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Video modelling intervention in teaching fraction problem-solving for students with autism spectrum disorder

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Abstract

The current study was conducted in order to determine whether the utilization of a self-monitoring checklist, concrete manipulatives and video modelling (VM) influenced the degree to which 40 pupils attending primary school diagnosed as having autism spectrum disorder (ASD) were able to find accurate solutions to fraction-related problems. A quasi-experimental design was used involving a single-case multiple probe between participants to identify whether significant relationships existed among the study variables. According to the study findings, compared to the baseline, after the implementation of the intervention, all participating students exhibited increased accuracy in solving problems involving simple proper fractions, while 32 were capable of solving whole proper fraction problems. Consequently, it is recommended that to meet the specific needs of ASD learners in a variety of conditions, educators should evaluate whether interventions consisting of concrete manipulatives and VM can be implemented in combination with specific behavioral techniques.

Keywords: primary school, autism, mathematics, video-based instruction, concrete manipulatives, self-monitoring strategy

INTRODUCTION

To allow students with autism to achieve their full potential in terms of their careers and living independently, it is important that they are afforded suitable educational guidance when attending school (Wong et al., 2021). It is possible for virtually all pupils with autism to achieve success in their lives if they are instructed in mathematics as well as basic academic concepts (Stroizer et al., 2015). In terms of mathematics skills, it is imperative that every student develop basic as well as more complex computational and conceptual skills (National Council for Teachers of Mathematics [NCTM], 2000). While autistic students do not necessarily experience academic challenges, a significant number do experience difficulties with learning mathematics (Wei et al., 2015). For example, this may include executive functioning problems that could affect their ability to self-manage, solve problems and organize (Ozonof & Schetter, 2007), limit their ability to engage in tasks (National Research Council, 2001) and cause problems with processing abstract mathematical concepts (Rourke & Strang, 1978) which add to the challenges students with autism experience when attempting to learn mathematics concepts. Such problems are more common in autistic students compared with their peers without disabilities, particularly in terms of their ability to solve problems involving fractions (Hecht & Vagi, 2010; Misquitta, 2011). It is evident that students with disabilities experience more difficulties with fractions when learning mathematics (National Mathematics Advisory Panel [NMAP], 2008; Sanders et al., 2005). An explanation for this could be that such students mistakenly attempt to employ rules pertaining to whole numbers when dealing with rational numbers (Ni & Zhou, 2005). For instance, while a larger product is generated from the multiplication of two positive rational numbers, the product is smaller when a number is multiplied by a fraction. In order to become proficient

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Contribution to the literature

- This study deals with determining whether the utilization of a self-monitoring checklist, concrete manipulatives and VM influenced the degree to which 40 pupils attending primary school diagnosed as having ASD were able to find accurate solutions to fraction-related problems.
- The study findings contribute to the literature and have practical implications for instructing autistic students on how to understand fractions and solve basic proper fraction problems, utilizing VM in combination with a self-monitoring checklist, concrete manipulatives, and a comprehension check.
- The results will be of value to those involved in mathematics teaching, including curriculum supervisors, educators, teachers and researchers.

in solving problems involving fractions, learners must be able to deal with two different quantities (denominators and numerators) at the same time and determine how they are associated (NCTM, 2013).

Despite being challenging, fractions represent critical mathematical skills for most students (Hecht & Vagi, 2010; Mazzocco et al., 2013). Nevertheless, students have noted that their ability to acquire mathematical skills is increased when instructed using visual and concrete examples, which improves their comprehension of various different mathematical concepts (Bouck et al., 2018; Satsangi et al., 2019; Yakubova et al., 2016). One form of visually-supported teaching in which technology is employed is video-based instruction, a teaching method based on evidence used to students with autism with a variety of skills throughout their education (Steinbrenner et al., 2020). It is possible to use this instructional approach to systematically instruct students using explicit modelling and consistent vocabulary, which allows them to observe the intended concepts and skills and then copy them (Hughes & Yakubova, 2019). Video modelling (VM) is now widely used as an evidence-based approach for teaching a broad range of skills to autistic students across all different grade levels, as reported in a review conducted by the National Professional Development Center on such practices (Wong et al., 2015). Hence, this study was conducted with the aim of evaluating whether the application of an intervention involving a VM instructional package with concrete manipulatives, a self-monitoring checklist and a comprehension check influenced the ability of elementary students with autism to accurately solve problems containing proper fractions.

Statement of the Problem

In order to comprehensively understand mathematics, students must have knowledge of decimals and fractions in addition to whole numbers (Fennell, 2007). Furthermore, it is believed that the ability to handle fractions is the most important basic skill (NMAP, 2008) as it has the potential to influence mathematics achievement (Bailey et al., 2012; Watt & Therrien, 2016) for up to five years in the future (Siegler et al., 2010). The argument has been made that if learners do not sufficiently understand fractions, they will not be adequately equipped to deal with more advanced mathematics concepts (Sanders et al., 2005). When attempting to learn mathematics, an area with which students with disabilities specifically experience problems is fractions (NMAP, 2008; Sanders et al., 2005). A disability that falls into this category is autism spectrum disorder (ASD), and such students generally exhibit:

(a) repetition in their behavior along with minimal interests and activities, and

(b) limited ability to communicate and interact socially (American Psychiatric Association [APA], 2013).

Consequently, learners with ASD experience challenges in terms of the effective development of relationships with others, academic performance, achieving independence and benefiting from sufficient quality of life (Schall et al., 2012). For example, Clarke et al. (2021) conducted a study to explore the vocational activity pathways among young autistic adults, with the findings showing that if such students are consistently supported, this can be beneficial in their attempts to become independent. Wehman et al. (2014) determined that the utilization of self-monitoring is crucial for interventions involving individuals. Numerous different stakeholders consider that the development of this skill has particular significance for autistic students (Hume et al., 2009; McDonald & Machalicek, 2013), as these characteristics persist across their lifetime and permeate throughout their daily lives (Hendricks and Wehman, 2009). Nevertheless, few researchers have focused on academic instruction for autistic students, and these studies generally only concentrate on literacy (Pennington, 2010; Spencer et al., 2014). Therefore, despite the fact that the number of professions that necessitate advanced mathematical knowledge and abilities continues to rise (Bureau of Labor Statistics, 2014), studies on how autistic students are instructed on mathematics remain limited (Spencer et al., 2014). However, a significant number of these learners are considered to have a disability in mathematics (Mayes & Calhoun, 2006) or experience difficulty with the subject (Meyer & Minshew, 2002; Rourke &Strang, 1978), and more than 25% consider learning mathematics to be more challenging than vocabulary (Williams et al., 2008).

Research Questions

The main research questions are listed below:

1. Are students with ASD able to solve problems containing proper fractions more accurately after being subjected to an intervention package consisting of a self-monitoring checklist, practice to verify comprehension, concrete manipulatives and VM instruction?
2. Are students with ASD capable of extending and applying their capacity to find solutions to problems containing proper fractions to those containing improper fractions?

THEORETICAL FRAMEWORK

Fractions Interventions for Students With ASD

As proficiency in fractions is now perceived to be critical to be competent and achieve success in mathematics, curricula specifically focus on instructing fractions (Booth & Newton, 2012; NMAP, 2008; Vukovic et al., 2014). As they pervade throughout our daily existence, it is contended that understanding how to handle fractions enables individuals to become more independent as adults (Jordan et al., 2017). Nevertheless, according to Maccini and Gagnon (2000) a significant number of teachers in the special education field have a minimal understanding of national mathematics standards and generally focus on basic mathematics. The existing standards that form the basis of the limited number of instructional models that teachers can utilize for autistic students are focused on simple numerical operations or financial management (Browder et al., 2012; Spencer et al., 2014).

Misquitta (2011) conducted a review of studies on the topic of support provided to learners experiencing challenges with mathematics with a specific focus on fractions, identifying four main types of interventions: anchored instruction (i.e., videodiscs that deal with real world situations requiring problems to be solved), the concrete-representational-abstract (CRA) framework, strategy instruction (e.g., mnemonics), and direct instruction. The findings of the study indicated that student performance in the area of fractions can be improved through the implementation of explicit techniques. This could be expected considering that explicit teaching, which constitutes the pedagogical foundation of the CRA framework, is an evidence-based approach endorsed by professionals for teaching students both high-incidence and low-incidence disabilities (Browder et al., 2012; Doabler & Fien, 2013; Gersten et al., 2009; Root et al., 2017). Previous meta-analyses have reported that both strategic and direct instruction can be beneficial for teaching mathematics to students with disabilities (Swanson & Hoskyn, 1998). A study recently conducted by Hughes (2019) reported the successful application of a strategy involving VM combined with self-regulation for teaching an autistic student in middle school the process of fraction simplification. Furthermore, the results showed that the students retained these skills across an extended period. Bouck et al. (2019) noted that the utilization of virtual manipulatives via a virtual-representational-abstract instructional sequence allowed a middle school autistic student to immediately become capable of identifying fraction-related problems.

Supported by evidence from many years of implementation, the CRA framework has been employed in various different areas of mathematics (e.g., algebra, fractions, multiplication, subtraction), (e.g., Agrawal & Morin, 2016; Bouck et al., 2017; Butler et al., 2003; Flores, 2010; Jordan et al., 1998; Miller & Mercer, 1993; Underhill, 1977). Via direct instruction, the CRA framework allows the teacher to show and verbalize thoughts so that students have a clear understanding of mathematics, guiding them in their efforts to find solutions to mathematical problems, ultimately enabling them to solve problems independently. CRA encourages learners to systematically find solutions to mathematical problems through the use of concrete manipulatives then representations or drawings, followed by abstractions in the form of mathematics (Agrawal & Morin, 2016). Explicit instruction forms the basis of all three aforementioned stages of the CRA framework, namely concrete manipulatives, representational, and abstract. Despite the limited research into the utilization of the CRA framework for providing instruction on fractions, it is widely considered to be an intervention based on evidence and informed by research for learners with learning and developmental disabilities (Agrawal & Morin, 2016; Bouck et al., 2017; Flores et al., 2014).

While few studies have been conducted in this area, research by Butler et al. (2003) made a comparison between two very similar frameworks for providing instruction on fractions to students with disabilities in middle school. The researchers presented a comparison between the CRA framework and another framework that only included the representational and abstract phases. A comparison of the post-test and pre-test results revealed that while both groups exhibited improved performance, students to whom the CRA framework was applied performed better according to all subtests. Nevertheless, a significant difference was only observed in the subtest assessing the students' ability to evaluate a fraction of a specific amount (e.g., draw a circle around 3-4 of 24 dots).

Based on the review of the literature, the authors could only find three empirical studies on the topic of fractions that had direct pertinence to autistic students. The first such study conducted by Yakubova et al. (2015) evaluated the usage of an intervention in which VM was used in combination with a self-monitoring checklist for teaching autistic high school students on the process of solving word problems through the subtraction of mixed fractions with rare denominators. According to the findings, the success of the intervention was confirmed as the students' ability changed by an average of 94%, with a subsequent evaluation indicating that they retained the acquired skills. The second study was conducted by Hughes (2019), who effectively utilized VM in combination with a self-regulation approach for teaching an autistic middle school student on the process of simplifying fractions. Furthermore, they were able to maintain these skills after the intervention. In the last study, an autistic middle school student was able to quickly acquire the skill of identifying problems containing fractions through the successful application of a virtual-representational-abstract instructional sequence.

It is interesting to mention before moving to next section that in order of visuospatial memory many children with ASD find it easier to process and remember tasks or concepts (such solving fractions) when they are represented visually and spatially through VM. By viewing and mentally practicing steps frequently, learners can improve their strength memory for both the sequence and spatial layout of the task (Vogan et a l., 2014).

Secondly, executive functions with video that clearly explain each step in a logical order, it helps students manage complex tasks like multi-step arithmetic problems and promotes planning and organization. Reducing cognitive load helps learners retain information by allowing them to pause, rewind, or replay videos rather than storing it all at once (Yakubova et al., 2015).

This is related to the social learning theory: learning happens through modelling, imitation, and observation. Through VM, students can observe a model (peer, teacher, or animated character) perform a task correctly, which they then imitate. By demonstrating successful task completion, it increases self-efficacy and the learner's belief in their own capacity to accomplish the same (Fleury et al., 2015).

Video modelling instruction with concrete manipulatives

The National Professional Development Center reviewed evidence-based practice, concluding that VM is such an intervention that can be employed for teaching a variety of different skills to autistic students across the range of grades (Wong et al., 2015). The systematic review of Hughes and Yakubova (2019) presented analogous findings. Essentially, in the VM approach, a video recording played containing explicit and methodical instruction to students prior to starting the process of solving a given mathematical problem (Hughes & Yakubova, 2019). Various researchers have used VM in their studies, demonstrating that it can be beneficial for learning, particularly when implemented in combination with behavioral and academic approaches including self-monitoring checklists, the CRA framework and manipulatives (e.g., Hughes, 2019; Hughes & Yakubova, 2019).

A significant volume of evidence supports the assertion that virtual or concrete mathematics manipulatives facilitate the process by which learners with disabilities fundamentally comprehend abstract concepts (Bouck & Park, 2018; Marley & Carbonneau, 2014). For example, these types of students (in all age groups) were observed to exhibit increased performance in terms of solving word and computation problems when instructed through VM in conjunction with concrete manipulatives and checklists (Hughes & Yakubova, 2019). Previous research in which concrete manipulatives were used have preferred to compare them with virtual manipulatives with/without VM or how they are used as part of the CRA teaching framework (Bouck et al., 2014; Stroizer et al., 2015; Yakubova et al., 2016). The findings of these studies indicate that when employed in combination with self-monitoring checklists and concrete manipulatives, VM could be effectively applied for these types of students.

The use of manipulatives both as part of and external to a CRA framework can enable the effective teaching of mathematical concepts to students across the educational spectrum (Bouck & Park, 2018; Peltier et al., 2019). Manipulatives are considered to be the best practice (NMAP, 2008) and their usage has been robustly endorsed by the NCTM (2000). The majority of researchers in this area have focused on the seamless transition from concrete (or virtual concrete) to abstract practice, where semi-concrete or pictorial representations are used to bridge this gap. Bouck and Park (2018) reviewed studies published between 1975 and 2017 in which manipulatives were used for teaching mathematics to students with disabilities. Their findings revealed that from the 36 studies included in the review, only seven assessed how manipulatives external to the CRA framework impacted learning, and autistic students were largely ignored. Thus, in order to understand how manipulatives impact this process independently and not within the CRA framework, it is necessary to conduct further research.

Commenting on Previous Studies

First of all, in participants aspect, previous studies varied in how they selected their participants and included samples from middle education and secondary education. For instance, Bouck et al. (2019) and Hughes (2019) conducted research with middle students, while Maccini and Gagnon (2000) and Yakubova et al. (2015) carried out research with participants at the secondary stage, while the current study's sample was applied to primary school students. Secondly, in methodology aspect, as previous studies by Bouck et al. (2014), Hughes (2019), Stroizer et al. (2015), and Yakubova et al. (2016), the current study adopts a quasi-experimental design. This contrasts with Bouck and Park (2018), Hughes and Yakubova (2019), and Pennington (2010), who employed another methodology. Finally, this study also differed from the previous studies in terms of the selection of the type of disabilities to apply the subject of the study, such as the studies conducted by Agrawal and Morin (2016), Bouck et al. (2017), and Flores (2010), while the current study was applied to students with ASD. Therefore, what distinguished from this study is that it dealt with determining whether the utilization of a self-monitoring checklist, concrete manipulatives and VM influenced the degree to which 40 pupils attending primary school diagnosed as having ASD were able to find accurate solutions to fraction-related problems, which had not been studied before.

Commenting on the previous studies as a whole: Having reviewed previous studies, the following points were noted: Most of the studies that deal with teaching fraction problem-solving to students with Autism indicate the modernity of the topic and its importance. In addition, the researchers benefited from the literature by drawing on the pedagogical literature and literature reviews, adopting scientific methodology to form the theoretical framework used in this research, and formulating their research methodology.

METHOD

Setting

The study participants comprised 40 elementary school students diagnosed as having ASD attending state schools in the cities of Dammam and Alkhobar. To be included in the study, the participants had to meet the following criteria:

(a) been given a primary diagnosis of ASD according to diagnostic and statistical manual of mental disorders-5 (DSM-5; APA, 2013),

(b) further guidance required for mathematics in line with the teacher's recommendations,

(c) no previous experience of VM in mathematics,

(d) teachers noted no gross motor, hearing, or vision impairments restricting their ability to use VM instruction, and

(e) showed a willingness to become a participant.

According to Creswell (2003), researchers are responsible for ensuring that the rights of participants are maintained. In this regard, a detailed explanation of the study's aim was provided to the parents/guardians of all participants. The parents/legal guardians were then required to sign an informed consent giving their permission for their child to become a participant, while all participants also voluntarily signed consent forms prior to joining the study. Copies of the relevant consent forms were given to all individuals involved. Participant anonymity was also ensured by concealing all identities, as well as anything that could identify them during the entire reporting process.

The research was conducted in a state elementary school for students diagnosed with ASD or other types of disabilities in grades one to six. The ratio of teachers to staff was set at 1:5 to enable the particular needs of each student to be met. The intervention was implemented in the classroom on a biweekly basis at which time students were given guidance to improve their ability in mathematics. The classroom included a computer that the teacher could use, a printer, interactive whiteboards, as well as a projector on which sample materials and programs could be displayed. The only people within the classroom where the research was being conducted were those participating, the person conducting the intervention (the researcher), and the individual responsible for collecting data on reliability.

With vast experience after completing both master's and doctoral degrees in both mathematical disabilities within the UK, the first researcher conducted considerable research and gained practical knowledge from engaging with students with ASD ranging from primary school to young adults. Prior to starting the study, the researcher received training on how to implement the intervention along with related research activities.

Participants

First school

A total of five fifth-grade male participants aged 10 were included in the research, all of whom had received a diagnosis of autism from a developmental pediatrician (two were diagnosed at the age of three, and the other three at the age of six). Regrettably, the report provided by the doctor offered no details on the diagnostic tests used when making this diagnosis. Thus, to determine their eligibility in line with IDEA, a school psychologist conducted a further detailed assessment, confirming the autism diagnosis. According to his IE, the school records further indicated a secondary diagnosis of specific learning disability (SLD) in mathematics, writing, and reading.

Additionally, it was determined that one student had an auditory processing disorder. According to the latest measure of academic progress–math (MAP-M) scores, their mathematics abilities were in the third percentile compared to those in the same age group. Their scores from recently conducted WJ-VJ tests ranged between 57 and 70 for the mathematics element, thus positioning them in the very low achievement range compared with other students in their age group. Despite their shyness, they were very willing to work with the researcher doing the intervention, However, their concentration and engagement with tasks fluctuated according to their mood.

All five participants were 11 years old and attending sixth grade. As indicated in the individualized education programs, two students had received a primary diagnosis of ASD along with secondary diagnoses of language development delays, attention deficit hyperactivity disorder (ADHD), SLD, and epilepsy. The IEPs for the other three students indicated secondary diagnoses of SLD in mathematics, writing, and reading. Recent scores for the MAP-M showed that compared to peers in their age group, they were ranked in various positions from the first to the third norms percentile, and position in the low-average range for a third-grade student. Additionally, according to their recent WJ-IV test results, their scores ranged between 53 and 64 for the mathematics element, meaning that they were positioned in the very low achievement group. Lastly, based on recently conducted evaluations and observations, they were mostly capable of solving mathematics problems in line with second-grade abilities, as well as fraction-related problems at the bottom end of the fourth grade level. However, the mathematical problems solving abilities of two participants were at third-grade level and their ability to solve fraction-related problems was comparable to the bottom end of fifth grade. The researcher observed that two participants exhibited shyness and experienced frustration when performing tasks, whereas the other three were eager to become engaged.

Second school

The next five participants were all 10 years old and in the fifth grade. They had been diagnosed with ASD by a pediatric psychologist when they were between the ages of four and seven. It is regrettable that more details on tests conducted when making the diagnosis were not included in the doctor's report. Resultantly, to determine their eligibility based on IDEA, a school psychologist conducted a further detailed evaluation which also resulted in an autism diagnosis. Based on their IEP, the school records show that they have been given secondary diagnoses of SLD in mathematics, writing, and reading. Their recent scores for the MAP-M test showed that compared to peers in their age group, their mathematics abilities varied, where three were positioned in the fourth percentile, and two in the fifth. Additionally, the scores from their latest WJ-IV assessment tests ranged between 54 and 64 for the mathematics aspect, meaning that they were positioned in the very low achievement group in comparison with peers in their age group. According to the researcher's observations, four of the students experienced attention problems and could not always adhere to the instructions in the lessons; however, one student who was engaged with the interventionist demonstrated increased focus and a willingness to follow instructions.

All aged 11, the five participants were all males in the sixth grade. While one was given a diagnosis of autism when aged four, the other four were diagnosed between the ages of five and eight. As no information was provided in the doctor's report regarding the particular tests applied when making the diagnosis, to make an assessment regarding their eligibility in line with IDEA, a school psychologist performed a further detailed evaluation which confirmed the autism diagnosis. As per his IE, the school records also showed secondary diagnoses of SLD in mathematics, writing, and reading. Additionally, two were identified as having an auditory processing disorder. Their latest scores for the MAP-M assessment revealed that their mathematical abilities were in the third percentile compared with other students in the same age group. Up-to-date scores for the WJ-IV assessment showed that they varied between 55 and 68 for the mathematics element, thus positioning them in the very low achievement category in comparison with other learners in the same age group. Despite their shyness, three showed a willingness to work with the researcher. However, their concentration and engagement with tasks fluctuated based on their mood.

Third school

The participants at the third school were all 10 years old, male and attending fifth grade. It is important to note that, based on his IEP, one participant was given an ASD diagnosis and had been provided with speech support from preschool onwards as a result of a language delay, as well as special education assistance as a result of the identification of a behavioral and emotional disorder. Additionally, he had been diagnosed with 'ADHD mixed rule-out pervasive developmental disorder'. A licensed psychologist gave him a diagnosis of high functioning autism in 2020, after which the focus of the services he began to receive changed from an emotional and behavioral disorder to autism. To evaluate the availability of the remaining participants in line with IDEA, a school psychologist conducted further detailed evaluations between 2020 and 2002, which affirmed the original diagnosis of autism. According to their latest WJ-IV test results, their scores for the mathematics element were in the 56 to 69 range, thus placing them in the low-achievement category in comparison with students in the same age group. Recent assessments and observations revealed that they were capable of solving mathematics problems at a second-grade level, while their fraction problem-solving ability was equivalent to low fourth grade. The researcher observed that three of the participants were shy and rapidly experienced frustration when attempting to perform tasks.

All five participants were male, 11 years old and attending sixth grade. It should be noted that one participant was diagnosed with ASD at the age of 22 months by a pediatric psychologist. As no details were provided in the doctor's report regarding the tests employed for diagnostic purposes, to make an assessment regarding their eligibility in line with IDEA, a school psychologist conducted a further detailed assessment which confirmed the autism diagnosis. The diagnosis of autism for the other four participants had been made between the ages of four and seven by a developmental pediatrician. Per the IEPs of all five participants, their school records revealed that they had been given secondary diagnoses of SLD in mathematics, writing, and reading. Their recent scores for the MAP-M assessment showed that compared with other students in the same age group, their mathematical abilities ranged between the third and fifth percentile. Additionally, recently conducted WJ-IV tests produced scores in the 48 to 68 range for the mathematics element, thus positioning them in the very low achievement category in comparison with their age group. According to the researcher's observations, two students experienced attention difficulties and were unable to consistently follow instructions in lessons.

Fourth school

The participants from the fourth school were 10 years old, male and attending fifth grade. It should be noted that two participants were diagnosed with ASD by a pediatric psychologist when aged from 23 to 25 months. However, particular details on the diagnostic tests utilized were not available, so a school psychologist conducted another comprehensive assessment which supported the original diagnosis of autism. The autism diagnosis for the other three students had been made by a developmental pediatrician when they were between the ages of three and six. According to the IEPs of the five participants, the school records revealed that they had been given secondary diagnoses of SLD in mathematics, writing, and reading, as well as an auditory processing disorder. Their recent scores for the MAP-M tests showed that compared with students in the same age group, their mathematical abilities ranged between the fourth and fifth percentile. Additionally, recently conducted WJ-IV assessments produced scores in the 49 to 70 range, thus positioning them in the very low achievement category in comparison with students in the same age group. According to the researcher's observations, one student exhibited attention problems and could not always follow instructions in the class.

The participants at the fifth school were all 11 years old, male and attending sixth grade. The had all been diagnosed with autism by a pediatric psychologist when they were between three and seven years of age. Regrettably, no specific details were provided in the doctor's report regarding the tests used to make this diagnosis; thus, a school psychologist conducted another detailed assessment to determine their eligibility in line with IDEA, which confirmed the autism diagnosis. Per their IEPs, the school records showed that they had additionally been given secondary diagnoses of SLD in mathematics, writing, and reading. Their recent scores for MAP-M showed that compared to students in the same age group, their mathematics skills varied, with two ranked in the fourth percentile and three in the fifth. Additionally, recently conducted WJ-IV tests produced scores in the 53 to 66 range for the mathematics element, which positioned them in the very low achievement category in comparison with their age group. Observations by the researcher revealed that three experienced attention challenges and could not follow instructions in the classes, whereas the other two were very engaged, focused and followed instructions.

Independent Variable

The independent variable consisted of the intervention, which included four methods: a VM recording from a point-of-view perspective, a self-monitoring checklist, a comprehension check and concrete manipulatives. When the intervention was applied in the lessons, the participants were shown the VM recording and were subject to a comprehension check from the interventionist based on an example and then asked to find solutions to probe problems utilizing manipulatives and a self-monitoring checklist. The participants were allowed to re-watch the VM recording if they wanted.

Video Modelling Instructional Clip

A customized VM recording was made by the researchers in collaboration with staff members skilled in programming for the intended task utilizing concrete manipulatives. The VM clip was recorded from a first-person perspective showing their point of view and only showed their hands and the task they were demonstrating; thus, it was considered to be a point-of-view modelling clip. For recording purposes, a document camera IPEVO (https://www.ipevo.com/) was used, as this allowed the operator to zoom in on the task/worksheet with no external assistance required. The worksheet used in the VM clip was formatted in the same way as those given to the participants in the baseline/intervention sessions and demonstrated the process of solving a given problem in which fractions needed to be added, as well as another where they needed to be subtracted. The method employed was divided into specific steps that were demonstrated one by one with both a printed checklist that mirrored a self-monitoring checklist, as well as verbally. Formatting the VM recording in this way meant that systematic and explicit instruction was provided. In the step-by-step instruction, the individual in the video commenced with a review of numerators; subsequently, they demonstrated the process of building a fraction with fraction tile manipulatives. The video then showed the initial step in the problem-solving checklist, as well as the first example question (addition). The researcher verbally articulated the question at this stage. The instructor then verbally described the solution to the problem, explaining each stage of the process in detail while also modelling it with appropriate tools, including fraction tiles, pencils, among others. An identical process was followed for the second example involving subtraction, with the duration of the video lasting four minutes. After being uploaded on to the desktop, the video recording was available for participant usage.

Concrete Manipulatives

To facilitate the participants' conceptual understanding of the problem and practically demonstrate the task, fraction tiles were employed as concrete manipulatives. Different colors were used according to the denominator and fractions were shown ranging from ½ to $^{1}/_{12}$where the number was represented by a whole fraction tile. The VM recording gave instructions on solving the respective fraction problems by utilizing the tiles to create physical representations of the fractions.

Self-Monitoring Checklist

Based on the color coding depicted in the video recording, the self-monitoring checklist showed the different tasks involved in solving the fraction problem in sequence. This checklist could then be used by the participants to prompt them on the individual steps required to solve the problem. This was done in order to ensure that the students would not depend on prompts from adults to remember the steps. The participants found the self-monitoring process beneficial as it immediately increased their independence in terms of understanding fractions and solving basic problems containing proper fractions. In reality, only eight of the students referred to the checklist, suggesting that everyone else remembered the steps. Moreover, although these eight participants used the list in the initial two sessions, their dependence on it was reduced during subsequent lessons.

Comprehension Check

After showing the VM recording in its entirety, the researcher then conducted a brief practice session with the students to verify their comprehension of the subject matter. This also provided the chance to give the participants individualized support, thus enabling them to rapidly gain the intended skills. A student focused approach was employed by the interventionist when doing the comprehension check, such that the sample problem was presented in the same way as the one employed in both the VM clip and study sessions; the participants were then invited to show the process by which they would attempt to solve the problem. For guidance purposes, the self-monitoring checklist, fraction tiles and VM could all be used by the participants such that they could visually demonstrate the problem using the tiles and then note down the solution or provide a verbal description of the problem-solving process. In situations where a participant experienced difficulties with a specific step, the interventionist would advise them to use the self-monitoring checklist. If their difficulties persisted, they would then be given questions and prompts to assist them in the creation of fractions with the fraction tiles, self-correcting where appropriate. Some of the questions used included 'for the fraction $^{5}/_{9}$, which fraction tiles are required?' and 'Is this addition or subtraction?'

Dependent Variable and Measurement

The dependent variable comprised the accuracy with which solutions to problems involving the addition and subtraction of proper fractions and suitable denominators were identified. As fraction tiles were used to prompt the students, only denominators that corresponded with the fraction tiles ($^{1}/_{2}$ to $^{1}/_{12}$) and numerators varying between 1 and one less than the number in the denominator (e.g., ¾ or $^{5}/_{6}$) were used by the interventionist. During the lessons, the students were given five problems involving proper fractions accompanied by an appropriate contextual explanation; for instance '$^{5}/_{12}$ cup of flour take away $^{4}/_{12}$ cup of flour', which was also expressed mathematically as follows: '$^{5}/_{12}$ - $^{4}/_{12}$ = ?'. The implementation of a dual format allowed the students to connect the skills being learnt with concrete examples of activities they could perform on a daily basis. Participants were subsequently asked to note down the right answer to every problem. Prior to starting the baseline stage, the researchers developed a list of suitable problems and then selected five that would be used in every lesson. Every lesson included distinct problems. The researchers selected the aimed topic in line with the specific mathematics objectives detailed on the respective participants', IEPs as well as the preliminary assessment of the extent to which they could compare and calculate problems involving fractions. In the generalization phases, the format used when presenting the problems was exactly the same as that used in both baseline and intervention sessions but included a while proper fraction (e.g., 1 ¼ cup of cream plus ¼ cup of milk, 1 ¼ + ¼ = ?) and employed fraction values with the denominators $^{1}/_{3}$ to $^{1}/_{12}$, and numerators varying between 1 and one less than the number in the denominator. Rather than improper fractions, each fraction was displayed as a mixed fraction less than 2. In terms of the generalization probes, participants could use one fraction tile that represented 1 as well as additional fraction tiles. The researchers utilized permanent product recording for the purpose of collecting data regarding the percentage accuracy with which the participants could solve problems involving fractions (Ledford et al., 2018). At the completion of every session, the interventionist calculated the percentage accuracy of the answers to the questions given. The mastery criterion was set at an accuracy of 100% for two successive lessons.

Experimental Design

To ascertain how the intervention impacted the accuracy with which 40 autistic students were capable of solving problems involving fractions, the researchers adopted a single-case research design that included a multiple probe (SCRD; Gast et al., 2018). The reason for selecting such a design was to:

(a) allow the researcher to identify the potential existence of a causal association between the independent and dependent variables and

(b) gather baseline data on a continual basis in the context of a multiple baseline design that could have negatively influenced the participants, such as the second participant who could have experienced frustration or engaged in problematic behavior.

Consequently, the effect could be replicated in all participants where a minimum of three attempts were made to realize this effect at three distinct time points (Kratochwill et al., 2013).

Ethical Procedures

Both prior to the study sessions and when they were ongoing, the students were advised that their participation was voluntary, meaning that they had the option of leaving the session or even the research in general whenever they wanted with no ramifications. Additionally, they were told that the inability to find a solution to a problem or giving the wrong answer would not reflect on them negatively. Students were given verbal reinforcement after every sentence with statements such as 'that's brilliant, thank you for your wonderful work'.

Baseline

Based on the multiple probe design, every participant took part in a minimum of five sessions at distinct time points. Progression between baseline and intervention phases was confirmed based on a visual examination of their work showing that their accuracy increased during a given session. Nevertheless, each participant finished at least five baseline sessions and then proceeded until their performance plateaued or started to decline, at which point the intervention was started. The interventionist advised the participants that the session would start and they would be given worksheets on which five problems containing fractions which required a solution would be printed. They were then requested to solve them to the best of their ability. In the baseline sessions, the participants were not offered any support or instruction.

Intervention

A minimum of five sessions were included in the intervention phases which proceeded until the mastery criterion of 100% accurate answers for two successive sessions was recorded. According to the design standards of What Works Clearinghouse (2017), the researcher gathered data from a minimum of five sessions, even where the participant achieved the mastery criterion in the initial sessions. This ensured that if the participants developed their skills during the sessions, it could not be attributed to coincidence. Before every session started, the interventionist gave a detailed explanation regarding what was required of them, namely, to watch the video recording, utilize manipulatives for solving a sample problem to demonstrate that they understood the task, and subsequently employ the manipulatives and self-monitoring checklist to find solutions to five problems displayed on a worksheet. The participants subsequently watched the VM on their own and utilized manipulatives for solving a sample problem so that the extent to which they understood the topic could be evaluated.

During the practice sessions, different students within the respective classes were observed to take charge, including the second participant in school one (fifth grade), the third participant in school one (sixth grade), the first participant in school two (fifth grade), the second participant in school two (sixth grade), the fourth participant in school three (fifth grade), the fifth participant in school three (sixth grade), the first participant in school four (fifth grade), and the third participant in school four (sixth grade). These students solved the problems independently by using or not using manipulatives. On the other hand, to find the correct solution to the problem, the other participants occasionally require prompts to reference their self-monitoring checklist regarding the process of matching denominators or using manipulatives. All participants were then given the worksheet on which five problems were displayed and asked to find the solution utilizing the self-monitoring checklist and manipulatives. If the participant sought guidance from the interventionist regarding problem-solving, they were advised to refer to the self-monitoring checklist or that they could watch the video recording again if deemed beneficial. In the initial couple of intervention sessions, all the other participants (apart from those described above) were instructed to utilize the fraction tiles and self-monitoring checklist when solving the problems. However, in subsequent sessions, their reliance on these tools lessened and they became capable of solving the problems to a more abstract degree. Conversely, the participants described above were able to solve problems without using the self-monitoring checklist or watching the video recording again. They immediately knew what to do after watching the VM clip.

Generalization

This phase was conducted with the aim of identifying the extent to which participants were capable of applying the steps required for solving simple proper fraction problems to those involving whole proper fractions. Each participant took part in three sessions during this phase, except the first and second participants in school three who only attended one session as the academic year had finished. The process largely mirrored that used in the baseline phase as the students were given a worksheet that included five problems where whole proper fractions were displayed as mixed fractions under 2.

Interobserver Agreement and Procedural Reliability

For the assessment of the percentage accuracy with which the individual students could find solutions to problems involving fractions in the respective phases, a second qualified observer graded a minimum of 32% of the worksheets. Subsequently, the interval agreement method was implemented for interobserver agreement (IOA) calculation. In this approach, the number of agreements was divided by the number of agreements added to disagreements, and the answer was then multiplied by 100% (Ledford et al., 2018). The result was an IOA of 100% per student for each phase. Reliability data were then collected by the observer through the implementation of the intervention for 43% of the intervention stage for every student, as well as procedural reliability for a minimum of 32% of every stage. Reliability (data for the intervention process and implementation) was calculated by dividing the number of steps the participant concluded successfully by the overall number of steps, then multiplying the result by 100% (Ledford et al., 2018). The outcome was that both the reliability per phase per student, as well as the reliability of the intervention implementation per student were 100%.

Social Validity

Once the generalization phase had finished, participants were required to answer a number of questions enquiring about what they liked, disliked and generally thought about the methods they used and the skills they acquired. The questions elicited either closed (yes/no) or open-ended responses. Questions pertaining to social validity included:

1. Did you enjoy the tasks you performed in the study? What aspects did you enjoy/not enjoy?
2. Did the materials you were given make learning easier?
3. Would you use such methods for learning in the future?
4. Are there any other aspects of your experiences in the study that you would like to share?

Data Analysis

To determine the existence of a causal relationship among the independent and dependent variables, as well as the potential effect's magnitude, systematic visual analysis was conducted which forms the basis of SCRD data analysis (Barton et al., 2018; Kratochwill et al., 2013). As part of this process, the analysis focused on patterns in the data and stability during baseline; data from the respective phases assessing variability, level, and trend, as well as an assessment between phases to examine where data overlapped, immediacy of potential effects, and consistency.

RESULTS

The analysis focused on the percentage accuracy with which individual students were able to solve problems involving fractions during the respective phases. According to the results of the visual analysis, the independent and dependent variables were linked by a causal association. Furthermore, 32 students demonstrated that they were capable of generalizing their skills acquired for solving simple proper fractions to solving whole proper fractions, see **Table 1**. It is notable that all participants found the intervention enjoyable and believed that it facilitated learning, where four participants from every school expressed their appreciation of the intervention and exhibited an eagerness to work with the interventionist.

First School

Fifth grade

The average baseline performance of the students in solving fraction word problems was 6%, 21%, 6%, 33% and 16%, respectively, with a slight increase being observed in the fifth baseline session with one out of five problems being correctly solved. After the intervention started to be implemented, an instant increase in response accuracy was recorded reaching means of 97%, 87%, 100%, 100% and 90% during the sessions. Resultantly, from baseline to intervention, mean level changes of 91%, 66 %, 94%, 67% and 74%, respectively, were observed where no data points were found to overlap between the respective phases. The problem-solving accuracy for tasks involving whole proper fractions achieved by the participants during the

Table 1. Mean accuracy of fraction problem-solving, standard deviation, and number of sessions until mastery was achieved

Student	B (SD)	I (SD)	G (SD)	n
First school: Fifth grade				
The first participant	6%	100%	100%	2
The second participant	33%	100%	0%	2
The third participant	16%	90%	87%	5
The fourth participant	6%	97%	100%	2
The fifth participant	21%	87%	88%	5
First school: Sixth grad				
The first participant	5%	100 %	100 %	2
The second participant	4%	100 %	**89** %	2
The third participant	18%	91 %	100 %	5
The fourth participant	17%	89 %	100 %	5
The fifth participant	40%	100 %	**0** %	2
Second school: Fifth grade				
The first participant	20%	88%	100%	2
The second participant	5%	100%	100%	5
The third participant	32%	100%	90%	2
The fourth participant	15%	91%	96%	5
The fifth participant	5%	98%	0%	2
Second school: Sixth grad				
The first participant	6%	100%	100%	2
The second participant	5%	92%	90%	2
The third participant	17%	100%	100%	5
The fourth participant	41%	100%	0%	5
The fifth participant	19%	88%	100%	2
Third school: Fifth grade				
The first participant	14%	91%	100%	5
The second participant	32%	100%	87%	2
The third participant	5%	100%	100 %	5
The fourth participant	22%	88%	0%	2
The fifth participant	7%	98%	85%	2
Third school: Sixth grad				
The first participant	7%	93%	100%	2
The second participant	6%	90%	100%	2
The third participant	43%	100%	0%	2
The fourth participant	16%,	88%	100%	5
The fifth participant	15%	100%	88%	5
Fourth school: Fifth grade				
The first participant	7%	100%	90%	2
The second participant	14%	97%	100%	5
The third participant	5%	100 %	99%	2
The fourth participant	27%	88%	0%	2
The fifth participant	12%	94%	90%	5
Fourth school: Sixth grad				
The first participant	39%	89%	90%	2
The second participant	15%	92%	100%	2
The third participant	16%	100%	100%	5
The fourth participant	5%	90%	100%	5
The fifth participant	4%	100%	0%	2

Note. SD: Standard deviation; B: Baseline; I: Intervention; G: Generalization; & n: Number of sessions until mastery achieved

generalization phase for three successive sessions was 100%, 88% 100%, 0% and 87%, respectively. It is important to note that stability was observed in terms of generalization data for the fifth participant as they achieved accurate percentages of 97% in the first session and 84% in the other two sessions.

The researcher observed that participants one, three, and four achieved 100% accuracy with minimal manipulative use. Participant two improved significantly, reaching high accuracy without tools. Participant five also improved markedly in the final sessions. Generalization data showed stable accuracy at 100%, then 81% for two sessions, except for participant four, who scored 0% on whole proper fractions.

Sixth grade

Students in the sixth grade demonstrated the ability to solve fraction problems with mean accuracies of 5%, 4%, 18%, 17%, and 40%, respectively, at baseline. Data from this phase revealed a low but consistent trend, apart from the fifth participant who was capable of accurately solving an average of three of five problems in every session. Once the intervention had been introduced, the accuracy of their responses rose to 100 %, 100 %, 91%, 89% and 100%. Resultantly, between baseline and intervention, their mean accuracy levels changed by 95%, 96%, 91%, 72%, and 60%, respectively and no data points overlapped. In the generalization phase, the accuracy with which they could solve whole proper fraction problems was 100%, 100%, 89%, 100%, and 0% for three successive sessions.

After the first session, participants one, two and three did not use fraction tiles and maintained 100% accuracy. Although both participants three and four exhibited increased reliance on the fraction tiles and self-monitoring checklist compared to the other two participants but achieved high accuracy in the final sessions. Generalization accuracy was 100%, then 86% and 80%. Similar to participants one and two, participant five largely ignored the fraction tiles, and demonstrated optimal accuracy in solving problems at an abstract level (without the manipulatives). Nevertheless, the assessment of his ability to generalize his skills to solve problems involving whole proper fractions in one session was extremely low, as the accuracy with which he could solve problems was zero, please see **Figure 1**.

Second School

Fifth grade

The average baseline performance for the five participants in solving fraction word problems was 15%, 32% , 5%, 20%, and 5%, respectively, where their performance was observed to marginally increase as they solved one of five problems in baseline session five. Once the intervention had been introduced, an instant rise in their accuracy occurred, with respective means of 91%, 100%, 100 %, 88% and 98% being recorded during the intervention. Thus, from baseline to intervention, mean level changes of 76%, 68%, 95%, 68% and 93% were

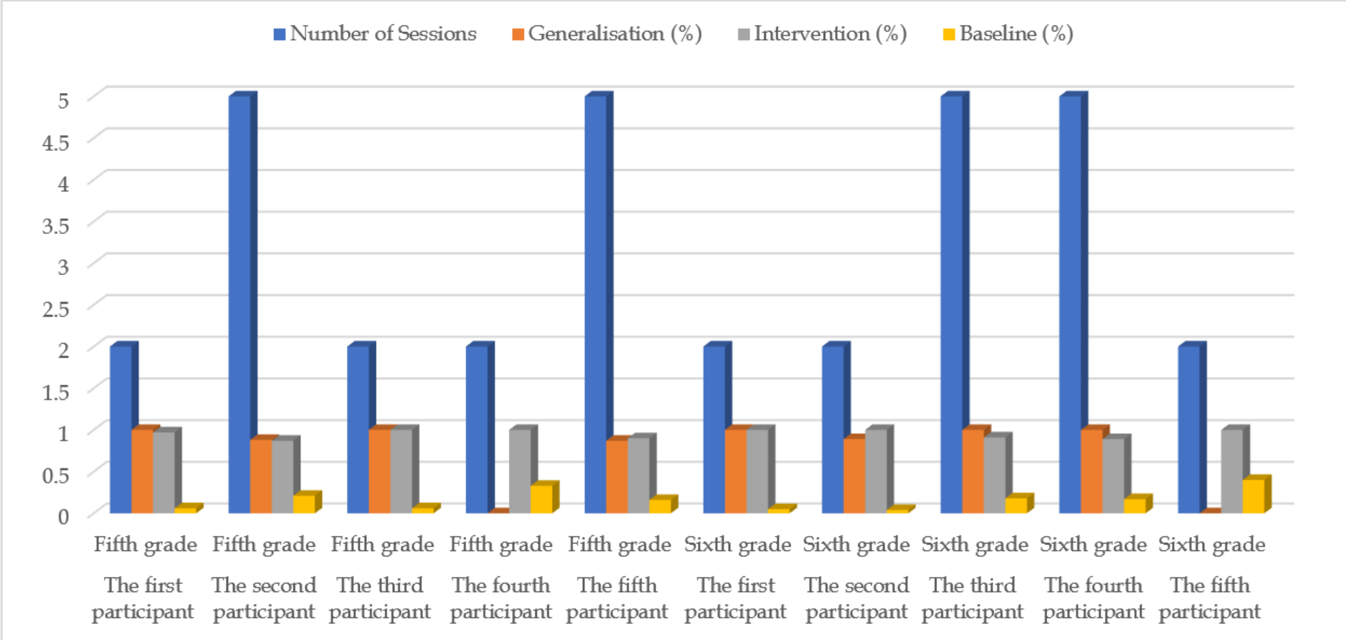

Figure 1. The summary of results of the first school (Source: Authors' own elaboration)

observed for the respective participants, with no data points overlapping between the different phases. When moving to generalization, the accuracy with which the participants were able to solve problems containing whole proper fractions for three successive sessions was 100%, 100%, 90%, 96% and 0%, respectively. It should be noted that participant four exhibited stability during the generalization phase, as they recorded 98% correct answers in session one and 95% for the other two sessions. Participant five demonstrated a limited ability to generalize the acquired skills to problems with whole proper fractions, as his accuracy for one session was 0%.

The interventionist seen that participant one disregarded the fraction tiles subsequent to the initial intervention session and successfully solved problems at an abstract level with an accuracy of 100% after this point (with no use of fraction tile manipulatives). Similar to participant four, participant two was more dependent on the self-monitoring checklist and fraction tiles compared with participants first, three and five; however, during the last two intervention sessions, he was able to accurately solve problems while not resorting to such tools. The interventionist observed that participant Three maintained 100% accuracy at an abstract level with no reliance on manipulatives and only resorted to fraction tiles in session one, choosing to subsequently disregard them. While participant four appeared to be more dependent on the self-monitoring checklist and fraction tiles compared with Andrew and Robert, he was able to accurately solve problems with no need to use such support in the last two sessions of the intervention. According to data from the generalization phase, stability was observed as they recorded 100% correct answers in session one and 82% in session two. Similar to participants one and three, participant five largely ignored the fraction tiles and was capable of solving problems at an abstract level at a consistently high level (with no need for manipulatives). Nevertheless, his ability to generalize the acquired skills to problems involving whole fractions in one session was lacking as his problem-solving accuracy in this session was 0%.

Without using fraction tiles, participants one, three, and five individually solved abstract problems with 100% accuracy and maintained that accuracy. In contrast, the second participants and fourth demonstrated a greater initial reliance on the self-monitoring checklist and manipulatives. Despite this dependency, both participants showed significant improvement and were able to solve problems accurately without these supports by the final two intervention sessions. During the generalization phase, performance was stable, beginning with 100% accuracy in the first session and maintaining a high level of 82% in the subsequent session. A notable exception was participant five, who, despite perfect accuracy on the trained tasks, failed to generalize his skills, scoring 0% on a novel problem type involving whole fractions.

Sixth grade

The mean accuracy of students in the sixth grade in solving problems involving fractions was 6%, 5%, 17%, 41%, and 19%, respectively, with data from this phase largely demonstrating limited but consistent abilities; however, it is notable that participant four accurately solved an average of three out of five problems in every session. After the intervention had been introduced, an instant increase in their response accuracy occurred, rising to 100%, 92%, 100%, 100%, and 88%, respectively. Resultantly, between baseline and intervention, mean accuracy changes of 94%, 87%, 83%, 59% and 69% were

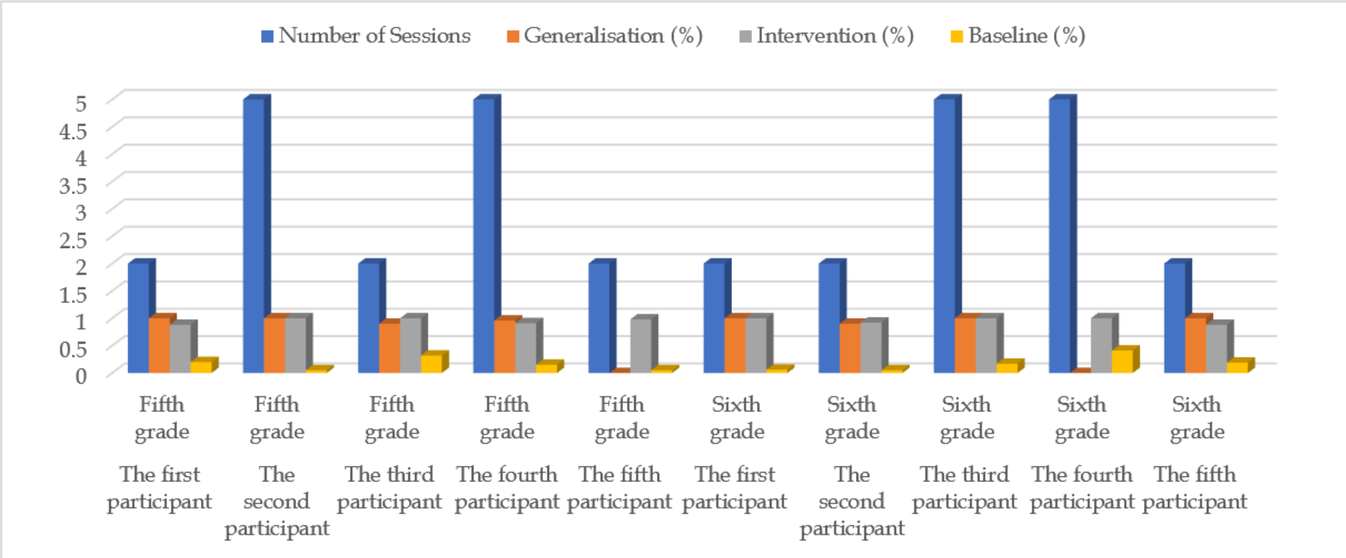

Figure 2. The summary of results of the second school (Source: Authors' own elaboration)

recorded, with no data points overlapping. In terms of generalizability, their accuracy in terms of solving whole proper fractions for three sessions in a row was 100%, 90%, 100%,0%, and 100%, respectively.

A notable observation made by the interventionist was that participants one and two discontinued their reliance on fraction tiles subsequent to the initial intervention session and sustained an accuracy of 100% in solving problems at an abstract level (with no use of fraction tile manipulatives). While participants three and four exhibited increased reliance on the fraction tiles and self-monitoring checklist, they were able to accurately solve problems without using these tools in the last two intervention sessions. With regard to generalization, their performance was relatively stable, with 100% correct answers in the initial session, and then 84% in all other sessions. Similar to participants one and two, participant five largely ignored the fraction tiles, successfully maintaining optimal accuracy in solving problems at an abstract level (with no need for manipulatives). Nevertheless, in terms of his ability to generalize these skills to problems involving whole proper fractions, he was unable to solve any such problems in one session, please see **Figure 2**.

Third School

Fifth grade

The average baseline performance of the fifth grade students in terms of solving fraction word problems was 14%,32%, 5%, 22%, and 7%, respectively, where the performance increased marginally in the fifth baseline session and one of five problems could be solved. Once the intervention had been introduced, an instant increase in their accuracy was achieved, with means rising to 91%, 100%, 100 %, 88%, and 98%, respectively, when the intervention was being implemented and data points did not overlap between the respective phases. With regard to the ability to generalize, the accuracy with which the participants were able to apply their skills to solving whole proper fraction problems for three successive sessions was 100%, 87% 100 %, 0%, and 85%, respectively. A notable observation was that the trend for participant five was largely stable, as his response was 88% correct in the initial session and then 86% for the other two sessions.

Similar to participant three, participant one was initially more dependent on the self-monitoring checklist and fraction tiles compared with participants two, four and five, but during the last two intervention sessions, they were able to accurately solve problems without such assistance. The interventionist observed that participant two maintained this optimal accuracy at an abstract level with no need for manipulatives and only resorted to fraction tiles in the initial session, choosing to subsequently ignore them. Although participant three appeared to be more reliant on the self-monitoring checklist and fraction tiles, he was also capable of accurately solving problems with no need to use these tools in the last two intervention sessions. In the generalization phase, stability was observed as responses were 100% correct in session one, then 81% in the other two sessions. Similar to participants two and five, participant four seldom utilized the fraction tiles and effectively sustained his ability to accurately solve problems at an abstract level (with no use of manipulatives). Nonetheless, an assessment of his ability to generalize these skills to problems involving whole proper fractions revealed that his accuracy was 0% in one session. Observations made by the interventionist revealed that participant five no longer used fraction tiles subsequent to intervention session one and sustained 100% problem-solving accuracy at an abstract level (with no use of fraction tile manipulatives).

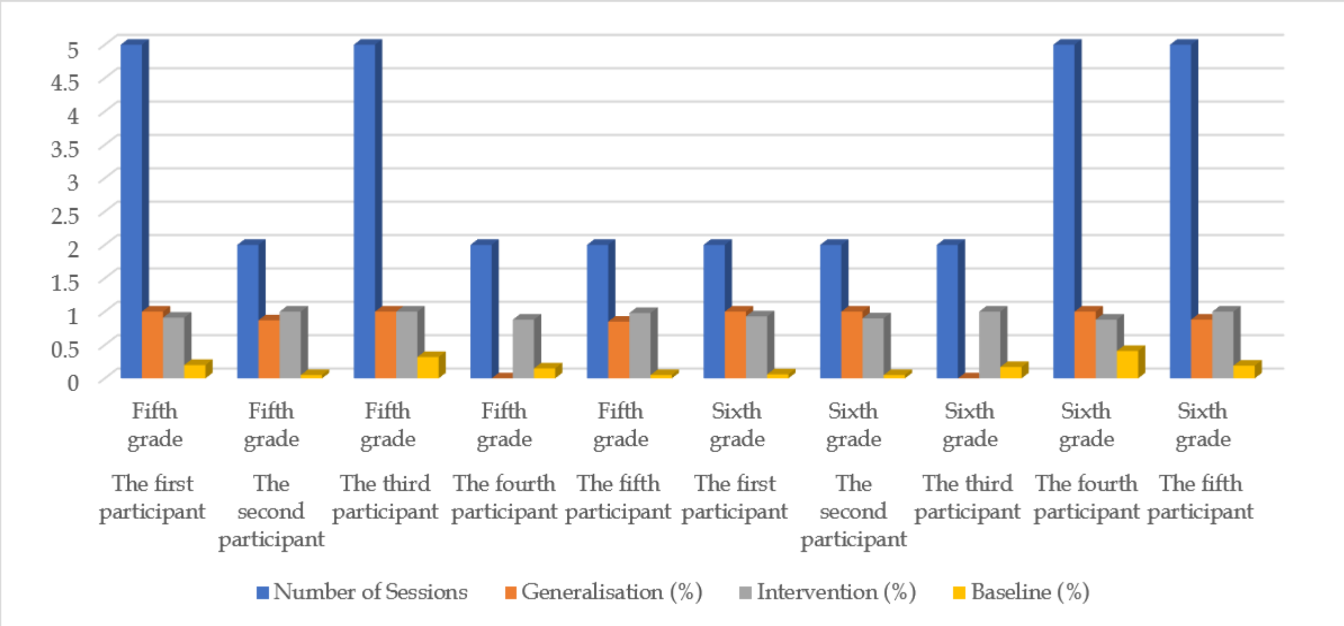

Figure 3. The summary of results of the third school (Source: Authors' own elaboration)

Sixth grade

The mean accuracy achieved by participants from Grade Six during baseline was 7%, 6%, 43%, 16%,and 15%, respectively; data from this phase revealed a low but stable pattern, apart from participant three who accurately solved and average of 3 out of 5 problems in the respective sessions.

After the intervention was implemented, an instant rise in the accuracy of their responses occurred, increasing to 93%, 90%, 100%, 88%, and 100%, respectively. Resultantly, between baseline and intervention, the mean accuracy changed by 86%, 84%, 57%, 72%, and 85%, with no data points overlapping between phases. In terms of generalization, the participants were capable of solving problems involving whole proper fractions at rates of 100%, 100%, 0%, 100%, and 88%, respectively, for three sessions in a row.

A notable observation made by the interventionist was that participants one and two no longer used the fraction tiles after the initial intervention session and then continued to achieve perfect accuracy in solving problems at an abstract level (with no use of fraction tile manipulatives). In regard to the third participant like the first and second participants, the third participant rarely used the fraction tiles, and was able to maintain his perfect problem-solving accuracy at an abstract level (without the manipulatives).

Nevertheless, an assessment of their ability to generalize these skills to problems involving whole proper fractions revealed that in one session, their problem-solving accuracy was 0%. While participants four and five exhibited increased reliance on the fraction tiles and self-monitoring checklist compared with two other participants, they were able to accurately solve problems with no need for these tools in the last two intervention sessions. They demonstrated a stable trend during generalization with 100% correct responses in the initial session, then 86% and 80%, respectively, in the following sessions, please see **Figure 3**.

Fourth School

Fifth grade

On average, the baseline performance of the fifth grade students in terms of solving fraction word problems was 7%, 14%, 5%, 27%, and 12%, respectively, where the performance rose marginally in the fifth baseline session with one out of five problems being solved. After the intervention had been introduced, an immediate increase in their ability to respond accurately occurred, with respective means of 100%, 97%, 100 %, 88% and 94% being recorded when the intervention was ongoing.

Consequently, from baseline to intervention, mean level changes of 93%, 83%, 95%, 61% and 82% occurred, with data points not overlapping between the different phases. With regard to generalization, the accuracy with which the participants solved problems containing whole proper fractions for three successive fractions was 90%, 100% 99%, 0%, and 90%, respectively. It is notable that according to the generalization data for the fifth participant, they were consistent in their ability to produce correct responses, with a rate of 97% in the initial session, then 84% in the other two sessions.

After the first session, three of the five participant: first, third and fourth achieved and maintained 100% accuracy with little to no use of fraction tiles. Although the other two participants (second and fifth) initially relied more on the self-monitoring checklist and

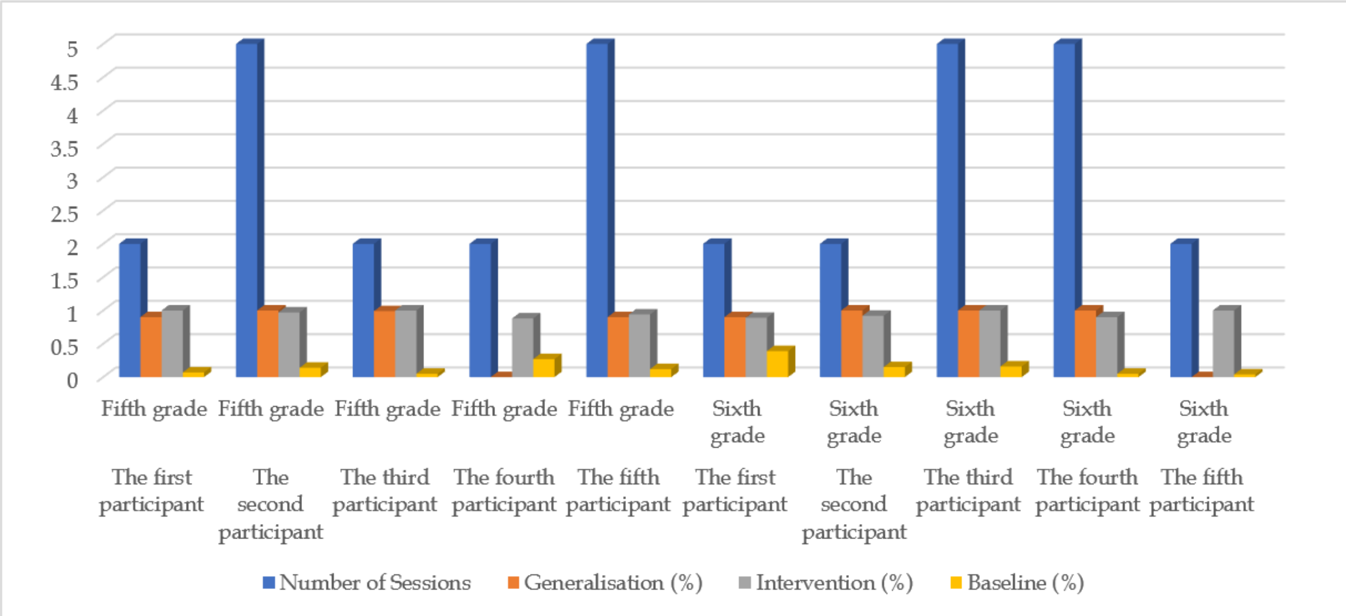

Figure 4. The summary of results of the fourth school (Source: Authors' own elaboration)

manipulatives, they significantly improved in the last two intervention sessions, correctly solving problems without these aids. Performance started off at 100% accuracy during the generalization phase but steadily dropped to 84% in later sessions.

One significant exception was participant four who scored 0% on a novel issue type including whole fractions, demonstrating a complete lack of ability to generalize his skills despite having flawless accuracy on training tasks.

Sixth grade

At the baseline stage, the mean accuracy with which students in the sixth grade solved fraction problems was 39%, 15%, 16%, 5%, and 4%, respectively; the trend was low but stable, apart from participant one who provided accurate solutions to an average of 3 out of 5 problems in the respective sessions. After the intervention had been introduced, an instant rise in the accuracy of their responses occurred, increasing to 89%, 92%, 100%, 90%, and 100%, respectively. Resultantly, between baseline and intervention, mean accuracy changes of 50%, 77%, 84%, 85%, and 96% occurred, where data points did not overlap between phases. With regard to generalization, the accuracy with which they were able to solve whole proper fraction problems across there successive sessions was 90%, 100%, 100%, 100%, and 0%, respectively.

It is noteworthy that the interventionist observed participants one and two disregarding the fraction tiles subsequent to the initial intervention session and maintain a perfect accuracy in solving problems at an abstract level (with no need for fraction tile manipulatives). While participants three and four were more dependent on the fraction tiles and self-monitoring checklist compared with two other participants, they became capable of accurately solving problems with no need for support in the last two intervention sessions. In terms of generalizability, a consistent trend was observed as they achieved 100% correct responses in the initial session, and then 85% and 84% in the remaining two sessions. Similar to participants one and two, participant five seldom resorted to the fraction tiles, and effectively maintained 100% accuracy in solving problems at an abstract level (disregarding manipulative). Nevertheless, his ability to generalize his skills to problems involving whole proper fractions was extremely limited as his accuracy in one session was 0%, please see **Figure 4**.

DISCUSSION

The current study was conducted with the aim of evaluating whether the utilization of a VM intervention involving concrete manipulatives in conjunction with a comprehension check and self-monitoring checklist affected the ability of 40 autistic elementary school students to accurately solve fraction problems. To provide ASD students with the opportunity to achieve their full potential in the future in terms of their careers and living independently, it is important that the teaching they are given during their education is suitable for their needs (Wong et al., 2021).

The main findings showed that between baseline and intervention, the students' accuracy significantly increased, and 32 were capable of generalizing their skills to whole proper fraction problems. These results concur with the findings of Hughes (2019), who effectively instructed an autistic middle-school student on fraction simplification through the use of VM in combination with a self-regulation method. In a different research, Bouck et al. (2019) found that the use of a virtual-representational-abstract instructional sequence as a type of virtual manipulative allowed an autistic middle-school student to quickly become capable of identifying problems involving fractions. By combining different methods, the study participants acquired knowledge of solving fraction problems and then applied this ability to solving analogous fraction problems; however, two participants from each of the schools (from fifth and sixth grade, respectively) were unable to transfer their knowledge to different types of problems in this manner. These findings indicate that the intervention was capable of enhancing the ability of the students to acquire a conceptual and procedural comprehension of the skills needed for solving fractions, which is a critical competency considering the scope and fundamental characteristics of mathematics.

For example, learners must fundamentally understand rational numbers (e.g., fractions) if they want to further their education in mathematics at more advanced levels. Even if they choose not to continue learning higher level mathematics, interventions aimed at improving their learning of rational numbers can increase life quality, and fractions are commonly encountered in people's daily lives, meaning they must understand and know how they should be handled. The lives of students categorized as having ASD after they leave education can be satisfying in terms of their careers and living independently if given suitable pedagogical instruction (Stroizer et al., 2015; Wong et al., 2021). To meet the varying learning requirements of autistic students in settings as varied as individual intensive tuition, inclusive classrooms and homework help, teachers will certainly appreciate the opportunity to implement VM teaching and concrete manipulatives combined with particular behavioral techniques.

It is an important also to discuss the reasons why approximately 20% of participants failed to generalize their skills to whole proper fraction problems. According to teachers report found that some students have poor numerical sense because of delay in understanding rational numbers. Students with limited working memory may lose track of steps or confuse procedures. Therefore, solving fractions anxiety can interfere with focus and confidence. In addition, repeated failure can lead to avoidance behaviors. It could be challenging to switch between representations of fractions (visual, symbolic, verbal, etc.) due to a lack of flexibility in thinking. This is aligned with research that suggest students with ASD require more systematic and intensive instruction in order to generalize (Hume et al., 2009)

As this intervention comprises various different elements, it can offer a range of benefits to learners. Firstly, it is possible to use VM for delivering systematically teaching particular subjects with great clarity and has been determined to be very successful for mathematics teaching. Secondly, to enable all students regardless of their learning difficulties to achieve similar achievement levels; VM in combination with manipulatives offers an extensive and in-depth technique for providing individualized instruction and facilitating the mastery of particular skills and concepts before moving on to more complex areas. For example, studies have shown that VM can be highly beneficial for mathematics learning, particularly when implemented in conjunction with academic and behavioral techniques such as manipulatives, self-monitoring checklists, and the CRA framework (e.g., Hughes, 2019; Hughes & Yakubova, 2019). Resultantly, teachers will be able to concentrate on improving particular skills and eliminating deficiencies in students' mathematical understanding. In this research, all participants acquired the ability to solve simple proper fraction problems and then proceeded from being able to solve concrete problems to those with more abstract properties. This implies that the use of concrete manipulatives enables learners to further comprehend the usage of abstract mathematical concepts (Maccini & Gagnon, 2000; Root et al., 2017). Furthermore, the systematic and visual way in which VM delivers mathematical content through the use of explicit and consistent language while also making sure students focus on the given topic increases its efficiency in teach a wide range of skills to autistic students (Hughes & Yakubova, 2019; Hughes et al., 2016; Yakubova et al., 2015). The design of the intervention means it is flexible enough to allow changes based on quantity and need; therefore, in the context of this study, extra sessions and opportunities would have allowed the study participants time to practice and become more proficient in skills they were unable to develop.

In summary, explicit teaching as detailed in the CRA framework requires the teacher to model and think aloud to provide clarity on the mathematics being studied, guiding learners in their attempts to find solutions to given problems, and then allowing them to solve example problems independently. The pedagogical foundation of the CRA framework means that it is based on many years of research (e.g., Agrawal & Morin, 2016; Bouck & Park, 2018; Bouck et al., 2017; Butler et al., 2003; Flores, 2010; Jordan et al., 1998; Miller & Mercer, 1993; Underhill, 1977) and is suggested for use with learners who have received a diagnosis of either a high-incidence or low-incidence disability (Browder et al., 2012; Doabler & Fien, 2013; Gersten et al., 2009; Root et al., 2017).

It is an important to mention that abstract mathematical ideas like fractions and ratios are difficult for many kids to understand. In order to help convert abstract symbols into tangible, visible information, video models frequently incorporate visual representations (such as fraction bars, pie charts, and manipulatives). This agrees with social learning theory, which suggests that people learn by observing others. It emphasizes the importance of imitation, modeling, and reinforcement in the learning process. In addition, video learning stimulates visuospatial memory, which some students may find more powerful than verbal memory. Students can develop procedural memory by frequently seeing a model handle a problem. This helps them remember not just what to do, but also how and when to do it.

Limitations

The emphasis of this study sample is solely on 40 students attending primary school diagnosed as having ASD, thus excluding teachers owing to the challenges associated with eliciting approval to extend the survey to a larger audience. This study focused only on government schools in the east of Saudi Arabia (in the cities of Alkhobar and Dammam). However, the researchers believe that these cities were a good place to conduct this study, because they have large populations drawn from different parts of the Kingdom of Saudi Arabia. One of limitation also the difficulty of adhering to the school schedule, as sometimes students were absent due to illness or visits to the doctor, and there were days when the scheduled support period for mathematics did not take place as students where following an alternative schedule.

Avenues for Future Research

In terms of potential areas in which research can be conducted in the future, it was evident that eight participants were incapable of generalizing the skill they had obtained to be able to solve whole proper fraction problems. An explanation for this could be that the academic year was ending, which meant their participation was limited to a single session. This conforms with other studies indicating that autistic students need methodical and intensive teaching to be able to generalize (Hume et al., 2009). Further studies are recommended to concentrate on identifying the potential for teaching advanced fraction problems to autistic students utilizing VM and concrete manipulatives in combination with self-monitoring methods. Future studies should investigate the relative effectiveness of the four instructional components (video modeling, manipulatives, self-monitoring checklist, and comprehension check) in improving learning outcomes among students with autism.

CONCLUSION

The study findings contribute to the literature and have practical implications for instructing autistic students on how to understand fractions and solve basic proper fraction problems, utilizing VM in combination with a self-monitoring checklist, concrete manipulatives, and a comprehension check. The outcomes showed that between baseline and intervention, each of the 40 students was capable of solving basic proper fraction problems with increased accuracy, while 32 could also transfer this skill to find solutions to whole proper fraction problems. The implication is, therefore, that the use of VM in conjunction with self-monitoring checklists offers an effective means of delivery clear systematic instruction with consistent pedagogical language to autistic students, thus facilitating their mastery and conceptual understanding of fraction problems. Furthermore, as the creation and implementation of VM are relatively easy processes, it offers a flexible method of delivering thorough, individualized and custom guidance that meets the specific needs of leaners within various classroom settings.

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