Both *Serious Games* were reviewed by Tsikinas and Xinogalos (2019). The authors concluded that *MEGA BLOKS®* improves autistic children's social, conceptual, and practical skills, while *MEDIUS* fosters autistic children's imitational and joint attention skills (Tsikinas & Xinogalos, 2019)

With *Hear the Invisible* and *Follow the Rabbit* two *Serious Games* for blind children and adolescents were developed. Both *Serious Games* are based on interactive sonification techniques to foster blind children's perception of shapes and colors (Radecki, Bujacz, Skulimowski, & Strumiłło, 2020). At *Hear the Invisible* a player focuses on discovering the content of an image through its sonic analysis and measuring the accuracy of its subsequent reconstruction. Players reconstruct the image structure as accurately as possible and in the shortest possible time (Radecki et al., 2020). In *Follow the Rabbit*, a single player needs to track a colorful rabbit that runs along a path representing a

geometric shape. The rabbit starts moving very slowly at the start of the game, but accelerates when it is successfully tracked. In accordance with a color sonification scheme (converting color information into sound), various sounds are played, depending on how far away the player is from the rabbit and the direction the player is moving in. Players are allowed to occasionally lose the rabbit, but the game ends after losing track of the rabbit for a certain period (Radecki et al., 2020). In a behavioral observation, the researchers used interactive sonification techniques to create sounds around the children. The sounds that the children perceived formed a geometric figure, which the children had to recognize and reconstruct. Although no clear effects resulted from the observation, a high degree of playfulness and motivation was observed among the six participating children and adolescents aged between 10 and 16 years. Moreover, the authors point out that most of the participants were able to correctly analyze and recognize the test images showing shapes (Radecki et al., 2020).

Finally, *Serious Games* can not only increase learning conditions, but also improve specific behavior that is important in the school context. This is also true for the Serious Game *MEBook*. It comprises social narrative and gaming. The social narrative part is an animated short story that describes greeting behavior: saying "hello" when arriving somewhere and "goodbye" when leaving a place. For both parts "making eye contact" is of great relevance. The game section occurs after the narrative part, providing the chance to practice what has been taught. The game part uses Microsoft Kinect hardware that allows players to control the game using body movements alone instead of traditional gamepads. The Microsoft Kinect hardware detects when the desired greeting, waving in this case, is performed in response to an animated character's greeting wave or in initiation when an animated character appears on the screen (Uzuegbunam, Wong, Cheung, & Ruble, 2015). In behavioral observation of three children aged 7 to 12 years, therapists recorded the number of the autistic children's responses to another person's greetings (such as vocalizing hi/bye, looking at the person, and waving) after the intervention with the *MEBook* Serious Game. The therapists concluded that *MEBook* improved the social skills of children with autism spectrum disorders (Uzuegbunam et al., 2015).

*Effective STEM-subject learning with Serious Games*

In addition to the effective acquisition of learning conditions, *Serious Games* also support the acquisition of content knowledge in particular subjects such as STEM.

The Serious Game *SmartLearn*, designed to enhance the learning performance of children with neuromuscular disabilities in basic science-related courses led to positive effects in terms of acquisition of several learning conditions (Khamparia et al., 2020). A quasi-experimental study including 30 children with neuromuscular disabilities on an elementary school level showed that overall science learning achievements were made to a significant ($p$=.03) extent by participants in the treatment group (Khamparia et al., 2020).

With regards to Mathematics Learning, *Dr Kawashima's Brain Training* was evaluated for its effectiveness. Researchers found that the Serious Game had a positive effect on mathematics skills learning and students' interest in mathematics (Main, O'Rourke, Morris, & Dunjey, 2016). In a further evaluation, the researchers conducted an intervention using *Dr Kawashima's Brain Training* for ten children, aged 6 to10 years, with cognitive disabilities and an IQ score of less than 70. In a

quantitative study, the researchers compared pre and post-test scores of the Westwood One Minute Test of Basic Number Facts (a basic mathematic functions test with 33 items). The results showed an overall improvement of children's addition, subtraction, multiplication, and division skills. However, the authors report that through the intervention with *Dr Kawashima's Brain Training* a significant ($p$<.05) increase was only measured in the children's subtraction skills (Main et al., 2016).

*NumberRace* is a Serious Game focused on core aspects of number sense. It includes emphasis on number sense, including numerical comparison and the link between number and space. Furthermore, it helps learners to link non-symbolic and symbolic representations of numbers. It supports the understanding of and fluency of access to basic addition and subtraction facts (Wilson, Dehaene, Dubois, & Fayol, 2009). In a quasi-experimental study with 60 preschool-aged children, researchers found that *NumberRace* effectively helped children with disabilities to acquire number comparison skills, but the results remained statistically insignificant ($p$=.069) (Räsänen, Salminen, Wilson, Aunio, & Dehaene, 2009). Researchers found that the intervention with *NumberRace* led to a significant ($p$=.014) increase in children's basic arithmetic skills (Salminen, Koponen, Räsänen, & Aro, 2015). Lämsä et al. (2018) reviewed the studies on the effectiveness of the Serious Game *NumberRace* designed to enhance mathematic skills of children with learning disabilities. They report that the game's effectiveness is due to an adaption of game design, meaning that target-group tailored time pressure was used to trigger playing. In game design, challenges may require time-critical or time-independent performance, but it is often conducted in haste and it puts a greater emphasis on motoric skills and reaction times. The importance of time adjustment was mentioned so that the time pressure does not affect the performance of students with disabilities. Lämsä et al. (2018) emphasized that the effectiveness of *NumberRace* on the mathematics skills of children with learning disabilities was due to having suitable time pressure in the game.

Furthermore, the two *Serious Games Hear the Invisible* and *Follow the Rabbit* for blind children were developed to support them in perceiving shapes and colors. Although *Serious Games* supported blind children in preparing for learning, their effectiveness in terms of the acquisition of mathematical skills could not be demonstrated among the six participating children and adolescents between 10 and 16 years of age (Radecki et al., 2020).

Finally, *Cheese Factory* is a Serious Game developed to support the acquisition of mathematical skills in the field of fractions, decimal and percentage understanding (Brown, Ley, Evett, & Standen, 2011). In a quasi-experimental study, 16 students with intellectual disabilities played *Cheese Factory* for twenty minutes a day over five weeks. The results showed that students who played the Serious Game significantly ($p$<.05) improved in both shape recognition and understanding of fractions (p<.05), while the control group showed no significant improvement (Brown et al., 2011). These findings were also discussed in the review on the impact of *Serious Games* on mathematical skills of students with intellectual disabilities. The authors point to a valuable effect of *Cheese Factory* on the mathematical skills of students with intellectual disabilities (Stančin et al., 2020).

*Effective Language-Learning with Serious Games*

In terms of language learning, *Headsprout®,* an early reading program that includes various *Serious Games*, was developed to provide instruction in phonemic awareness, phonics, fluency, vocabulary, and comprehension to children with autism and intellectual disability. In addition, it teaches segmenting, blending, and language decoding (Yakkundi, Dillenburger, & Goodman, 2017). In a behavioral observation, baseline data was collected for three autistic children on their learning readiness, and reading ability using the DIBELS reading assessment tool (Dynamic Indicators of Early Literacy Skills). First findings from behavioral observations of the three children playing *Headsprout®* showed that they progressed in verbal ability and improved their reading skills (Yakkundi et al., 2017).

Furthermore, the six *Serious Games Letters' Store, Twins, Guess the Missing, Match-it-up, Dragon's Words,* and *Sentences* for reading and writing skills in the Arabic language were evaluated with children who had either dyslexia or dysgraphia (El Kah & Lakhouaja, 2018). Researchers conducted a quasi-experimental study with 46 primary school pupils and found significant ($p<.05$) effects on children's reading and spelling skills due to playing the *Serious Games* mentioned. The six *Serious Games* supported the young learners in overcoming their reading and writing difficulties which manifest as a lack of short-term and visual memory, phonological awareness disorder, word-building difficulty, and lack of vocabulary (El Kah & Lakhouaja, 2018).

The *GraphoGame* teaches kindergarten and primary school children early-grade literacy in different languages and improves their reading speed. It combines special needs expertise with research in neuroscience (Lämsä et al., 2018). Adapted for the Persian language, the effectiveness of *GraphoGame* was evaluated in a quasi-experimental study with 30 children aged 7 to 11 years (Zare, Amani, & Sadoughi, 2020). The researchers found that *GraphoGame* strengthened children's phonological awareness significantly ($p<.001$). Furthermore, *GraphoGame* was included in a review about games designed to enhance basic reading skills. The authors concluded that playing *GraphoGame* had a positive influence on reading accuracy and fluency, as well as letter knowledge and spelling (Lämsä et al., 2018).

Another Serious Game to foster language learning is *Eventaurs*. It was developed for children with autism spectrum disorders. By touching the correct sequence of symbols and words, players create speech chains and synthesize entire sentences (McGonigle-Chalmers, Alderson-Day, Fleming, & Monsen, 2013). In a quantitative experiment with nine autistic children aged 5 to19 years, the effectiveness of *Eventaurs* was evaluated. The results of the study vary to such an extent that a general statement about the effectiveness of *Eventaurs* is inconclusive. The authors of the study as well as those of the review conclude that *Eventaurs* had a positive impact on children's and adolescents' language skills, however (McGonigle-Chalmers et al., 2013; Tsikinas & Xinogalos, 2019).

The *Serious Games Vocabulary App* was developed to increase the vocabulary expertise of children with autism spectrum disorders (ASDs) and/or other developmental disabilities. Although, the game had a significant effect on supporting learning conditions among 15 children, the researchers reported statistically insignificant effects on improving vocabulary (Esposito et al., 2017).

## Discussion

This review aims to answer the question of how effective *Serious Games* are in supporting the learning of children and adolescents with disabilities in an inclusive school context. For this purpose, a systematic search for peer-reviewed articles published in the past five years was conducted. Twenty-one articles presenting empirical research on the effectiveness of 26 different *Serious Games* for children and adolescents with disabilities were included. Of the thirteen articles based on quantitative data (mixed methods included), the effects found tended to be large, with three studies reporting no effects. Ten studies reported statistically significant effects, whereas three reported non-significant effects. The five articles reviewed with qualitative data exclusively indicated that the *Serious Games* supported children and youth with disabilities in learning

The results show that *Serious Games* can in many ways support the *learning process* and *outcomes* among children and adolescents with disabilities. Firstly, *Serious Games* can improve conditions and behaviors that are conducive to learning, such as increasing attentional capacity or focusing ability and visual contact. Secondly, *Serious Games* enhance learning motivation, self-efficacy, self-confidence, enjoyment in learning, enthusiasm, calmness and engagement, and also improve short-term, visual memory performance. Thirdly, *Serious Games* can improve the recognition and understanding of facial expressions and increase players' collaboration and social interaction skills. Finally, *Serious Games* can effectively support the acquisition of content knowledge and subject-related skills in mathematics (e.g., basic arithmetic, number comparison, or understanding of fractions) and more generally in the field of STEM. They can likewise support language acquisition (verbal ability, reading, spelling, vocabulary, or phonological awareness). These findings are in line with the state of research on the effectiveness of *Serious Games* (Abrams & Walsh, 2014; Alyaz et al., 2017; Barros et al., 2019; Riopel et al., 2020; Tsai & Tsai, 2020; Vu & Feinstein, 2007; Wastiau et al., 2009; Wronowski et al., 2020; Zhonggen, 2019), which highlights that *Serious Games* are also suitable tools for enhancing effective learning conditions, improving learning-related behaviors and outcomes among learners with special educational needs.

Despite the great potential of *Serious Games* for use in inclusive school contexts and opportunities to learn with them, it is surprising that no specific *Serious Games* for other school subjects were found, such as arts (e.g., drawing, designing) or the acquisition of other learning-related skills (e.g., organization, time management, or the development of individual learning strategies). It is possible that such *Serious Games* exist but did not match our selection criteria as they were not explicitly developed for learners with disabilities and/or were not empirically analyzed with respect to their effectiveness.

This systematic literature review includes a variety of different disabilities. Therefore, the results seem to be generic at first glance, but the diversity of disabilities addressed is ultimately a strength of the review. However, for schools implementing aspects of inclusive education, it would be beneficial to know about *Serious Games* for children and adolescents with different educational needs. In this regard, it is interesting that most of the articles examined the effectiveness of *Serious Games* designed specifically for children and adolescents with *cognitive disabilities*. In contrast, only a few studies analyzed the effectiveness of *Serious Games* developed specifically for children and adolescents with *physical disabilities*, such as visual impairment and neuromuscular diseases. Finally,

the results also indicate that there are *Serious Games* for effective learning for learners with both cognitive *and* physical disabilities.

In comparison with the previous reviews (Lämsä et al. 2018, Tsikinas & Xinogalos, 2019, Stančin et al., 2020), the present review provides further insights into the effectiveness of *Serious Games* for children and youth with disabilities. Firstly, the three existing reviews refer exclusively to students with cognitive disabilities. Lämsä et al. (2018) investigated *Serious Games* for students with learning disabilities in language and mathematical subjects, mostly students with dyslexia and dyscalculia. Whereas Tsikinas and Xinogalos (2019) reviewed studies related to *Serious Games* for students with cognitive disabilities or autism spectrum disorders. Likewise, in the review by Stančin et al. (2020), only *Serious Games* for students with cognitive disabilities were included in the analysis. The present review further includes empirical findings on *Serious Games* for children and adolescents with physical disabilities, albeit in small numbers. Although the existing reviews mention different learning domains, the focus of two reviews is mainly on *Serious Games* for the promotion of mathematical and linguistic skills for the school context. The review by Tsikinas and Xinogalos (2019) added the acquisition of skills in an out-of-school context. For example, practical everyday skills such as reading a timetable, using a phone book, or using money safely. The present study complements these areas with a review of *Serious Games* that promote conditions conducive to learning, such as fostering an increase in motivation to learn or an increase in concentration. In addition, *Serious Games* enhancing the acquisition of specialized knowledge in STEM subjects could be added. Finally, the *Serious Games* Table (in the Appendix) provides a detailed overview of all reviewed articles including the *Serious Games* for children and adolescents with disabilities.

Summarizing, it can be stated that in light of the UN Convention on the Rights of Persons with Disabilities (CRPD), in which all signatory states guarantee equal educational opportunities for people with disabilities, *Serious Games* have a promising potential and can be used to promote inclusive education in schools. The results of the present review as well as the findings of the current state of research indicate that *Serious Games* may offer possibilities to enable collaborative, barrier-free, and effective learning. Collaborative learning can be enabled with *Serious Games* as they allow all students in the class have a joint-learning experience. Barrier-free learning can be facilitated by *Serious Games* because they are developed explicitly for special target groups and their needs. However, the effective implementation of *Serious Games* in the inclusive educational setting requires an IT-infrastructure as well as ICT-competence among teachers and a willingness to use *Serious Games* in their classes. Therefore, more research is needed with respect to the institutional structures and individual attitudes and competences for successful use of *Serious Games* in inclusive education.

## Conclusion and Limitations

This systematic review indicates a promising potential for *Serious Games* in terms of school-relevant learning or acquiring competencies for children and adolescents with cognitive or physical disabilities. The results show that there are *Serious Games* that effectively promote subject-specific learning (i.e., STEM-subjects, language), the acquisition of learning-relevant skills as well as improvement of behavior necessary for learning (see Table 2). Thus, it can be concluded that

*Serious Games* have the potential to make an important contribution to educational settings with aspects of inclusive education.

Although the potential of *Serious Games* is promising, this is a young field in which little research is available, and the effectiveness of *Serious Games* as well as approaches to its meaningful methodical and didactic integration into school lessons have not yet been sufficiently researched. As the digitalization of education advances, countless new *Serious Games* will be created within a short time. The challenge here is to identify them in the shortest possible time and analyze their effectiveness.

Finally, a search in other databases such as Psycinfo, Psyindex, PubMed was omitted due to the initially large number of hits in the ERIC database. For further research, it can be assumed, that other databases will provide further studies on the effectiveness of *Serious Games* for children and adolescents with disabilities.

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## Appendix

**Table 1. Category system**

| *Category*/Code | Content | Code anchors |
|---|---|---|
| *Serious Game* | | |
| /Serious Games' Name | Reference to a specific Serious Game/specific Serious Games. | Name or Title of Serious Game |
| /Serious Games' Taxonomy | Reference to the taxonomy of Serious Games to ensure that the requirements for classification as a serious game are met. | Game, activities that involve players, including constraints or rules, involves goals and possibilities to achieve goals through moves or actions, played with a computer, cause a mental contest, providing learning, skill acquisition and/or training |
| /Serious Games' Goals | Reference to certain goals the use of Serious Game achieves, achievements in the context of school learning, preconditions that make learning possible | achievement, learning, knowledge, expertise, competences (e.g. counting, reading, explaining), subject (e.g. mathematics, language, science), behavior, learning motivation, learning precondition (e.g. motivation, memory performance) |
| /Serious Games' Target Group | Reference to the target group for which the Serious Game was developed. | Child/children, 4-12 years, K-12, kindergarten, primary school, compulsory school, adolescents, 13-19 years, secondary school, high school, teenager, disabled, disability, disabilities, cognitive, intellectual, learning difficulties, physical, impairment, |
| *Research Approach* | | |
| Quantitative Study | Reference to a study that includes the collecting and analyzing of numerical data and a presentation and discussion of the results. | Experiment, survey, (systematic) observation, secondary research (e.g. meta-analysis), effect, effectiveness, impact |
| Qualitative Study | Reference to a study that includes the collecting and analyzing of non-numerical data and a presentation and discussion of the results. | Observations, interviews, focus groups, surveys (e.g. questionnaires), secondary research (e.g. reviews), effect, effectiveness, impact |

**Table 2. *Serious Games* for Children and Adolescents with Disabilities**

| Serious Game | Target Group | Purpose, Application & Game objectives | Research method | Results | Reference |
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| Story360 (with Wildcard system) | Students with cognitive disabilities, and developmental disorders | Learning-Precondition: Improvement of attention, concentration, concept, and understanding | Qualitative | Based on their observations of children's behavior, the researchers found that the children interacted with the virtual world, and that they increasingly followed the avatar with their eyes, which the authors interpreted as increased attention. Therapists further observed that children enjoyed playing the game. | Gelsomini et al. (2016) |
| Letters' Store<br>Twins<br>Guess the Missing<br>Match-it-up<br>Dragon's Words<br>Sentences Game | Students with cognitive disabilities, dyslexia, dysgraphia | Learning-Precondition, Language-Learning: Improvement of short and visual memory performance, improvement of reading and spelling skills | Quantitative | A paired-sample t-test of pre-post intervention scores showed an enhancement of reading skills ($p$<.001) and spelling skills ($p$=.016) of students with cognitive disabilities, and an enhancement of reading skills ($p$=.028) and spelling skills ($p$=.026) of students with dyslexia. The authors do not report effect sizes[1]. | El Kah & Lakhouaja (2018) |
| SmartLearn | Students with neuromuscular disability | Learning-Precondition, STEM-Learning: Improvement of learning motivation, reducing anxiety level, and enhancing self-efficacy, improvement of science learning | Quantitative | An analysis of covariance (ANCOVA) was performed to compare posttest scores obtained by students in the experimental (*SmartLearn*) and control group, with pretest scores as covariate.<br>For learning motivation analysis, a significant difference was observed between the groups ($F$=9.04, $p$<.001): After the intervention, students in the experimental group showed | Khamparia et al. (2020) |

[1] For all articles in which no effect sizes were reported, we contacted the authors by email and added the effect sizes if provided to us by authors.

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| | | | | higher motivation than control group students.<br>For self-efficacy analysis, a significant difference was observed between the groups ($F$= 8.94, $p$<.05): After the intervention, students in the experimental group showed a higher level of self-efficacy than control group students.<br>For anxiety level analysis, a significant difference was observed between the groups ($F$=10.82, $p$<.05): After the intervention, students in the experimental group showed a lower anxiety level than control group students.<br>For science learning achievement analysis, a significant difference was observed between the groups ($F$= 9.02, $p$=.002): After the intervention, students in the experimental group showed higher science learning achievement than control group students. | |
| Unboxit<br>Melody tree<br>(both Kinect-based) | Students with cognitive disabilities | Learning-Precondition: Improvement of self-confidence, joy, enthusiasm, calmness, engagement, and motivation to participate | Qualitative & quantitative | In a mixed methods study, teachers were asked to note their observations and reflections upon each session, guided by two specific questions: (a) what were the specific learning goals for the session? and (b) how was the child's performance in relation to these goals? Finally, all teachers were interviewed regarding their overall experience. The researchers found that playing *Unboxit* and *Melody tree* help students to improve their performance in memory tests, particularly students' ability to execute a series of tasks and the ability to make choices toward solving a problem. The games also improved | Kosmas et al. (2018) |

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| | | | | students' self-confidence. The researchers reported that the longer the students played, the better the cognitive performance:<br>A paired -sample t-test of pre-post intervention scores showed an enhancement of cognitive performance ($p$<.05, $d$=0.60). | |
| Barrage Task App<br>Vocabulary App<br>Imitation App | Students with autism spectrum disorders, and developmental disabilities | Learning-Precondition Language-Learning: Improvement of attention and receptive identification of objects, improvement of vocabulary expertise | Quantitative | A t-test of differences between pre and post intervention scores showed that students in the experimental group increased their attention scores more ($M$=2.90, $SD$=2.60) than students in the control group ($M$=2.00, $SD$ =1.90) who did not play the *Serious Game*, $z$=1.89, $p$=.348. In addition, students in the experimental group increased their ability to receptively identify objects more (M=60.70, $SD$=55.50) than those in the control group ($M$=52.90, $SD$=59.70), $z$=1.26, $p$=.712. All results were statistically insignificant. | Esposito et al. (2017) |
| Ucime Emocii | Students with autism spectrum disorders | Learning-Precondition: Improvement of emotion comprehension skills | Quantitative | The analysis of recognition of the four basic emotions (sadness, happiness, fear, and anger) shows a significant difference between the experimental and control group on all three tasks employed: Face task ($F$(1, 26) = 17.52, $p$<.001, $\eta_p^2$=.40), Pictogram task ($F$(1, 26) = 52.60, $p$<.001, $\eta_p^2$=.66), and Situation task ($F$(1,26) = 6.13, $p$<0.05, $\eta_p^2$=.19), where scores were better in the experimental group for all tasks. | Vasilevska Petrovska & Trajkovski (2019) |

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| Mega Bloks® | Students with autism spectrum disorders | Learning-Precondition, Improving certain Behavior: Improvement of social, conceptual, and practical skills, improvement of collaboration and social interaction | Quantitative | The researchers reported that students played more cooperatively and increased the number of social interactions when playing *Mega Bloks*®. A paired-sample t-test of pre-post intervention scores showed a significant increase in the number of social interactions ($p$=.005), a significant increase in collaborative play time ($p$=.004), and better performance during the computer game ($p$=.009), based on the number of minigames completed. The authors do not report effect sizes[2]. | Barajas et al. (2017); Tsikinas & Xinogalos (2019) |
| Medius *Serious Games* | Students with autism spectrum disorders | Learning-Precondition: Improvement of imitational and joint attention skills | Qualitative | In a behavioral observation, the researchers used a computer system with a camera that detected if players turned their head left or right, up or down. If the computer system found that the child was no longer focusing on the task, it automatically stopped the counter. Findings from behavioral observations showed that *Medius Serious Games* increased the amount of time students were paying attention and concentrating on task. | Daouadji Amina & Fatima (2018); Tsikinas & Xinogalos (2019) |
| Hear the Invisible Follow the Rabbit | Blind, and visually impaired Students | Learning-Precondition: Improvement in perceiving shapes and colors as well as learning motivation | Qualitative | In a behavioral observation, the researchers used interactive sonification techniques to support blind children in perceiving shapes and colors. The sounds that the children perceived formed a geometric figure, which the children had to recognize and reconstruct. Findings from behavioral observations showed that playing | Radecki et al. 2020) |

[2] For all articles in which no effect sizes were reported, we contacted the authors by email and added the effect sizes if provided to us by authors.

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| | | | | *Hear the Invisible* and *Follow the Rabbit* supported students in perceiving basic mathematical functions and geometric shapes. | |
| Dr Kawashima's Brain Training | Students with cognitive disabilities | Mathematics-Learning: Improvement of addition, subtraction, multiplication, and division skills | Quantitative | With a Wilcoxon signed ranks test the pre- and posttest scores of the Westwood One Minute Test of Basic Number Facts were analyzed. Results showed a significant increase ($z$=-2.11, $p$=.035) in subtraction skills, but not in addition ($p$=.258), multiplication ($p$=.546) and division ($p$=.666) skills. | Main et al. (2016) |
| NumberRace | Students with cognitive disabilities | Mathematics-Learning: Improvement basic mathematic skills | Quantitative | An analysis of variance (ANOVA) was performed to compare posttest scores obtained from students in the experimental (*NumberRace*) and control groups. For number comparison analysis, an insignificant difference was observed between the groups ($F$=3.661, $p$=.069). After intervention, students in the experimental group scored higher than control group students. A Wilcoxon Signed Ranks Test showed there was a significant between-group difference in intervention gain scores of basic arithmetic ($Z$=-2.30, $p$=0.014), favoring the experimental group | (Räsänen et al., 2009); (Salminen et al., 2015); Wilson et al. (2009); Lämsä et al. (2018) |
| Cheese Factory | Students with cognitive disabilities | Mathematics-Learning: Improvement of understanding of fractions in mathematics | Quantitative | An analysis of pre- and posttest scores showed that the intervention group who played the *Cheese Factory* Serious Game showed significant improvements in both shape recognition and understanding of fraction in mathematics ($p<.05$), while the control group showed no significant improvement. The authors do not | Brown et al. (2011); Stančin et al. (2020) |

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| | | | | report effect sizes[3] | |
| Headsprout® | Students with autism spectrum disorders | Language-Learning: Improvement of verbal ability and reading skills | Qualitative | In a behavioral observation, baseline data was collected on autistic children's learning readiness, and reading ability using the DIBELS reading assessment tool (Dynamic Indicators of Early Literacy Skills). First findings from behavioral observations showed that children progressed in verbal ability and improved their reading skills. | Yakkundi et al. (2017) |
| GraphoGame | Students with cognitive disabilities | Language-Learning: Improvement of letter knowledge, spelling and phonological aware-ness | Quantitative | The researchers found that the number of spelling errors students made was reduced, reading accuracy and fluency was enhanced, and phonological awareness was strengthened after learning with the *GraphoGame*. A Mann-Whitney-U test was used to compare the difference of pretest and posttest scores in a spelling test between the experimental and control groups. Results showed a significant difference between the two groups ($Z=-3.51$, $p<.001$), meaning that incorrect answers in the experimental group decreased more sharply than did those in the control group. | Zare et al. (2020); Lämsä et al. (2018) |
| Eventaurs | Students with autism spectrum disorders | Language-Learning: Improvement of language skills | Quantitative | Observing the learning progress and performance of nine children with profound expressive language impairment and autism, the researchers found that playing *Eventaurs* could increase the students' skills in creating speech | McGonigle-Chalmers et al. (2013); Tsikinas & Xinogalos (2019) |

[3] For all articles in which no effect sizes were reported, we contacted the authors by email and added the effect sizes if provided to us by authors.

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| | | | | chains (students learned to touch words on a screen in the correct sequence in order to see a corresponding animation). While all children were able to attempt the task, performance varied widely between participants. However, no child failed to demonstrate learning at least up to three-word levels. | |
| MEBook | Students with autism spectrum disorders | Improving certain Behavior: Improvement of social skills | Qualitative | In a behavioral observation, data was collected on autistic children's social skills (such as saying "Hello" and "Bye" to others) after an intervention with the *MEBook Serious Game*. Recordings from therapists showed that children increased the number of their responses to another person's greetings (i.e., vocalizing hi/bye, looking at the person, and waving) | Uzuegbunam et al. (2015); Tsikinas & Xinogalos (2019) |