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Review Paper

Teaching Mathematics, Science and Reading Skills to Students with Special Needs: A Review of Augmented Reality Studies

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ABSTRACT

In line with the needs emerging in education day by day, integrating teaching technologies into education is becoming increasingly important. In this direction, instructional technologies are used to make education more effective and efficient. One of these technologies is Augmented Reality. Augmented Reality (AR) applications, an up-to-date application-based technology that adds extra virtual information in real-time on the real-world perception, can be used within the framework of the needs of students with special needs. Within the scope of this research, postgraduate theses and AR studies published in peer-reviewed journals, which aim to provide students with special needs with academic skills, were examined. While determining the studies be included in this research, basic selection criteria were employed. A comprehensive search was conducted based on electronic databases, journal indexes, and research references. In this direction, there were only eight studies meeting the criteria were obtained. The result of the study revealed that quasi-experimental model was the most common research model, and Augmented Reality applications have positive effect on reading, math and science skills.

INTRODUCTION

Educators constantly develop evidence-based practices, use effective methodologies and introduce new ones so that students with special needs who have difficulties acquiring academic skills can achieve better learning outcomes. Students who need additional educational support due to disability or certain behavioral disorders are defined as students with special needs (Garner, 2009). It is also very important for students with special needs to acquire basic academic skills for independent living skills (Kellems et al., 2020; McMahon, Cihak, Wright & Bell, 2016). However, when considered and examined more comprehensively, it is seen that these students are faced with the teaching of skills independent of the curriculum content (McMahon et al., 2016). These students need to show competence in basic academic skills to participate in society and fulfill the expected tasks (Kellems et al., 2020; Lin & Chang, 2015; McMahon et al., 2016; Salah, Abdennadher & Atef, 2017).

Students with special needs experience problems in information processing, and considering these problems, they need different information inputs (visual and verbal) through more stimuli (Swanson, 2010). For this reason, it is emphasized that providing structured and enriched learning environments (e.g., videos, 3D images and animations) facilitates students' ability to process instant and relevant information, increases their learning motivation, improves their understanding of tasks, and they can acquire higher-level academic skills (Çakır & Korkmaz, 2019; Kim, 2017). Augmented reality (AR) applications, which offer a more structured and enriched environment, as the name suggests, are recommended to gain academic skills and improve these skills (Baragash, Al-Samarraie, Alzahrani & Alfarrai, 2020; Kellems et al., 2020). By connecting the physical world with the virtual world, AR presents an enriched and augmented reality compared to the physical world (Klopfer & Squire, 2008). It is believed that the use of AR will allow students with special needs to apply their skills in real-life situations, that is, through a mix of both real-world and virtual elements (Baragash, Al-Samarrraie, Moody & Zaqout, 2020). AR can also function as assistive or instructional technology and support students' learning processes with special needs by the principles of universal learning design (Walker, McMahon, Rosenblatt & Arner, 2017). Indeed, Baragash et al. (2020a) found in their meta-analysis study that the effect size of AR applications on the learning skills of individuals with special education needs was higher than other skills. In other words, the effect size of AR applications on students' learning academic skills was higher than social skills, life skills, and physical skills. These findings from single-subject experimental design studies show that AR is an effective and functional application in students' academic learning. In addition to single-subject experimental studies, meta-analysis studies conducted on studies with pretest-posttest control group experimental design also reveal the importance of the potential effect of using AR on learning academic skills (Baragash et al., 2020b).

This has led few researchers to discover the role of AR reality applications in enhancing students' learning with special needs. For

example, in their intervention study conducted with post-high school students using AR technology, MacMahon et al. (2016) found that AR-based interventions produced effective results in teaching science vocabulary. In another study, Kim (2017) taught science concepts to preschool students with an AR-based intervention study and reported positive results. In addition to science concepts, Cacciatore (2018) found that AR applications increased solving mathematical problems in her intervention study with adult students. Also, in their AR-based intervention study Cascales-Martínez, Martínez-Segura, Pérez-López, and Contero (2017) conducted to teach students mathematical knowledge and money transactions skills, they reported that students' money processing skills and math knowledge increased. Kellems et al. (2020) reported that students' math problem-solving skills improved in their intervention study through AR to teach math problem-solving skills to middle school students. Salah et al. (2017) tested the effect of an AR-based and interactive application on students' arithmetic skills and reported that the results increased the development of arithmetic skills. In addition to teaching science and mathematics skills, AR applications have been developed within teaching literacy skills. Likewise, Lin and Chang (2015) examined the effectiveness of AR applications when teaching word reading and writing skills to students. The study result showed that word literacy accuracy increased, and students could choose the correct word from a sentence. In general, the results of the study conducted on the teaching of academic skills with AR applications show that these applications are effective in the academic skills learning process of students with special needs.

In addition to increasing students' academic skills with special needs, AR applications/interventions contribute to processes such as attention, motivation, absorption of knowledge, collaboration, and information-based feedback (Cascales-Martínez et al., 2017; Çakır & Korkmaz, 2019; Lin & Chang, 2015). In addition, AR also allows the development of new skills as it offers specialized training that includes the repetition of the same task in an environment with developed verbal and visual cues for students (Cascales-Martínez et al., 2017; Lin & Chang, 2015). Generally, repeated application of the same task or skill increases automaticity (e.g., reading) and decreases demands to control attention. Therefore, using AR in a task that requires focus helps students perform academic skills independently without distracting them (Jerome, Frantino & Sturmeyi 2007). AR applications are also very important because they activate processes such as attention, motivation, cooperation, and information-based feedback, which are very effective in teaching academic skills to students with special needs and in learning these skills. Therefore, it is seen that AR-based interventions play an important role in meeting both the cognitive and emotional needs of students as well as learning academic skills. However, intervention studies using AR should be examined to reinforce AR applications' place in the academic skills learning process of students with special needs. In this direction, the general purpose of this research is to determine the applications of augmented reality applied to improve the academic skills of students with special needs since 2010 and to provide information for advanced research and practitioners by examining the studies in terms of certain variables.

METHOD

Within the scope of this research, postgraduate theses conducted in the last ten years and augmented reality studies published in peer-reviewed journals aimed at providing students with academic skills were examined. In this section, sub-sections of research selection criteria, research identification process, descriptive analysis process, and inter-coder reliability are given, respectively.

Some major steps should be followed while conducting literature research. Fraenkel, Wallen, and Hyun (2012) list these steps as follows: (1) determining the research problem as clearly as possible, (2) deciding the scope of the research, (3) determining the databases to be screened, (4) determining the screening criteria, (5) scanning the main reference sources for primary resources, and (6) obtaining, reading, extracting notes and summarizing important points. The clear explanation of each of the steps followed in the systematic literature review studies saves this method from bias and enables it to be seen as a repeatable and verifiable method (Karaçam, 2013).

Research Selection Criteria

One of the steps to be followed in the systematic literature review studies is to determine the criteria according to which studies will be included and not included in the research. These criteria are extremely important as they directly affect the research results. The following criteria were selected to determine the studies included in this research:

(1) The study should be conducted between the years 2010-2021,
(2) Participant group should include students with special needs,
(3) Augmented Reality applications should be used,
(4) The study should include the teaching of academic skills,
(5) The study should be published in a national or international refereed journal or the relevant approved as a thesis study.

The following criteria were determined to determine the studies that will not be included in this study:

(1) If the findings regarding students with special needs are not given separately in the study from the students with normal development,
(2) If the study includes virtual reality applications in research.

Research Identification Process

The determination of the articles and theses to be examined within the scope of this research was carried out in four steps: identification, scanning, eligibility, and inclusion. The operations performed in each step are explained below.

Identification

In this step, the databases examined to reach the studies and the keywords used in this process are included. ULAKBIM national database of Turkey, EBSCOhost, Education Research Complete, Education Resources Information Center (ERIC), Web of Science, Psychological Abstracts Index (PsycINFO), Google, and Google Academic databases were used to access the articles. The Higher Education Council of Turkey National Thesis Center and ProQuest Dissertations & Theses databases were used to reach the theses. In these databases, keywords were entered in Turkish and English, and a search was carried out. In the scans, augmented reality, special education, special education needs, academic skills, intellectual disabilities, learning disabilities, autism, visual impairment, attention deficit hyperactivity disorder, physical disabilities, hearing disabilities, instruction, teaching, writing, reading, math, science keywords were used. At the end of the screening, 269 studies were reached at the identification stage. In addition, articles published in the Journal of Special Education, Journal of Learning Disability, Journal of Special Education Technology, Journal of Research on Technology in Education, Journal of Computer Science, which are considered as key journals of the relevant literature, where technology-mediated interventions are frequently applied to students with special needs were examined, and four more studies were obtained.

Scanning

In this step, the titles, abstracts, and keywords of the research gathered during the identification step were examined, and book chapters, reports, systematic descriptive analyses, and meta-analysis research were eliminated. Sixty studies were obtained as a result of the scanning.

Eligibility

The studies obtained in this step were evaluated to determine whether they conform to the variables examined in this study. The selection was made by considering the basic selection criteria for the studies in this research. First, a form was prepared by considering the basic selection criteria. All of the studies obtained were examined in detail by the authors and recorded in the form prepared. In this way, 14 articles on interventions offered through augmented reality for students with special needs were examined. Since six of these articles aimed to teach independent living skills through augmented reality, they were eliminated.

Inclusion

Eight studies were obtained that met the inclusion criteria of this research. The process carried out in the literature review is shown in Figure 1.

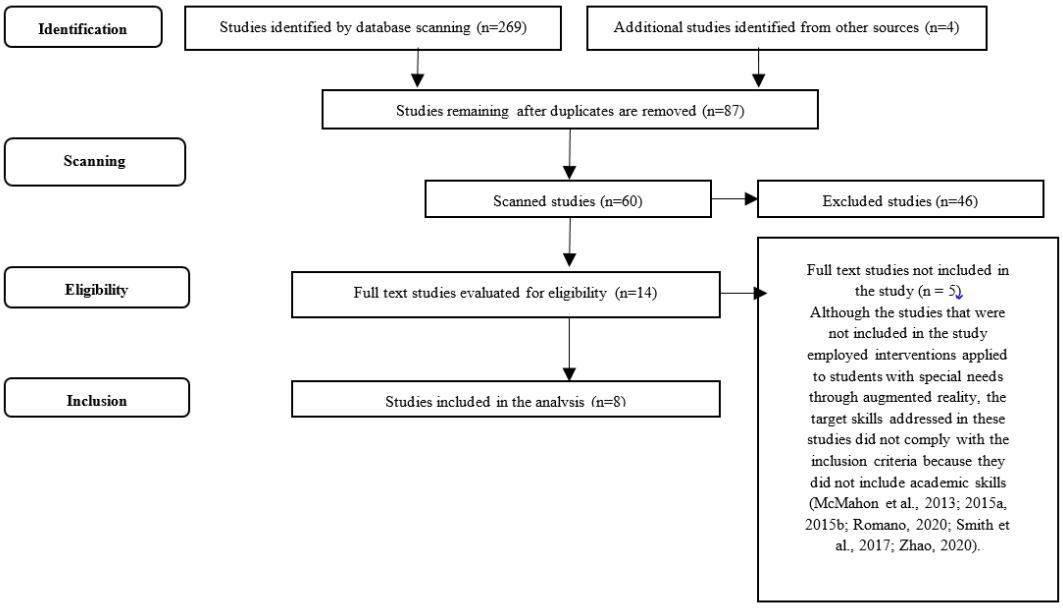

Figure 1. Research Identification Process
Source: Adapted from: Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*, *151*(4), 264-269 7.

Descriptive Analysis Process

The articles and theses included in the research were analyzed under the following headings in line with the variables in the research examination form: a) diagnosis, b) number of participants, c) grade and age level, d) gender, e) academic field, f) target skill, g) target skill acquisition, h) research design, i) practice environment, j) reliability k) social validity and l) findings.

Inter-coder Reliability

Inter-coder reliability of the study was calculated by comparing the data obtained from the first researcher with the second researcher in at least 25% of the obtained studies, using the formula "consensus / [consensus + disagreement] X 100" (Gast, 2010).

FINDINGS

The findings of these studies were examined under two headings as descriptive analysis and inter-coder reliability findings.

Descriptive Analysis Findings

Participants

Participants in the studies were examined in terms of a) diagnosis, b) number of participants, c) grade and age level, and d) gender variables. Information about the participants in the research is presented in Table 1.

Table 1. Information on Participants

Studies	Diagnosis	Number of Participants	Grade/Age Level	Gender
McMahon et al. (2016)	Autism spectrum disorder and mental disability	4	10-20 Years	3F-1M
Martinez et al. (2017)	Attention deficit and hyperactivity disorder, learning disability, mental disability, developmental disability	22	1-3rd Grade /6-12 Years	Not specified.
Cacciatore (2018)	Mental Disability	3	21-24 Years	3F
Fecich (2019)	Special Needs	4	9-12th Grade /12-20 Years	2F-2M
Işık (2019)	Learning Disability	3	5th Grade /11 Years	3F
Morris (2019)	Learning Disability	3	4th Grade	1F-2M
Kellems et al. (2020)	Learning Disability	7	7-8th Grade /13-14 Years	4F-3M
Turan & Atila (2021)	Learning Disability	4	6th Grade /10-13 Years	2F-2E

Table 1 shows 50 participants with special needs in the studies. Of these participants, 2% (n = 1) has autism spectrum disorder, 4% (n = 2) developmental disability, 8% (n = 4) special needs, 10% (n = 5) attention deficit and hyperactivity disorder, 16% (n = 8) intellectual disability and 60% (n = 30) learning disabilities. While 60% of the participants (n = 30) were male, 26% (n = 13) were female, the gender of 44% (n = 22) was not specified. When the class and age levels of the participants were examined, it was determined that they were at a wide-ranging grade and age level from primary school to higher education and from 6 to 24 years old.

Descriptive Information of the Studies

Studies were examined in a) academic field, b) target skills, and c) acquisitions. The descriptive information of the studies can be seen in Table 2.

Table 2. Descriptive Information of Studies

Studies	Academic Field	Target Skill	Acquisitions
McMahon et al. (2016)	Science	Science terms	Teaching vocabulary related to bones, organs, and cells topics

Martinez et al. (2017)	Math	Money	Distinguishing paper and coins, teaching the solution to the problem by calculating the appropriate amounts.
Cacciatore (2018)	Math	Problem-solving	Teaching the solution of ratio problems
Fecich (2019)	Reading	Improving Vocabulary	Teaching unknown words, giving examples, and improving their use in appropriate contexts
Işık (2019)	Math	Properties of Geometric Shapes	Teaching the corner, edge, and facial features of the square prism
Morris (2019)	Math	Rational numbers	Converting rational numbers and decimal numbers, adding and subtracting numerators in equal numbers, using the equivalence feature of numbers to find the numerator or denominator, and equalizing teaching
Kellems et al. (2020)	Math	Problem-solving	Teaching the solution of ratio problems using basic arithmetic operations on integers
Turan & Atila (2021)	Science	Changing states of matter	Teaching changing states of matter such as melting, freezing, evaporation, condensation, sublimation, and frosting

When the studies are examined, it is seen that one (12%) of the augmented reality applications developed for teaching academic skills is for reading, two (25%) are for science, and five (63%) are for math.

Information on Research Application

The information on the application of the studies was examined in terms of a) application design, b) application model, c) generalization and follow-up, d) inter-observer and application reliability, and e) social validity. The information about the application of the studies can be seen in Table 3.

Table 3. Information on Research Application

Studies	**Application Design**	**Application Model**	**Generalization / Follow-up**	**Inter-observer / Application Reliability**	**Social Validity**
McMahon et al. (2016)	Single-subject experimental design	Multiple probes across behaviors	-/-	+/+	+
Martinez et al. (2017)	Group experimental design	Single group pre-test post-test	-/-	-/-	+
Cacciatore (2018)	Single-subject experimental design	Multiple probes across behaviors	+/+	+/+	+
Fecich (2019)	Descriptive design	Descriptive model	-/-	+/+	+
Işık (2019)	Single-subject experimental design	Multiple probe model between subjects	+/+	+/+	+
Morris (2019)	Single-subject experimental design	Multiple probe model between subjects	+/+	+/+	+
Kellems et al. (2020)	Single-subject experimental design	Multiple probe model between subjects	-/+	+/+	+
Turan & Atila (2021)	Single-subject experimental design	Multiple probe model between subjects	+/-	-/-	+

When the application designs of the studies were examined, it was observed that single-subject experimental designs were used in six of the studies (75%), and group experimental designs and survey models were used in one study (25%). In general, it is seen that there are reliability data that ensures that the application process is applied to all participants correctly and similarly and that social validity data are obtained in all of the studies.

RESULT OF STUDIES

As a result of examining the visual graphics and written findings of eight studies examined in this study determined that the interventions carried out through augmented reality in various academic fields were effective in the acquisition of target skills. When the graphics of single-subject experimental designs using these interventions were examined, it was determined that the curves at the baseline level increased in the application phases, the post-test scores were higher in the experimental designs, and there was an increase in the percentage and frequency data in the descriptive designs. The results of the studies are shown in Table 4.

Table 4. Results of the Studies

Studies	Results
McMahon et al. (2016)	Augmented reality applications effectively improved students' skills to identify words related to science subjects and label their visuals.
Martinez et al. (2017)	It was revealed that augmented reality applications are an appropriate technology that can be successfully applied to distinguish money in the context of the needs of students with special needs.
Cacciatore (2018)	It was found that all participants achieved significant gains immediately after the intervention was implemented, and they maintained the learned skills even after the withdrawal of the intervention.
Fecich (2019)	It was observed that the targeted vocabulary acquisition was achieved in the participants.
Işık (2019)	It was found that the augmented reality application effectively solved ratio problems by using basic arithmetic operations in integers, and the number of digits that students completed correctly increased.
Morris (2019)	The applied intervention showed that the participants effectively achieved goals for three different rational numbers. At the same time, it was found effective in maintaining these skills and generalizing them.
Kellems et al. (2020)	It was observed that augmented reality technology effectively taught the concept of square prism, and the conservation of the concept acquired by using augmented reality technology continued after the teaching.
Turan & Atila (2021)	It was found that augmented reality applications effectively supported students' learning with learning difficulties. It was also stated that the students were willing to use this technology.

Findings on Inter-Coder Reliability

The inter-coder reliability data was calculated as 97% in the descriptive analysis process, with a minimum of 94% and a maximum of 100%. It was calculated as 95%, with a minimum of 89% and a maximum of 100%.

DISCUSSION

This study aims to determine the applications of augmented reality to improve students' academic skills with special needs between 2010 and 2021 and to provide information for future studies and practitioners by examining the studies in terms of certain variables. Four main results can be emphasized in line with the articles' findings examined. The first result is that there are very few augmented reality applications to support students with special needs academic skills. Second, interventions implemented through augmented reality provide basic academic skills for students with special needs such as reading, mathematics and science, and have positive results. Third, when all disability groups in need of special education are considered, some disability groups either participate in the research with very few participants or not at all. The last one is that studies are mostly conducted with quasi-experimental research models. Accordingly, more research needs to be conducted to support students with special needs academic performance. These studies focus on such subjects as reading, writing, basic arithmetic operations, and problem-solving in the context of basic academic skills. Within the aim of special education, academic skills that will enable students to live independently in society should be directed. In addition, research should be carried out using real experimental designs (e.g., pre-test post-test with the control group, post-test with the control group, paired random design, etc.).

When the findings of the studies included in this study were examined, the instruction offered through augmented reality was effective in learning various academic skills of students with special needs. This finding can be discussed in what augmented reality applications provide in the learning process in line with students with special needs characteristics. The use of tablets and smartphones has increased considerably in the second decade of the 21st century, and it is almost certain that it will increase further in the third decade. Since mobile applications are widely accessible, these applications are also used in educational technology, and it can be said that they are impossible to ignore. Augmented reality applications, an up-to-date application-based technology that

adds virtual information in real-time on real-world perception, provide instant feedback according to the students' individual needs. In this context, augmented reality offers significant advantages in teaching academic skills to students with special needs. Augmented reality contains many features such as providing natural experiences, viewing difficult-to-understand relationships, concretizing abstract issues, supporting student participation, and visually enriching teaching (Kellems et al., 2020; Mundy, Hernandez, & Green, 2019; Morris, 2019). Considering the characteristics of students with special needs having poor conceptual understanding, working memory deficits, recalling information from the mind, and seeing academic skills as a difficult field (McMahon, Cihak & Wright, 2015; Özkubat, Karabulut & Sert, 2021), it can be said that these limitations can be minimized with augmented reality applications. These limitations cause students not to meet academic standards and develop themselves mentally, cognitively, and behaviorally. These augmented reality applications have the potential to make learning more enjoyable and satisfying while learning academic skills such as reading, writing, and math for students with special needs, as well as making learning more meaningful by using digital objects and diagrams that make concepts more concrete (Baragash et al., 2020a, 2020b; Kellems et al., 2019). Students with special needs may have difficulties understanding and remembering mathematical concepts necessary for success in math, or they may have difficulties using symbols. Similarly, they may have difficulty in completing visuospatial concepts (Price & Ansari, 2013). These skills cause a decrease in school success and pose problems and difficulties in students' daily lives (Bugden & Ansari, 2016). However, with the necessary support and strategies, students can be equipped with the skills they need. In this context, it is thought that the use of augmented reality applications developed by computers or mobile devices will be effective thanks to their features, such as the ability to offer multiple displays to students, to handle concrete materials and visuals together, to be highly interactive, and to have an instant feedback structure.

Science is one of the targeted areas other than math in the studies examined in this study. Science is among the academic fields in which students with special needs in other special education categories such as learning disability, intellectual disability, visual and hearing impairment, and autism spectrum disorder generally have difficulty (Brigham, Scruggs & Mastropieri 2011; Özkubat, Akçayır & Özpınar, 2020). Therefore, for students with special needs to receive education in general education classes, appropriate teaching methods, strategies and techniques, and instructional support should be provided. It is stated that the performance of students with special needs in science education is lower than that of their peers with normal development (McMahon et al., 2016; Karaer & Melekoğlu, 2020). One of the most important reasons students' performance is lower than their peers is their reading, writing, and math (Sanır & Özkubat, 2018). Because science education is intertwined with reading, writing, and math skills, inadequacy in one of these skills also affects the science course. Other reasons why students' performances are lower than their peers can be listed as follows: keeping science concepts in memory is a difficult skill for students with special needs, some science subjects have a spiral structure (e.g., systems in our body, states of matter, classification of living things, etc.), the students cannot understand the subject holistically by switching to other subjects without clearly grasping the previous subject, and not sparing sufficient time for teaching in the science course (McMahon et al., 2016). Augmented reality applications enable students to repeat as much as they need and to reach information by progressing at their own pace (Klopfer & Yoon, 2004). In addition, students with special needs may lack experience due to reasons such as not being able to access relevant science materials in real life, and some materials are costly, and some are dangerous. In this context, it can be said that augmented reality applications provide equality of opportunity in favor of students with special needs by removing this limitation.

Single-subject experimental designs are mostly used in the studies examined in this research. While these designs are used in research, they are expected to meet certain standards (Özkubat et al., 2021). For this reason, it is important to evaluate the quality level of practice in single-subject studies and the appropriateness of procedural procedures. To make this evaluation, there must be determined objective criteria. In this way, it can be measured whether the research meets the lowest acceptable level of quality (Horner et al., 2005). Items that show high-quality research are called quality indicators (Cook, Collins, Cook & Cook, 2019). There are studies in the literature to measure the methodological appropriateness of single-subject research (Busk & Serlin, 1992; Kratochwill & Stoiber, 2002). In addition to these studies, Horner et al. (2005), in a study they conducted, identified various quality indicators that should be addressed to determine whether a single-subject study met 'acceptable' criteria in terms of method. Some of these indicators are participants and reliability. In some of the studies examined in this research, participants were specifically stated in which disability group they belonged to in special education (e.g., learning disability, intellectual disability or autism spectrum disorder, etc.), while some were specified as special needs. This situation negatively affects the repeatability and generalizations of the studies (Tankersley, Cook & Cook, 2008). To prevent this, it can be said that special education researchers should cooperate with computer and instructional technologies or mathematics and science education researchers. A similar situation is also valid for the reliability data in some of the studies examined. Paying attention to these issues while designing the research makes it possible to see the independent variable's effect. Thus, the researchers and readers in the findings of the study will be higher (Odom et al., 2005).

When the diagnoses of the students with special needs in the studies are examined, it is seen that the majority of the students are students with learning difficulties. This finding is not surprising and can be explained in two different ways. First, when students with special needs are considered, most of these students (on average 50%) are students with learning difficulties (NCDL, 2017). Secondly, students with learning difficulties are among the groups that need academic skills support (Lee, Bryant, Ok & Shin 2021). For this reason, it can be said that it is an expected finding that students with learning difficulties constitute the main disability group in these studies examined in the present research, in which augmented reality applications are discussed in the development of academic skills. Similarly, students with autism spectrum disorders were the least common disability group among the participants of the studies. This may be because students with autism spectrum disorder focus heavily on non-academic skills such as language, communication, and social interaction from early childhood (Kulage et al., 2020; Smith, Cihak, Kim, McMahon & Wright 2015), and this process can continue throughout school life. In addition, mental disability may accompany some students with autism

spectrum disorder, which is thought to limit the ability to study academic skills.

As in every study, there are some limitations in this study. Within the scope of the research, articles containing studies published in refereed journals and theses approved by institutes were examined. The studies reached are limited to the results of the search engines determined in line with the inclusion criteria. It is possible that studies that did not appear in search engines were not included in the evaluation. Based on the research findings, there are suggestions for education, practice, and further research. The literature shows that when students with special needs are supported with augmented reality interventions according to their appropriate needs, the academic performance of these students improves. Experts working with special needs students will improve students' academic performance by using augmented reality applications. For this, special education, Turkish, math, science education, and computer and instructional technologies need to work together. A limited number of studies in Turkey provide intervention to students with special needs through augmented reality (Turan & Atila, 2021). For this reason, it is necessary to develop various augmented reality applications and use them in classroom environments to support the basic academic skills of students with special needs. For these reasons, it is expected that the findings of this study will form the basis for the augmented reality teaching studies to be carried out in the national literature in the future and shed light on the intervention programs to be prepared.

DECLARATIONS

Abbreviations: 3D: Three dimensional, AR: Augmented Reality

Availability of Supporting Data: This study examines previous research about learning with AR for special education. The bibliographic information of these studies and related index information were shared. Therefore, data that support the findings of this study are publicly available.

Competing Interests: To the best of our knowledge, the named authors have no conflict of interest or financial, relevant to this article. The authors declare that they have no competing interests.

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REFERENCES

Baragash, R. S., Al-Samarraie, H., Alzahrani, A. I., & Alfarraj, O. (2020a). Augmented reality in special education: A meta-analysis of single-subject design studies. *European Journal of Special Needs Education*, *35*(3), 382-397. https://doi.org/10.1080/08856257.2019.1703548.

Baragash, R. S., Al-Samarraie, H., Moody, L., & Zaqout, F. (2020b). Augmented reality and functional skills acquisition among individuals with special needs: A meta-analysis of group design studies. *Journal of Special Education Technology*. https://doi.org/10.1177/0162643420910413

Brigham, B. J., Scruggs, T. E., & Mastropieri, M. A. (2011). Science education and students with learning disabilities. Learning Disabilities Research & Practice, 26(4), 223-232. https://doi.org/10.1111/j.1540- 5826.2011.00343.x

Bugden, S., & Ansari, D. (2016). Probing the nature of deficits in the 'approximate number system in children with persistent developmental dyscalculia. *Developmental Science*, *19*(5), 817-833.

Busk, P. L., & Serlin, R. C. (1992). Meta-analysis for single-case research. T. Kratochwill & J. Levin (Eds.), *Single case research design and analysis* (pp. 187-212). London: Routledge.

Cacciatore, G. (2018). Video Prompting Delivered via Augmented Reality to Teach Transition-Related Math Skills to Adults with Intellectual Disabilities. Master Thesis, Brigham Young University.

Cakir, R., & Korkmaz, O. (2019). The effectiveness of augmented reality environments on individuals with special education needs. *Education and Information Technologies 24* (2), 1631–1659. https://doi:10.1007/s10639-018-9848-6.

Cascales-Martínez, A., Martínez-Segura, M. J., Pérez-López, D., & Contero, M. (2016). Using an augmented reality enhanced tabletop system to promote learning of mathematics: A case study with students with special educational needs. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(2), 355-380. https://doi 10.12973/eurasia.2017.00621a.

Cook, B. G., Collins, L. W., Cook, S. C., & Cook, L. (2019). Evidencebased reviews: How evidence based practices are systematically identified. *Learning Disabilities Research & Practice*, *35*(1), 6-13. https://doi.org/10.1111/ldrp.12213

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). How to design and evaluate research in education (Eight Edition). New York: McGraw-Hill.

Garner, P. (2009). Special educational needs: The key concepts. Routledge.

Horner, R. H., Carr, E. G., Halle, J., McGee, G., Odom, S., & Wolery, M. (2005). The use of single-subject research to identify evidence-based practice in special education. *Exceptional Children*, *71*(2), 165-179. https://doi.org/10.1177/001440290507100203

Jerome, J., Frantino, E. P., & Sturmey, P. (2007). The effects of errorless learning and backward chaining on the acquisition of internet skills in adults with developmental disabilities. *Journal of Applied Behavior Analysis, 40*(1), 185–189. https://doi.org/10.1901/jaba.2007.41-06.

Karaçam, Z. (2013). Systematic Review Methodology: A Guide for Preparation of Systematic Review. *Dokuz Eylul University Electronic Journal*, 6(1), 26-33

Karaer, G. & Melekoglu, M. A. (2020). Review of studies on teaching science to students with specific learning disabilities. Ankara University Faculty of Educational Sciences Journal of Special Education, 21(4), 789- 819. doi: 10.21565/ozelegitimdergisi.532903

Kellems, R. O., Eichelberger, C., Cacciatore, G., Jensen, M., Frazier, B., Simons, K., & Zaru, M. (2020). Using video-based instruction via augmented reality to teach mathematics to middle school students with learning disabilities. *Journal of Learning Disabilities*, *53*(4), 277-291. https://doi.org/10.1177/0022219420906452.

Kim, B. (2017). The Effectiveness of Mixed Reality-Based Intervention for Children with Autism Spectrum Disorders: A Meta-Analysis and Single-Case Study." Doctoral diss., Knoxville: University of Tennessee.

Klopfer, E., & Squire, K. (2008). Environmental Detectives—the development of an augmented reality platform for environmental simulations. *Education Tech Research Development, 56*(2), 203–228. https://doi.org/10.1007/s11423-007-9037-6.

Klopfer, E., & Yoon, S. (2005). Developing games and simulations for today and tomorrow's tech savvy youth. *Tech Trends*, *49*(3), 33-41.

Kratochwill, T. R., & Stoiber, K. C. (2002). Evidence-based interventions in school psychology: Conceptual foundations of the procedural and coding manual of division 16 and the society for the study of school psychology task force. *School Psychology Quarterly*, *17*(4), 341-389. https://doi.org/10.1521/scpq.17.4.341.20872

Kulage, K. M., Goldberg, J., Usseglio, J., Romero, D., Bain, J. M., & Smaldone, A. M. (2020). How has DSM-5 affected autism diagnosis? A 5-year follow-up systematic literature review and meta-analysis. *Journal of Autism and Developmental Disorders*, *50*(6), 2102-2127. https://doi.org/10.1007/s10803-019-03967-5

Lee, J., Bryant, D. P., Ok, M. W., & Shin, M. (2021). A systematic review of interventions for algebraic concepts and skills of secondary students with learning disabilities. *Learning Disabilities Research & Practice*, *35*(2), 89-99. https://doi.org/10.1111/ldrp.12217

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

McMahon, D. D., Cihak, D. F., Wright, R. E., & Bell, S. M. (2016). Augmented reality for teaching science vocabulary to postsecondary education students with intellectual disabilities and autism. *Journal of Research on Technology in Education*, *48*(1), 38–56. http://dx.doi.org/10.1080/15391523.2015.1103149.

McMahon, D., Cihak, D., & Wright, R. (2015a). Augmented reality as a navigation tool to employment opportunities for postsecondary education students with with ıntellectual disabilities and autism. *Journal of Research on Technology in Education 47*(3), 157–172. https://doi.org/10.1080/15391523.2015.1047698.

McMahon, D., Cihak, D., Gibbons, M., Fussell, L., & Mathison, S. (2013). Using a mobile app to teach ındividuals with ıntellectual disabilities to ıdentify potential food allergens. *Journal of Special Education Technology 28(3)*, 21–32. https://doi.org/10.1177/016264341302800302.

McMahon, D., Smith, C., Cihak, D., Wright, R., & Gibbons, M. (2015b). Effects of digital navigation aids on adults with ıntellectual disabilities: Comparison of paper map, google maps, and augmented reality. *Journal of Special Education Technology 30*(3), 157–165. https://doi.org/10.1177/0162643415618927.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine*, *151*(4), 264-269 7.

Morris, J. (2019). Effects of an Explicit Instruction and Video Modeling Intervention with Augmented Reality on the Rational Number Mathematics Outcomes of Students with Disabilities Doctoral Dissertations, The Pennsylvania State University.

Mundy, M. A., Hernandez, J., & Green, M. (2019). Perceptions of the Effects of Augmented Reality in the Classroom. *Journal of Instructional Pedagogies*, *22*, 1-15.

NCDL (2017). https://www.ncld.org/

Odom, S. L., Brantlinger, E., Gersten, R., Horner, R. H., Thompson, B., & Harris, K. R. (2005). Research in special education: Scientific methods and evidence-based practices. *Exceptional Children*, *71*(2), 137-148. https://doi.org/10.1177/001440290507100201

Özkubat, U., Akçayır, İ., & Özpınar, M. (2020). Science Education with Intelligence Games for Students with Learning Disabilities. Çıkılı, Y., Yüksel, İ. (Eds), Science Education and Activity Examples with Intelligence Games for Students with Special Education Needs (pp. 77-104). Nobel Academic.

Özkubat, U., Karabulut, A., & Sert, C. (2021). Math problem solving interventions for middle school students with learning disabilities: A comprehensive literature review. *Ankara University Faculty of Educational Sciences Journal of Special Education*, Advance Online Publication. https://doi.org/10.21565/ozelegitimdergisi.774650

Price, G. R., & Ansari, D. (2013). Dyscalculia: Characteristics, causes, and treatments. *Numeracy*, *6*(1), 1-16.

Salah, J., Abdennadher, S., & Atef, S. (2017, November 23–24). Galaxy shop: Projection-based numeracy game for teenagers with down syndrome. In Joint International Conference on Serious Games (pp. 109–120). Springer. https://doi.org/10.1007/978-3-319-70111-0_10.

Sanır, H., & Özkubat, U. (2018). Learning Disability During the Preschool Period. In Deniz, U. (Ed.), Currents Trends in Preschool Education (p. 70-96). Lambert Academic Publishing.

Smith, C. C., Cihak, D. F., Kim, B., McMahon, D. D., & Wright, R. (2016). Examining augmented reality to improved navigation skills in postsecondary students with intellectual disability. *Journal of Special Education Technology*, *32*, 3–11.

Smith, C. C., Cihak, D., Kim, B., McMahon, D., & Wright, R. (2017). Examining augmented reality to ımprove navigation skills in postsecondary students with ıntellectual disability. *Journal of Special Education Technology 32*(1), 3–11. https://doi.org/10.1177/0162643416681159.

Swanson, H. L. (2010). Meta-analysis of research on children with reading disabilities. In *Handbook of reading disability research* (pp. 489-499). Routledge.

Tankersley, M., Cook, B. G., & Cook, L. (2008). A preliminary examination to identify the presence of quality indicators in single-subject research. *Education and Treatment of Children, 31*(4), 523-548.

Turan, Z., & Atila, G. (2021): Augmented reality technology in science education for students with specific learning difficulties: Its effect on students' learning and views. *Research in Science & Technological Education*, Advance Online Publication. https://doi.org/10.1080/02635143.2021.1901682

Walker, Z., McMahon, D. D., Rosenblatt, K., & Arner, T. (2017). Beyond Pokémon: Augmented Reality Is a Universal Design for Learning Tool. *SAGE Open*. https://doi.org/10.1177/2158244017737815.