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The Impacts of Mathematics Instructional Strategy on Students with Autism: A Systematic Literature Review

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Abstract: Mathematics is one of the most challenging subjects for many students. A similar problem is faced by special needs students, such as students with Autism Spectrum Disorder (ASD). Various instructional strategies are implemented by specialists to help ASD students understand mathematics in schools. To explore the impacts of an instructional strategy of mathematics on ASD students, the authors conducted a review of literature from 2011 to 2017 using various databases including ProQuest Digital Dissertations and Theses Full Text, Google Scholar, and Science Direct. A total of 39 articles were found. Most of the instructional strategy aimed to assist ASD students in solving mathematics problems. The implications of the study are also discussed in this literature review, which indicates that teachers need to use the appropriate instructional strategy to meet the needs of students with ASD and maximize their mathematics learning outcomes in schools.

Keywords: *Mathematics, instructional design, autism spectrum disorder, systematic literature review.*

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Introduction

Autism is the developmental disruption of a person's neurological system in terms of his or her social and communication skills, limited and repetitive behaviour, information processing senses, and experience of an uncommon and variety of interests when doing tasks (Autism Spectrum Disorder, 2018; Hood, 2015; Iuculano et al., 2014; Jx et al., 2017; Oie, 2016). Examples of such interruptions are language delay, lack of social interaction in the environment, unstable emotions, persistent preoccupation with objects of interest, and intellectual deficiencies (Baio et al., 2018). Often, these interruptions are not easily identified by individuals, because students diagnosed with autism spectrum disorder (ASD) can typically communicate, interact, and learn (Autism Spectrum Disorder, 2018).

Some students diagnosed with ASD develop faster than students with other types of disorder (Oie, 2016; Whitby, 2012) such as emotional disorders, intellectual disability, deafness, orthopeadic impairment, learning disabilities, traumatic brain injury, hearing loss, speech impairment, vision impairment, language impairment as well as other health impairment (Ging et al., 2018; Pichitpunpong et al., 2019; Wright et al., 2015; Yusoff et al., 2018). The number of students diagnosed with ASD has increased by 78 per centover the last decade, and in every 59 children, there is one child with ASD (Baio et al., 2018). Therefore, there is an urgent need for an education system with effective teaching and learning of mathematics for ASD students (Oie, 2016; Whitby, 2012; Yusaini et al., 2019), considering that half a million ASD children will enter adulthood over the next decade (Baio et al., 2018). If this need is not met, it can negatively affect the quality of ASD children in the future (Roux et al., 2013; Taylor & Mailick, 2014). Mathematics is no deemed challenging to understand for most students, but especially for ASD students, as mathematics is abstract. Appropriate teaching and learning can help ASD students overcome the problem-solving limitations that they

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encounter in the learning process (Root et al., 2017; Vanmeirhaeghe, 2012). Furthermore, one way to improve ASD students' cognitive development is by learning mathematics, which can help to organize the students' brains (Iuculano et al., 2014).

Some students diagnosed with ASD have difficulties in mathematics because learning mathematics requires a high level of cognitive ability. Moreover, having a slower understanding compared to their peers, it is difficult for them to learn complex and high-level thinking concepts (Casner, 2016; Hallahan, 2015). Students diagnosed with ASD often struggle to gain a good understanding of mathematical concepts while learning the subject (Burney, 2015). To ensure that they can understand, teachers implement repetitive ASD methods (Hallahan, 2015). However, to date, researches have shown that the teaching and learning of mathematics for students diagnosed with ASD yield a variety of outcomes (Gevarter et al., 2016; Titeca et al., 2014). Carlson et al. (2011) and Wei et al. (2013) showed that the mathematics skills and mathematics test scores of students diagnosed with ASD were lower than those of students with other disabilities.

Concrete evidence-based instruction is commonly used by teachers to overcome the constraints of learning mathematics among students diagnosed with ASD (Green, 2014)—for example, using visual supports such as numbered cards, graphic columns, graphic organizers, numbered lines, highlighted keywords and written models (Casner, 2016). With the use of visual aids, students diagnosed with ASD respond well to mathematics topics such as identification, the use of calculators, number recognition, calculations, algebra, money and geometry skills (Hughes & Yakubova, 2019). Furthermore, students who learn in the kinaesthetic style are those who learn better using physical movements (Ahad & Ahmad, 2019) such as the self and match method or hands-on (Croce, 2015; Vitalo, 2017). The kinaesthetic learning style implemented in mathematical learning means that teachers show the numbers from 0 to 20 using physical interaction (Okkonen et al., 2016). On the other hand, auditory learning styles involve the transfer of information through hearing (Ahad & Ahmad, 2019)—for instance, stories and storybooks (Green, 2014; Jimenez & Kemmery, 2013). Teachers create appropriate questions and ask students verbally, conducting question-and-answer sessions during the teaching and learning process. For example, a teacher asks students to count out loud correct numbers written in a workbook, and the student say the numbers 1, 2, 3 and 4 (Green, 2014).

In implementing appropriate instructional types in the learning process, teachers are always concerned to identify students with ASD students according to their learning style: visual, kinaesthetic or auditory (Meshram & Vaishnav, 2020). Choosing the right learning style, teacher attitude and school administration to manage and implement the programme can positively impact ASD learning outcomes (Mezquita-Hoyos et al., 2018; Ozen & Topal, 2019).

Methodology and Results

This section discusses the steps used in the literature review to answer a given research question. In accordance with Khan et al. (2003), five stages were applied to conduct the literature review, namely 1) developing the research question; 2) identifying articles; 3) evaluating articles' appropriateness; 4) summarizing articles; and 5) interpreting articles' findings.

Step I: Developing the Research Question

Developing the research question is an important step, as it forms the basis for initiating the study (Squires et al., 2013). Also, this help find and define the terms or keywords that fit the scope of the study by using databases, narrowing and refining the questions and reducing errors (Parfrey & Ravani, 2008; Squires et al., 2013). The research question for this literature review is: What were the methods of teaching mathematics to students diagnosed with ASD between the years 2011 and 2017?

Step II: Identifying Articles

This section discusses two steps to identify related articles. The first step was to identify the right keywords in the search process using the database. The keywords used were "Mathematics Instruction for Autism Students"; "Mathematics AND Autism"; "Mathematics AND Disorder"; "Mathematics AND Disability"; and "Mathematics AND Students with ASD". The databases used in this literature review are a) ProQuest Digital Dissertations and Theses Full Text, b) Google Scholar and c) ScienceDirect. The search was limited to articles published between 2011 and 2017. The second step was to search for the articles, which resulted in 49,800 articles (ProQuest: n = 37,900; Google Scholar: n = 11,186; ScienceDirect: n = 714). It was found that not all of the articles met the topics required in this study. Therefore, the second round of the search was conducted, which resulted in a total of 52 articles. The final step was to review the articles in depth.

It was found that only 39 articles met the criteria. All articles were theses, dissertations and journal articles. The eligibility criteria that constituted inclusion in this review were: (a) published on a valid database; b) involved students at the preschool, primary and secondary levels; c) involved students diagnosed with ASD; d) experimental research design; e) reporting teaching and learning applied by teachers in teaching mathematics; and f) published in English.

A total of 13 articles were excluded, eight for having a non-experimental research design (i.e. Carlson et al., 2011; Hood, 2015; Judge & Watson, 2011; Morgan et al., 2011; Schulte & Stevens, 2015; Stevens et al., 2015; Wei et al., 2013; Whitby, 2012), one for not involving ASD students (i.e. Praet et al., 2013), and four for being literature reviews (i.e. Kim & Cameron, 2016; Klaren et al., 2017; Powell et al., 2013; Su et al., 2012).

Step III: Evaluating Articles

Inclusion and exclusion criteria were set and established to evaluate the suitability of the articles for this literature review. Both requirements were intended to act as feedbacks to achieve the objectives of the review. In addition, the aim of setting the criteria was to optimize the external and internal validity of the studies. The most critical aspect in evaluating individual article always refers to "what methods are used by the teachers in teaching mathematics to students diagnosed with ASD." This literature review is based on a recent study by Hord and Bouck (2012, who asked what kind of academic instruction in mathematics was used to teach students diagnosed with mild intellectual disability (MID) in the last 11 years. The conclusions drawn from the findings of Hord and Bouck (2012) suggested that a majority of teachers were concerned with the planning of mathematics teaching interventions to improve computational procedures, knowledge of mathematical facts, and mathematical problem-solving. Some of the interventions implemented by teachers were 1) using flashcards, 2) using traditional algorithms, and 3) using technology. In addition, Desoete et al. (2013) and Praet et al. (2013) suggested that teachers' knowledge plays a significant role in determining the method of intervention or type of instruction in the teaching and learning of mathematics to address the needs of students with disabilities.

Step IV: Summarizing Articles

The researcher summarized the related articles to answer the research question (Oxman et al., 2002). As stated in step II, the articles used in this study underwent several screening steps based on the determined criteria until only 39 articles remained. A total of 13 articles were excluded because they did not meet the criteria of this study. The articles were all relevant to the topic to be discussed in this literature review, mathematical instruction for autistic students. Galvan and Galvan (2017) encouraged the development of a table that would assist researchers in compiling, summarizing and concluding articles that are in line with the literature review. Table 1 below details the articles used in this literature review.

Table 1. Source of selected articles

Database	**N**	**n**
Google Scholar	39	29
ProQuest Digital Dissertations and Theses Full Text	10	9
Science Direct	3	1
Total	52	39

Step V: Interpreting Findings

A total of 39 articles were included based on the inclusion and exclusion criteria. The next step was to perform the coding process based on the information obtained from the study. The purpose of the coding process is to examine the mathematics instructions used during the seven-year period under study. Codes were given according to the characteristics of the study—e.g. author, number of participants, study area, instructional strategy, study design, teaching duration. A summary of the research findings is given in Appendix A. Data in Appendix A present the specific instructional strategies implemented by teachers during the teaching and learning of mathematics. The application of instructional strategies was based on students with different ASD learning styles, which are categorized as visual (V), kinaesthetic (K), auditory (A) or a combination of VKA. The analysis showed that teachers more often implement visual teaching styles than kinaesthetic, auditory or VKA styles. Twenty-two empirical studies apply visual teaching styles, such as (a) concrete-representational-abstract; (b) mathematical word problem-solving interventions; (c) non-symbolic and symbolic number word; (d) schematic approach; (e) writing equations on paper; (f) real-life problems; (g) using materials that are both concrete (physical objects) and virtual (3-D objects on the computer); (h) video modelling package based on iPad; (i) number line mapping; (j) strategic schema-based instruction; (k) modified schema-based instruction; (l) flash cards; (m) numerical competencies; (n) mathematics based on conceptual approach; (o) the role of specific symbolic difference; (p) special cognitive criteria; (q) e-book education; (r) executive functioning; (s) computer-aided instruction; (t) interactive whiteboard and discrete trial training; (u) mathematical facts mastery; and (v) metacognitive, based on the computer. Interestingly, SBI is the most frequently used instructional strategy (Aagten-Murphy et al., 2015; Bae, 2013; Bae et al., 2015; Bouck et al., 2014; Burney, 2015; Casner, 2016; Cox & Root, 2018; Cravalho et al., 2014; Delisio et al., 2018; Desoete, 2012; Fries, 2013; Göransson, 2016; Hansen, 2014; Henning, 2018; Hiniker, 2016; Jowett et al., 2012; Kasap & Ergenekon, 2017; Maajeeny, 2017; Maras et al., 2017;

Oie, 2016; Rasmussen & Bisanz, 2011; Rockwell, 2012; Rockwell et al., 2011; Root et al., 2017, 2018; Shamir & Baruch, 2012; Titeca et al., 2014; Toll et al., 2011).

The remaining 11 studies integrated either A, K or a combination of several teaching styles. Only five empirical studies in Appendix A implemented instructional strategies based on kinaesthetic learning: for example, (a) self and match, (b) hand technique and manipulation, (c) mathematical cognition, (d) mathematics recovery programme and (e) functional magnetic resonance imaging (Croce, 2015; Geary et al., 2012; Iuculano et al., 2014; Tzanakaki et al., 2014; Vitalo, 2017). Another three studies used instructional strategies based on auditory learning styles such as (a) mathematics instruction based on stories with systematic instruction; (b) metacognitive monitoring (one-on-one); and (c) storybooks (Brosnan et al., 2016; Green, 2014; Jimenez & Kemmery, 2013). The final three studies utilizing a combination of several instructional strategies, namely (a) clinical and cognitive criteria, (b) mathematical problem-solving, and (c) the multi-component approach (Alter, 2011; Oswald et al., 2016; Titeca et al., 2015).

Discussion

The majority of the researchers designed learning methods for students diagnosed with ASD based on the data from formative and summative assessments to identify the needs of the students in the teaching and learning process before a learning plan was created (Forbringer & Fuchs, 2014; Hagaman et al., 2013). Students who succeed in studying mathematics possess two types of knowledge: (a) conceptual understanding and (b) procedural skills (Rittle-Johnson, 2017). Conceptual understanding is a student's ability to understand the principles of mathematics or the relationship underlying the targeted concepts (Rittle-Johnson & Schneider, 2015). However, conceptual understanding is one of the most challenging aspects for students diagnosed with ASD to achieve, because they have impaired functional skills (Happe et al., 2006), making it difficult to grasp the multidimensional relationships that require knowledge of many mathematics concepts (Rittle-Johnson & Schneider, 2015). For example, when teaching fractions to students diagnosed with ASD, teachers must be able to relate previous knowledge of the whole number and use concrete models to scaffold knowledge construction.

Meanwhile, procedural skills denote the ability of students to identify which procedure needs to be used to find the right answer (Rittle-Johnson & Schneider, 2015). The most challenging problem for students diagnosed with ASD is the difficulty they face when translating mathematical forms into mathematical concepts and applying them to solve mathematical problems (Root et al., 2017). By emphasizing high conceptual and procedural understanding, students diagnosed with ASD will be able to use the knowledge they have to solve mathematical problems (Common Core State Standards Initiative, 2014; Griffin et al., 2013; Rockwell et al., 2011).

The results show that students with ASD are poor at understanding new information and procedural computation (Gomot & Wicker, 2012; Maes et al., 2011). Thus, we need to change our perception that there is a need for an instructional strategy that emphasizes student engagement, building own knowledge, discussion, exploration, communication and working in groups (Griffin et al., 2013). In the 39 articles obtained, the most frequent method used by researchers was the schema-based method, as studied by Bae (2013), Casner (2016), Cox and Root (2018), Delisio et al. (2018), Kasap and Ergenekon (2017), Rockwell (2012), Rockwell et al. (2011) and Root et al. (2017, 2018). The schematic strategy emphasizes the grasp of procedural concepts and step-by-step skills, aided by visual representations in the form of images or diagrams, and numerical equations which are suitable to solve the problem (Fang et al., 2015; Jitendra & Star, 2011). In addition, this strategy emphasizes computational skills (addition and subtraction) and problem-solving (Forbringer & Fuchs, 2014; Rockwell, 2012). The modified schema strategy focuses on three aspects of instruction: 1) the technique of solving problems in writing and pairing them with pictures; b) every image being colour-coded or coded with the main criteria from the type of problem (concrete scheme); and c) clearly and systematically emphasizing each step of the question so that the students can understand in more depth the concept of the knowledge and the procedural skills (Root et al., 2017). This strategy has assisted ASD students in computational problems, solving mathematical problems, and improving their cognitive abilities (Rockwell et al., 2011; Spooner et al., 2017). Meanwhile, the second method is computer-based (iPad-based video modelling, physical objects and 3-D virtual objects). This method is based on conceptual approaches (symbolic numbers, flashcards, CRAs, and real-life problems).

Conclusion

Instructional strategies implemented by teachers are one way to improve the quality of teaching in schools, especially for students with ASD. Many studies have called for a change in the way teachers teach mathematics as a subject in schools and have encouraged comparisons with instructional strategies used globally. Effective mathematics-based methods have a positive impact on ASD students' skills in solving mathematical problems. Therefore, teachers should use instructional strategies to meet the needs of students to maximize their learning outcomes in schools.

Recommendation

Based on the findings, it is recommended that other researchers further identify teachers applying instructional strategies based on (a) the type of learning style, (b) age, (c) gender, and (d) family background of each study, and (d) analyse the interaction between these variables.

Limitations

There are several limitations to this study. The article search process was based on particular keywords, so the researcher only obtained a few articles. Moreover, the researcher set appropriate article criteria for analysis in this study so that the citation information obtained was more limited. The databases used in this study were ProQuest Digital Dissertations and Theses Full Text, Google Scholar and ScienceDirect. The most cited database is Google Scholar. Future studies need to find and use more diverse databases with a longer duration.

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References

*References marked with an asterisk indicate studies included in the systematic literature review.

*Aagten-Murphy, D., Attucci, C., Andiel, N., Klaric, E., Burr, D., & Pellicano, E. (2015). Numerical estimation in children with autism. *Autism Research*, *8*(6), 668-681. https://doi.org/10.1002/aur.1482

Ahad, S. M., & Ahmad, N. A. (2019). A conceptual framework for makeupbed module in helping learning disabilities improving make up guest bed skills. *International Journal of Academic Research in Business and Social Sciences*, *9*(11), 1161-1171. https:// doi.org/10.6007/IJARBSS/v9-i11/6644

*Alter, P., Brown, E. T., & Pyle, J. (2011). A strategy-based intervention to improve math word problem-solving skills of students with emotional and behavioral disorders. *Education and Treatment of Children*, 535-550. https://doi.org/10.1353/etc.2011.0028

Autism Spectrum Disorder (2018). *Facts about ASD*. CDC Autism Spectrum Disorder (ASD). https://www.cdc.gov/ncbddd/autism/facts.html

*Bae, Y. S. (2013). *Word problem solving of students with autistic spectrum disorders and students with typical development* [Unpublished doctoral dissertation]. Columbia University.

*Bae, Y. S., Chiang, H. M., & Hickson, L. (2015). Mathematical word problem solving ability of children with autism spectrum disorder and their typically developing peers. *Journal of Autism and Developmental Disorders*, *45*(7), 2200-2208. https://doi.org/10.1007/s10803-015-2387-8

Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., Kurzius-Spencer, M., Zahorodny, W., Rosenberg, C. R., White, T., Durkin, M. S., Imm, P., Nikolaou, L., Yeargin-Allsopp, M., Lee, L., Harrington, R., Lopez, M., Fitzgerald, R. T., Hewitt, A., … & Dowling, N. F. (2018). Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 11 sites, United States, 2014. *MMWR Surveillance Summaries*, *67*(6), 1-23. https://doi.org/10.15585/mmwr.ss6706a1

*Bouck, E. C., Satsangi, R., Doughty, T. T., & Courtney, W. T. (2014). Virtual and concrete manipulatives: A comparison of approaches for solving mathematics problems for students with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *44*(1), 180-193. https://doi.org/10.1007/s10803-013-1863-2

*Brosnan, M., Johnson, H., Grawemeyer, B., Chapman, E., Antoniadou, K., & Hollinworth, M. (2016). Deficits in metacognitive monitoring in mathematics assessments in learners with autism spectrum disorder. *Autism*, *20*(4), 463-472. https://doi.org/10.1177/1362361315589477

*Burney, S. L. (2015). *Interventions to improve student achievement in mathematics for middle school students with autism* [Unpublished master's thesis]. Georgia College and State University.

Carlson, E., Jenkins, F., Bitterman, A., & Keller, B. (2011). A longitudinal view of the receptive vocabulary and math achievement of young children with disabilities (NCSER 2011-3006). ERIC. https://files.eric.ed.gov/fulltext/ED523202.pdf.

Casner, B. 2016. *A mixed method study on schema-based instruction, mathematical problem solving skills, and students with an educational disability* [Unpublished doctoral dissertation]. Lindenwood University.

Common Core State Standards Initiative (CCSSI). (2014). *Common core state standards for mathematics*. http://www.corestan dards.org/assets/CCSSI_Math%20Standards.pdf.

*Cox, S. K., & Root, J. R. (2018). Modified schema-based instruction to develop flexible mathematics problem-solving strategies for students with autism spectrum disorder. *Remedial and Special Education*, 1-13. https://doi.org/10.1177/0741932518792660

*Cravalho, C. J., McLaughlin, T. F., Derby, K. M., & Waco, T. (2014). The effects of direct instruction flashcards on math performance with measures of generalization across elementary students with learning disabilities and autism spectrum disorder. *International Journal of Basic and Applied Science*, *2*(4), 16-31. ERIC.

*Croce, K. M. (2015). *Effectiveness of self & match as an intervention for increasing appropriate classroom behavior in children with autism spectrum disorders* [Unpublished doctoral dissertation]. Saint Joseph's University.

*Delisio, L. A., Bukaty, C. A., & Taylor, M. (2018). Effects of a graphic organizer intervention package on the mathematics word problem solving abilities of students with autism spectrum disorders. *Journal of Special Education Apprenticeship*, *7*(2), 1-22. https://files.eric.ed.gov/fulltext/EJ1185372.pdf

*Desoete, A., Ceulemans, A., De Weerdt, F., & Pieters, S. (2012). Can we predict mathematical learning disabilities from symbolic and non-symbolic comparison tasks in kindergarten? Findings from a longitudinal study. *British Journal of Educational Psychology*, *82*(1), 64-81. https://doi.org/10.1348/2044-8279.002002

Desoete, A., Praet, M., Titeca, D., & Ceulemans, A. (2013). Cognitive phenotype of mathematical learning disabilities: What can we learn from siblings? *Research in Developmental Disabilities*, *34*(2013), 404-412. https://doi.org/10.1016/j.ridd.2012.08.022

Fang, H., Hartsell, T., Herron, S., Mohn, R., & Zhou, Q. (2015). The effects of simplified schema-based instruction on elementary students' mathematical word problem solving performance. *Journal of Mathematics Education*, *8*(1), 37-55.

Forbringer, L., & Fuchs, W. (2014). *RtI in math: Evidence-based interventions for struggling students*. Routledge.

*Fries, K. M. (2013). *Effectiveness of mastering math facts on second-and third-grade students with specific learning disabilities in mathematics* [Unpublished doctoral dissertation]. The Pennsylvania State University.

Galvan, J. L. & Galvan, M. C. (2017). *Writing literature reviews: A guide for students of the behavioral sciences.* Routledge

*Geary, D. C., Hoard, M. K., Nugent, L., & Bailey, D. H. (2012). Mathematical cognition deficits in children with learning disabilities and persistent low achievement: A five-year prospective study. *Journal of Educational Psychology*, *104*(1), 206-223. https://doi.org/10.1037/a0025398

Gevarter, C., Bryant, D. P., Bryant, B., Watkins, L., Zamora, C., & Sammarco, N. (2016). Mathematics interventions for individuals with Autism Spectrum Disorder: A systematic review. *Review Journal of Autism and Developmental Disorders*, *3*(3), 224-238. https://doi.org/10.1007/s40489-016-0078-9

Ging, W. G., Din, N. C., & Ahmad, M. (2018). The development and feasibility evaluation of a module in improving functioning of children with Autism Spectrum Disorder (ASD). *Malaysian Journal of Public Health Medicine, Special Volume(1)*, 146-155.

Gomot, M., & Wicker, B. (2012). A challenging, unpredictable world for people with autism spectrum disorder. *International Journal of Psychophysiology, 83*(2), 240-247. https://doi.org/10.1016/J.Ijpsycho.2011.09.017

*Göransson, K., Hellblom-Thibblin, T., & Axdorph, E. (2016). A conceptual approach to teaching mathematics to students with intellectual disability. *Scandinavian Journal of Educational Research*, *60*(2), 182-200. https://doi.org/10.1080/00313831.2015.1017836

*Green, K. B. (2014). *The effects of the integration of mathematics within children's literature on early numeracy skills of young children with disabilities* [Unpublished doctoral dissertation]. Georgia State University.

Griffin, C., League, M., Griffin, V., & Bae, J. (2013). Discourse practices in inclusive elementary mathematics classrooms. *Learning Disability Quarterly*, *36*(1), 9-20. https://doi.org/10.1177/0731948712465188

Hagaman, J., Lienemann, T., & Reid, R. (2013). *Strategy instruction for students with learning disabilities.* Guilford Press.

Hallahan, D. (2015). *Exceptional learners: An introduction to special education.* Pearson.

*Hansen, M. (2014). *Helping children with autism learn with mathematics software* [Unpublished doctoral dissertation]. Nova Southeastern University.

Happe, F., Booth, R., Charlton, R., & Hughes, C. (2006). Executive function deficits in autism spectrum disorders and attention-deficit/hyperactivity disorder: Examining profiles across domains and ages. *Brain and Cognition*, *61*(1), 25-39. https://doi.org/10.1016/j.bandc.2006.03.004

*Henning, B. L. (2018). *Using number talks with supports to increase the early number sense skills of preschool students with autism spectrum disorder* [Unpublished doctoral dissertation]. Florida State University.

*Hiniker, A., Rosenberg-Lee, M., & Menon, V. (2016). Distinctive role of symbolic number sense in mediating the mathematical abilities of children with autism. *Journal of Autism and Developmental Disorders*, *46*(4), 1268-1281. https://doi.org/10.1007/s10803-015-2666-4

Hood, D. R. (2015). *Elementary school transition and the reading and math achievement of students with autism spectrum disorder, traumatic brain injury, or emotional behavioral disturbance* [Unpublished doctoral dissertation]. University of Oregon.

Hord, C., & Bouck, E. C. (2012). Review of academic mathematics instruction for students with mild intellectual disability. *Education and Training in Autism and Developmental Disabilities*, *47*(3), 389-400.

Hughes, E.M., Yakubova, G. (2019). Addressing the mathematics gap for students with ASD: An evidence-based systematic review of video-based mathematics interventions. *Review Journal of Autism and Development Disorders*, 6, 147–158. https://doi.org/10.1007/s40489-019-00160-3

*Iuculano, T., Rosenberg-Lee, M., Supekar, K., Lynch, C. J., Khouzam, A., Phillips, J., Uddin, L. Q., & Menon, V. (2014). Brain organization underlying superior mathematical abilities in children with autism. *Biological Psychiatry, 75*(3), 223-230. https://doi.org/10.1016/j.biopsych.2013.06.018

*Jimenez, B. A., & Kemmery, M. (2013). Building the early numeracy skills of students with moderate intellectual disability. *Education and Training in Autism and Developmental Disabilities*, *48*(4), 479-490.

Jitendra, A, & Star. (2011). Meeting the needs of students with learning disabilities in inclusive mathematics classrooms: The role of schema-based instruction on mathematical problem-solving. *Theory into Practice*, *50*(1), 12-19. https://doi.org/10.1080/00405841.2011.534912

*Jowett, E. L., Moore, D. W., & Anderson, A. (2012). Using an iPad-based video modelling package to teach numeracy skills to a child with an Autism Spectrum Disorder. *Developmental Neurorehabilitation*, *15*(4), 304-312. https://doi.org/10.3109/17518423.2012.682168

Judge, S., & Watson, S. M. R. (2011). Longitudinal outcomes for mathematics achievement for students with learning disabilities. *Journal of Educational Research*, *104*(3), 147-157. https://doi.org/10.1080/002206710036367

Jx, L., Si, O., Vy, L., & Ar, F. N. (2017). Parenting stress among Malaysian parents of children with Autism Spectrum Disorder (ASD). *Med & Health, 12*(1), 42-55. https://doi.org/10.17576/MH.2017.1201.06

*Kasap, C., & Ergenekon, Y. (2017). Effects of a schema approach for the achievement of the verbal mathematics problem-solving skills in individuals with autism spectrum disorders. *Educational Sciences: Theory & Practice/ Kuram ve Uygulamada Egitim Bilimleri*, *17*(6), 1787-1809. https://doi.org/10.12738/estp.2017.6.0660

Khan, K. S., Kunz, R., Kleijnen, J., & Antes, G. (2003). Five steps to conducting a systematic review. *Journal of the Royal Society of Medicine*, *96*(3), 118-121.

Kim, H., & Cameron, C. E. (2016). Implications of visuospatial skills and executive functions for learning mathematics: Evidence from children with autism and Williams syndrome. *AERA Open*, *2*(4), 1-16. https://doi.org/10.1177/2332858416675124

Klaren, M., Pepin, B., & Thurlings, M. (2017, February). *Autism and mathematics education*. https://hal.archives-ouvertes.fr/hal-01925514/document

*Maajeeny, F. S. (2017). *The effects of interactive whiteboard instruction on early numeracy skills of students with autism spectrum disorders* [Unpublished doctoral dissertation]. University of Maryland.

Maes, J. H. R., Eling, P., Wezenberg, E., Vissers, C., & Kan, C. C. (2011). Attentional set shifting in autism spectrum disorder: Differentiating between the role of perseveration, learned irrelevance, and novelty processing. *Journal of Clinical and Experimental Neuropsychology*, *33*(2), 210-217. https://doi.org/10.1080/13803395.2010.501327

*Maras, K., Gamble, T., & Brosnan, M. (2017). Supporting metacognitive monitoring in mathematics learning for young people with autism spectrum disorder: A classroom-based study. *Autism*, *23*(1), 60-70. https://doi.org/10.1177/1362361317722028

Meshram, J. D., & Vaishnav, R. (2020). Multimedia as a method of enhanced learning for students with learning disabilities. *Our Heritage*, *68*(9), 1176-1184.

Mezquita-Hoyos, Y. N., Sanchez-Monroy, M. H., Morales-Martinez, G. E., Lopez-Ramirez, E. O., & del Roble Reyna-Gonzalez, M. (2018). Regular and special education Mexican teachers' attitudes toward school inclusion and disability. *European Journal of Educational Research*, *7*(3), 421-430. https://doi.org/10.12973/eu-jer.7.3.421

Morgan, P. L., Farkas, G., & Wu, Q. (2011). Kindergarten children's growth trajectories in reading and mathematics: Who falls increasingly behind? *Journal of Learning Disabilities*, *44*(5), 472-488. https://doi.org/10.1177/0022219411414010

*Oie, M. (2016). Educational instruction in a mathematics class for elementary school children with autism and emotional disorders: The method of instruction for multiplication with calculation writing computation on paper. *International Journal of Education and Research, 4*(11)*,* 331-340.

Okkonen, J., Sharma, S., Raisamo, R., & Turunen, M. (2016). Kinesthetic elementary mathematics-creating flow with gesture modality. *International Journal of Serious Games*, *3*(2), 1-12. https://doi.org/10.17083/ijsg.v3i2.80

*Oswald, T. M., Beck, J. S., Iosif, A. M., McCauley, J. B., Gilhooly, L. J., Matter, J. C., & Solomon, M. (2016). Clinical and cognitive characteristics associated with mathematics problem solving in adolescents with autism spectrum disorder. *Autism Research*, *9*(4), 480-490. https://doi.org/10.1002/aur.1524

Oxman, A., Guyatt, G., Cook, D., & Montori, V. (2002). Summarizing the evidence. *Users' Guides to The Medical Literature a Manual for Evidence-Based Clinical Practice*, 155-173.

Ozen, F., & Topal, T. (2019). The inclusion of social issues in the curricula adopted at the elementary education level in Turkey. *European Journal of Educational Research*, *8*(1), 361-375. http://dx.doi.org/10.12973/eu-jer.8.1.361

Parfrey, P., & Ravani, P. (2008). On framing the research question and choosing the appropriate research design. *Methods in Molecular Biology™*, 1-17. https://doi.org/10.1007/978-1-59745-385-1_1

Pichitpunpong, C., Thongkorn, S., Kanlayaprasit, S., Yuwattana, W., Plaingam, W., Sangsuthum, S., Aizat, W. M., Baharum, S. N., Tencomnao, W., Hu, V. W., & Sarachana, T. (2019). Phenotypic subgrouping and multi-omics analyses reveal reduced diazepam-binding inhibitor (DBI) protein levels in Autism Spectrum Disorder with severe language impairment. *PLoS ONE*, *14*(3), 1-30. https://doi.org/10.1371/journal.pone.0214198

Powell, S. R., Fuchs, L. S., & Fuchs, D. (2013). Reaching the mountaintop: Addressing the common core standards in mathematics for students with mathematics difficulties. *Learning Disabilities Research & Practice*, *28*(1), 38-48.

Praet, M., Titeca, D., Ceulemans, A., & Desoete, A. (2013). Language in the prediction of arithmetics in kindergarten and grade 1. *Learning and Individual Differences*, *27*(2013), 90-96. https:// doi.org 10.1016/j.lindif.2013.07.003

*Rasmussen, C., & Bisanz, J. (2011). The relation between mathematics and working memory in young children with fetal alcohol spectrum disorders. *The Journal of Special Education*, *45*(3), 184-191. https://doi.org/10.1177/0022466909356110

Rittle-Johnson, B. (2017). Developing mathematics knowledge. *Child Developmental Perspectives*, *11*(3), 184-190. https://doi.org/10.1111/cdep.12229

Rittle-Johnson, B., & Schneider, M. (2015). Developing conceptual knowledge of mathematics In R. C. Kadosh & A. Dowker (Eds.), *The Oxford Handbook of Numerical Cognition* (p. 1118–1134). Oxford University Press https://doi.org/10.1093/oxfordhb/9780199642342.013.014

*Rockwell, S. B. (2012). *Teaching students with autism to solve additive word problems using schema-based strategy instruction* [Unpublished doctoral dissertation]. University of Florida.

*Rockwell, S. B., Griffin, C. C., & Jones, H. A. (2011). Schema-based strategy instruction in mathematics and the word problem-solving performance of a student with autism. *Focus on Autism and Other Developmental Disabilities*, *26*(2), 87-95. https://doi.org/10.1177/1088357611405039

*Root, J. R., Browder, D. M., Saunders, A. F., & Lo, Y. Y. (2017). Schema-based instruction with concrete and virtual manipulatives to teach problem solving to students with autism. *Remedial and Special Education*, *38*(1), 42-52. https://doi.org/10.1177/0741932516643592

*Root, J. R., Henning, B., & Boccumini, E. (2018). Teaching students with autism and intellectual disability to solve algebraic word problems. *Education and Training in Autism and Developmental Disabilities*, *53*(3), 325-338.

Roux, A. M., Shattuck, P. T., Cooper, B. P., Anderson, K. A., Wagner, M., & Narendorf, S. C. (2013). Postsecondary employment experiences among young adults with an autism spectrum disorder. *Journal of American Academy of Child and Adolescent Psychiatry*, *52*(9), 931-939. https://doi.org/10.1016/j.jaac.2013.05.019

Schulte, A. C., & Stevens, J. J. (2015). Once, sometimes, or always in special education: Mathematics growth and achievement gaps. *Exceptional Children*, *81*(3), 370-387. https://doi.org/10.1177/0014402914563695

*Shamir, A., & Baruch, D. (2012). Educational e-books: A support for vocabulary and early math for children at risk for learning disabilities. *Educational Media International*, *49*(1), 33-47. https://doi.org/10.1080/09523987.2012.662623

Spooner, F., Saunders, A., Root, J., & Brosh, C. (2017). Promoting access to common core mathematics for students with severe disabilities through mathematical problem solving. *Research & Practice for Persons with Severe Disability*, *42*(3), 171-186. https://doi.org/10.1177/1540796917697119

Squires, J. E., Valentine, J. C., & Grimshaw, J. M. (2013). Systematic reviews of complex interventions: Framing the review question. *Journal of Clinical Epidemiology*, *66*(11), 1215-1222. https://doi.org/10.1016/j.jclinepi.2013.05.013

Stevens, J. J., Schulte, A. C., Elliott, S. N., Nese, J. F., & Tindal, G. (2015). Growth and gaps in mathematics achievement of students with and without disabilities on a statewide achievement test. *Journal of School Psychology*, *53*(1), 45-62. https://doi.org/10.1016/j.jsp.2014.11.001

Su, H. F. H., Lai, L., & Rivera, H. J. (2012). Effective mathematics strategies for preschool children with autism. *Australian Primary Mathematics Classroom*, *17*(2), 25-30.

Taylor, J. L., & Mailick, M. R. (2014). A longitudinal examination of 10-year change in vocational and educational activities for adults with autism spectrum disorders. *Developmental Psychology*, *50*(3), 699-708. https://doi.org/10.1037/a0034297

*Titeca, D., Roeyers, H., Josephy, H., Ceulemans, A., & Desoete, A. (2014). Preschool predictors of mathematics in first grade children with autism spectrum disorder. *Research in Developmental Disabilities*, *35*(11), 2714-2727. https://doi.org/10.1016/j.ridd.2014.07.012

*Titeca, D., Roeyers, H., Loeys, T., Ceulemans, A., & Desoete, A. (2015). Mathematical abilities in elementary school children with autism spectrum disorder. *Infant and Child Development*, *24*(6), 606-623.

*Toll, S. W., Van der Ven, S. H., Kroesbergen, E. H., & Van Luit, J. E. (2011). Executive functions as predictors of math learning disabilities. *Journal of Learning Disabilities*, *44*(6), 521-532. https://doi.org/10.1177/0022219410387302

*Tzanakaki, P., Hastings, R. P., Grindle, C. F., Hughes, J. C., & Hoare, Z. (2014). An individualized numeracy curriculum for children with intellectual disabilities: A single blind pilot randomized controlled trial. *Journal of Developmental and Physical Disabilities*, *26*(5), 615-632. https://doi.org/10.1007/s10882-014-9387-z

Vanmeirhaeghe, B. (2012). *Divided by numbers. Studying with dyscalculia.* Documentary: Artevelde University College. http://www.studerenmetdyscalculie.be/synopsis.

Velasco, E. (2010). Inclusion criteria. In N. J. Salkind (Ed.), *Encyclopedia of research design*. (pp. 589-591). SAGE Publications, Inc.

*Vitalo, K. (2017). *Multi-modal mathematic instructional strategies and students with severe disabilities* [Unpublished master's thesis]. Hofstra University.

Wei, X., Lenz, K. B., & Blackorby, J. (2013). Math growth trajectories of students with disabilities: Disability category, gender, racial, and socioeconomic status differences from ages 7 to 17. *Remedial and Special Education*, *34*(3), 154-165. https://doi.org/10.1177/0741932512448253

Whitby, P. J. S. (2012). The effects of solve it! On the mathematical word problem solving ability of adolescents with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*, *28*(2), 78-88. https://doi.org/10.1177/1088357612468764

Wright, P. W. D., Wright, P. D., & O'Connor, S. W. (2015). *All about IEPs: Answers to frequently asked questions about IEPs.* Harbor House Law Press.

Yusaini, N. A., Maat, S. M., & Rosli, R. (2019). Touch-point mathematics instruction for children with Autism Spectrum Disorder: A systematic literature review. *International Journal of Academic Research in Business and Social Sciences, 9*(3), 609-625. https://doi.org/10.6007/IJARBSS/v9-i3/5730

Yusoff, Y. M., Salehuddin, K., Abdullah, I. H., & Toran, H. (2018). An account of high-functioning Autism Spectrum Disorder (ASD) children focusing on their language abilities. *Journal of Advanced Research in Dynamical and Control Systems*, *10*(6), 15-22.

Appendix A. The details of the 39 studies included in the systematic literature review

Author	n	Setting	Instructional Strategy	Design	Length of instruction	Summary
Aagten-Murphy et al. (2015)	32	London	Symbolic, Non-symbolic and number line mapping	Experiment	During instruction session	The symbolic use and numerical mapping method can increase the proficiency of ASD students
Alter et al. (2011)	3	Primary School (Midwestern)	Mathematical problem-solving (PMM)	A multiple-baseline across participants design	15 minutes	The study supports the use of PMM interventions to improve students' mathematical problem-solving skills
Bae (2013)	40	Primary School (New York State)	Schematic Approach	Mixed method	30-40 minutes/session	There is a remarkable improvement in the achievements of ASD students regarding problem-solving and mathematics knowledge
Bae et al. (2015)	20	Public School (US)	Real-life problems	Quantitative	30-45 minutes for 3 weeks	The real-life problems method can improve ASD students' problem-solving abilities
Bouck et al. (2014)	3	Autism Clinic	Using concrete materials (physical objects) and virtual (3-D objects in computer)	Single subject	1 year	Applying concrete material methods (physical objects) and virtual (3-D objects in a computer) can increase the ASD student's abilities in solving problems
Brosnan et al. (2016)	56	Classroom (UK)	Metacognitive monitoring	Experiment	Based on UK curriculum	Metacognitive monitoring can support learning for ASD students
Burney (2015)	3	Secondary School Bandar (United States of America)	Concrete-Representational-Abstract (CRA) and Multiple Baseline Design (computer-assisted)	Multiple Baseline A-B (pre-test/post-test)	30 minutes every week	Findings show that using concrete-representation-abstract (CRA) teaching and explicit direction can improve ASD students' achievement in mathematics
Casner (2016)	21	Primary School (Midwest)	Schematic instruction	Mixed method	School year 2013-2014	Schematic-based instruction can improve students' mathematical problem-solving skills
Cox & Root (2018)	2	Home (United States of America)	MSBI with provided visual supports	A single-case ABAB	2 or 3 times a week	MSBI strategy could solve mathematical problems of ASD students

Appendix A. Continued

Author	n	Setting	Instructional Strategy	Design	Length of instruction	Summary
Cravalho, et al. (2014)	3	Primary School (Pacific)	Flash cards	A multiple baseline design across number/fact groups and participants	1 and 3 days a week	Flashcard intervention is effective towards the teaching of number correspondence and interpretation
Croce (2015)	7	Classroom (US)	Self & Match	Experimental	30 minutes, (1 time per weeks)	The Self & Match method is effective in increasing the behaviour of ASD students in the classroom
Delisio et al. (2018)	3	Classroom (Florida)	1) Mathematical Word Problem Solving Interventions 2) SBI 3) The K-N-W-S graphic organizer 4) Video Modelling	A quasi-experimental	Six sessions	There is an increase in mathematics learning
Desoete et al. (2012)	16	Preschool (Belgium)	Non-symbolic and symbolic (number word (NW) and Arabic number (AN)	Comparison	Short version	There is a NW relationship in increasing students' achievement in arithmetic subjects
Fries (2013)	4	Primary School (US)	MMF (Mathematical Facts Mastery)	A single case	30-minutes every day- 40 days/8 weeks	The MMF method was effective towards the students' skills in solving the problem of basic subtraction, adding and mixed subtraction
Geary et al. (2012)	16	Primary School (US)	Mathematical cognition	Experiment	Based on mathematics curriculum when the children are starting the research	Mathematical cognition is a very important aspect and contributes to the difference in individual and group performances for the starting point of numerical operations
Göransson et al. (2016)	60	Classroom (Swedish)	Mathematics based on conceptual approach	A qualitative content analysis	735 minutes	This strategy effects students so that they be involved in the learning process individually or in group
Green (2014)	50	Preschool (US)	Storybook	Quasi-experimental group design	20 minutes/3 days (6 weeks)	This method can help the cognitive development of students

Appendix A. Continued

Author	n	Setting	Instructional Strategy	Design	Length of instruction	Summary
Hansen (2014)	8	Primary School (US)	Mathematics courseware Computer-aided instruction (CAI)/ TeachTown software	Mixed method	15 weeks	The method of mathematics application (computer-assisted instruction (CAI) was effective for students' academic achievement
Henning (2018)	3	Classroom (US)	Number of conversations with support	Experiment	5-18 sessions	This method can improve the ENS skills of ASD students
Hiniker et al. (2016)	36	Living Room (San Francisco)	The Role of Specific Symbolic Difference	Experiment	500-1500 minutes	Symbolic systems may help ASD students to give inaccurate information.
Iuculano et al. (2014)	18	Autism Clinic (US)	Functional magnetic resonance imaging (fMRI)	Experiment	6 minutes 36 seconds for every task	The method of fMRI activation can help increase the ability of ASD students to solve number problems independently
Jimenez & Kemmery (2013)	5	Classroom (Carolina)	Mathematics instruction based on stories with systematic instruction	Experimental	4 months	Increasing proficiency and deeper knowledge relating to mathematics
Jowett et al. (2012)	1	Living Room	VM package based on iPad	A single-subject, multiple baseline across-tasks	6 weeks	The VM Package based on iPad method was effective to increase the ASD students' proficiency in calculating
Kasap & Ergenekon (2017)	3	Home (Turkey)	Schematic Approach	A single-subject, multiple-probe design	1-5 weeks	The schematic approach is effective in teaching ASD students to solve mathematics problems
Maajeeny (2017)	4	Classroom (Atlantic)	Interactive whiteboard (IAW) and discrete trial training (DTT)	Experimental design & a single case design (SCD)	5-10 minutes	There were IAW and DTT effectiveness towards the ASD students' initial computational skills
Maras et al. (2017)	40	Secondary School (England)	Metacognitive based on computer	Comparison	For subjects taught in school suitable with the curriculum	The “metacognitive” approach can improve ASD students' mathematical achievements
Oie (2016)	6	Primary School (Tokyo)	Writing equations on paper	Observation	1 hours at instruction opening	Writing the calculations on paper could help students to achieve correct answers
Oswald et al. (2016)	27	Secondary School (California	Clinical and Cognitive Criteria	Experiment	48 hours	The results revealed that the most powerful predictor in solving mathematics problems was reasoning

Appendix A. Continued

Author	n	Setting	Instructional Strategy	Design	Length of instruction	Summary
Rasmussen & Bisanz (2011)	21	Primary School (Canada)	Special cognitive criteria	Experiment	1.5 hours	Teaching methods based on cognitive skills can improve ASD students' mathematics achievement
Rockwell et al. (2011)	1	Room at Home (US)	Strategic schema-based instruction (SBI)	A multiple-probes across behaviours single-case	2 hours 45 minutes (8 weeks)	The SBI method is effective for solving the problems of addition and subtraction among ASD students
Rockwell (2012)	2	Home (Dining Room)	Strategic schema-based instruction (SBI)	A multiple-probes across behaviours single-case	30-min (Monday to Friday)/ during summer holiday	The SBI method improves the achievement of solving problems among ASD students
Root et al. (2017)	3	Primary School (US)	Modified schema-based instruction (MBSI)	A multiple probe across participants	15-20 minutes	Instructions based on modified scheme can improve performance in solving mathematical problems among students
Root et al. (2018)	3	Primary School (US)	Modified schema-based instruction (MSBI)	A multiple probe across participants design	4 days a week	MBSI method could improve student's method to analyse task independently
Shamir & Baruch (2012)	52	Primary School (Israel)	E-book education	Experiment	30 minutes	E-book education is recovering vocabulary skills and early mathematical skills of students
Titeca et al. (2014)	27	Primary School (US)	Numerical competencies (vs, c, mc,e, ao)	Experiment	Final year of preschool	The numerical performance method is the foundation for the development of ASD students' mathematical knowledge
Titeca et al. (2015)	121	Primary School	Multi-component approach	Quantitative	50 minutes	There is strength, mathematical ability among students by stressing on the importance of other mathematics field
Toll et al. (2011)	227	Secondary School	Executive functioning	Comparison	30 minutes	Benefits of executive functioning to predict the future achievement of students and target students with low scores to continue to perform in mathematics
Tzanakaki et al. (2014)	24	Primary School (UK)	Mathematics recovery program	Experiment	12 weeks (3 hours 30 minutes until 10 hours 20 minutes)	Mathematical recovery can improve to students' calculation ability
Vitalo (2017)	4	Primary School (US)	Hand technique and manipulation, CRA instructional	Mixed method	30 minutes	Techniques and manipulation of hand and instructional CRA showed remarkable improvement in learning outcomes, student engagement and positive impressions on student attitudes in learning mathematics