World Academy of Science, Engineering and Technology
International Journal of Educational and Pedagogical Sciences
Vol:16, No:9, 2022

Teaching Math to Preschool Children with Autism

Hui Fang Huang Su, Jia Borror

***Abstract*—**This study compared two different interventions for math instruction among preschoolers with autism spectrum disorder (ASD). The first intervention, a combination of discrete trial teaching and Strategies for Teaching Based on Autism Research (STAR), was the regular math curriculum utilized at the preschool. The second activity-based, naturalistic intervention was Project Mind, also known as Math is Not Difficult. The curricular interventions were randomly assigned to four preschool classrooms with ASD students and implemented over three months for Project MIND. Measurements gained during the same three months for the STAR intervention were used. A quasi-experimental, pre-test/post-test design was selected to compare which intervention was the most effective in increasing mathematical knowledge and skills among preschoolers with ASD. Standardized pre and post-test instruments included the Bracken Basic Concept Scale-3 Receptive, the Applied Problems and Calculation subtests of the Woodcock-Johnson IV Tests of Achievement, and the TEMA 3: Test of Early Mathematics Ability – Third Edition. The STAR assessment is typically administered to all preschoolers at the study site three times per year, and those results were used in this study. We anticipated that the implementation of these two approaches would lead to improvement in the mathematical knowledge and skills of children with ASD. Still, it is essential to see whether a behavioral or naturalistic teaching approach leads to more significant results.

***Keywords*—**Autism, mathematics, preschool, special education.

I. Introduction

ASD is a developmental disorder that typically begins during the first three years of a person's life. Symptoms, abilities, and behaviors may vary significantly among individuals with ASD. It is defined by deficits in social communication and a narrow, repetitive repertoire of behavior [1]. The Centers for Disease Control and Prevention have found a prevalence rate of 1:68, with a male-to-female ratio of 5:1 [2]. In the Broward County School District, there are more than 6,400 students in grades PreK-12 with educational eligibility for services related to autism [29].

Due to their unique learning styles, most young students with ASD require specialized instruction and low teacher-student ratios. They need specialized instructional techniques based on applied behavior analysis principles [3], [4]. These instructional techniques have the most prosperous research foundation for students with ASD [5]. Public school systems are struggling with providing appropriate educational programs for students with ASD. The high cost of providing enough staff to meet needed ratios and the need for specialized training and supervision for staff have presented challenges [6].

A. The Star and Discrete Trial Teaching

Young students with ASD must be taught learning readiness skills like sitting in a chair, following 1-step directions, attending to the teacher, and imitating gross and fine motor movements before learning other skills [7]. These skills are best taught using discrete trial teaching. In discrete trial teaching, skills are broken down into small steps or elements and taught one step at a time, called task analysis. Discrete trial teaching provides the repetition students with ASD need to master tasks. A discrete trial has five components: getting the student's attention, providing the direction (i.e., discriminative stimulus in behavioral terms), prompting the student if necessary to get him to perform the skill, the student's performance of the skill, the consequence which is generally reinforcement, and the inter-trial interval to provide an apparent onset and offset to the trial [8]. An example of a discrete trial would be giving the direction, "Show me 1," to a child when the instructor gives him a page with three different numerals. The child will receive a reinforcer if he gives the correct response (i.e., a preferred food item, an activity, or a toy to play with) or be prompted by the teacher, if necessary. The teacher would take the data during the inter-trial interval, which separates the offset of one trial and the onset of the next. The power of discrete trial teaching for the child comes with the association of the reinforcer with the behavior, which is how he learns [7].

Discrete trial teaching is effective for teaching-learning readiness, receptive vocabulary, and pre-academic skills [9]. However, it is less effective than other techniques for teaching social skills, play, and expressive communication to young children with autism [10]. Discrete trials have a long research history and be an evidence-based teaching strategy according to both the National Professional Development Center for Autism Spectrum Disorders (NPDCASD) [11] and the National Autism Center [12], which both published reviews of the literature to identify evidence-based effective practices. The NPDCASD found that discrete trial teaching met the criteria for being an evidence-based practice based on 13 single case design studies with preschool and elementary-aged students. Reference [12] included discrete trials in the categories of Behavioral Interventions and Comprehensive Behavioral Interventions as effective practices.

B. Project Mind and Activity-Based Intervention

One of the drawbacks to discrete trial teaching is the potential lack of generalization to untrained materials, adults, or environments. That creates significant barriers to the actual mastery of knowledge or skills. Another approach found in the research is called activity-based intervention, where skills are targeted in the regular instructional routines of the classroom. Losardo and Bricker conducted a single-subject study using an

Hui Fang Su is with Nova Southeastern University, United States (e-mail: shuifang@nova.edu).

alternating treatment design [13]. Six preschool children with developmental delays participated in the study and received direct instruction as one treatment and activity-based instruction as the other treatment. The targets were naming objects. Each child received both treatments for 15 minutes each per day. There was also a generalization session following the completion of the 6-week intervention. Both interventions showed positive effects on acquisition [13].

In 1988, Su created a unique program that utilized innovative strategies and instructional models to get all students, including children with special needs. Teachers of all abilities and grade levels are excited about mathematics through games, stories, poems, songs, art, puzzles, mental math activities, and competitions for all children [14]. Students exposed to the MIND strategies, especially at the elementary level, obtained impressive test results [15]. According to the Annenberg Challenge Report, "low-income schools that participated in Project MIND, a pilot program, could become a model for math instruction throughout the county. Not only teachers but administrators, secretaries, nurses, cafeteria workers, and teacher's aides had all attended 30 hours of training in Project MIND strategies" [15]. The Annenberg Challenge Report, an independent evaluator of the Project MIND strategy, clearly supported the effective use of the strategies for all learners.

II. Using Project Mind with Children with Autism

In 2005 and 2006, Su used an exploratory approach to analyze the effectiveness of the unique Project MIND curriculum with a quasi-experimental pre-/post-plus comparison group design in a South Florida preschool serving children with autism. The experimental study aimed to identify the effective uses of instructional strategies that impacted students' learning. Instruction consisted of direct and embedded instruction derived from the Project MIND curriculum [14]. One class with ASD children and one integrated class were randomly assigned to a study group, while the control group consisted of the two other classes. Study participants comprised 25 students with ASD and ten typically developing peers. Subtests from the Hawaii Early Learning Profile (HELP) were administered for pre- and post-mathematics achievement scores to assess students' reasoning and problem-solving skills, along with the Bracken Basic Concept Scale-Revised (BBCS-R), which evaluates students' knowledge of the language of mathematical concepts. In addition to a pre- and post-test comparison, students were assessed on their cognitive and visual-spatial abilities before the intervention. Cognitive abilities were assessed using the Mullen Scales of Early Learning (MSEL), a comprehensive, individually administered measure of cognitive functioning. The Beery Developmental Test of Visual-Motor Integration, or VMI, was used to evaluate visual-spatial skills. Both assessments were utilized to identify the outcome measures between the intervention and control groups on acquiring knowledge of mathematical concepts [16]. Results of the study indicated that students with high-functioning ASD increased their understanding of mathematical concepts when Project MIND was employed. Additionally, the study results showed a significant difference in the MSEL and VMI results between the study and control groups [16].

Project MIND uses familiar concepts to build bridges to unfamiliar and abstract concepts. For example, an introduction to the base-10 concept can begin by demonstrating these concepts with items that students understand (i.e., people, fruits and vegetables, candies, classroom items, toys, and animals). For example, Su created mathematical 'best friends' to teach higher-level concepts for solving mathematical problems [17]. One MIND-based strategy shows children that combinations of numbers such as 1 and 9, 2 and 8, 3 and 7, and 4 and 6 are 'best friends because the sum of each combination is 10. The *Best Friend's* concept has been shown to help students perform activities such as adding multi-digit numbers, subtraction, multiplication, division, fractions, and other numeric operations. The idea of best friends is easily extended to other numeric systems [17].

A. Autism and Math Education Research

The push for research regarding academic learning for children with autism has grown over the past few years, with the primary focus being on reading and cooperative learning [18]. Although autism studies in academic areas exist, there is an apparent lack of mathematics and research in math with preschool-aged children. Mathematics is an area of particular concern for children with autism. An estimated 25% of students with ASD have a mathematics learning disability [19]. A combination of the limited literature on the topic of mathematics, and the growing need for this subject as a core curriculum, make this research vital. Barnett and Cleary stated that a factor that causes children with autism to have difficulties with mathematics would be the lack of targeted direct instructional opportunities [20]. A meta-analysis on teaching mathematics to students with cognitive disabilities presented a total of 68 research studies; only four of the included experiments had children below the age of 6 years [21]. Students having difficulties with meaningful core curricula during the early years of education will often find problems that carry on to later grades. The area of mathematics is a crucial target for children with autism and other cognitive disabilities [22]. A longitudinal study by the U.S. Department of Education looked at math achievement of children with disabilities aged 3 to 10. This study found that the most significant increase in age-specific growth occurs during preschool, ages 3 to 6 years [23]. Furthermore, the researchers concluded that children receiving a preschool special education program have a better base of growth in math performance.

B. Objectives

The objective of this study was to compare two interventions to build math skills in preschool children with autism. The first treatment was based on the curriculum, STAR, which uses discrete trial teaching for skill acquisition in pre-academics and receptive language. This was considered the BAU treatment as it was the curriculum used at the study's preschool. The second intervention was Project MIND (Math is Not Difficult). It was implemented through an innovative, game-based instructional

approach where mathematics was embedded in developmentally appropriate daily activities.

The expected outcomes of the study were:

1. There will be a significant difference in STAR assessment scores between students receiving the Project MIND intervention and those receiving BAU.
2. There will be a significant difference in scores on the Woodcock-Johnson between students receiving the Project MIND intervention and students receiving BAU.
3. There will be a significant difference in scores on the TEMA-3 between students receiving the Project MIND intervention and students receiving BAU.
4. There will be a significant difference in scores on the Bracken between students receiving the Project MIND intervention and students receiving BAU.

C. Intervention Location

The Baudhuin Preschool is located on the main campus of Nova Southeastern University and is an internationally recognized model program for young children with ASD. The program is offered under an agreement with the School Board of Broward County, Florida. Due to the unique setting located on a university campus, there are ample opportunities for collaboration among various clinical, academic, and research departments that enrich the overall educational program for students and their families. This therapeutic program was designed for children 3-5 years of age and focuses on developing cognitive, social-emotional, adaptive, behavioral, motor, and communication skills in a relationship-based environment.

The preschool currently has 122 students eligible for a special education program under the category of autism. Each student has an Individual Education Program (IEP) document that is developed by a multidisciplinary team of professionals and parents listing the child's present level of performance, the impact of their disability, the priority educational needs, goals, and objectives for the coming year, and the services and supports the student will receive to address the intents and purposes defined in the plan. Each plan is reviewed at least annually. Students receive speech-language, occupational, and physical therapy as listed in the IEP. A family counselor provides a range of educational and support activities for the families.

There are 16 classrooms for students with autism in the Baudhuin Preschool. Each classroom has between seven and 12 students, depending upon the complexity of the needs of the students assigned to each one. A Florida-certified teacher teaches each classroom in Preschool-Primary Education. There are three to four aides assigned to each classroom.

D. Potential Benefits

There is little evidence about the effectiveness of interventions for preschool children with autism implemented in public school settings due to the constraints of small group size and lack of random assignment to interventions. School systems often refuse to allow researchers to conduct research in their settings due to the demands on teachers and time away from instruction for students. As a university-based public-school program, this setting allows the implementation of research where students meet public school eligibility requirements. Still, teachers are not part of a public-school union. The university-based program serves as an observation site, practicum placement, and research setting for faculty, staff, and students. Because faculty and staff at the Baudhin Preschool are NSU employees, they willingly assist and participate in studies related to autism interventions because research is encouraged and supported.

E. Methodology and Research Design

A quasi-experimental pre-test/post-test design was used for this study. Four classrooms at the Baudhuin Preschool were randomly assigned to the two treatment conditions. The first was defined as the Business-as-Usual Model (BAU) and included using the STAR curriculum. The regular curriculum used at the study site is STAR, based on applied behavior analysis [24]. The curriculum has an assessment component administered three times a year to all students in the school and drives the skills targeted for each student. There are three levels of the curriculum, and children advance through the levels as they gain skills. Each level has a pre-academic concepts strand that includes math skills. Three instructional strategies are used in this curriculum to build skills: discrete trial teaching, pivotal response training, and functional routines. They are all grounded in ABA and have been determined to meet the criteria for evidence-based practice by the NPDCASD [11]. The pre-academic strand is taught using discrete trial teaching. Discrete trial teaching is a systematic instruction technique where skills are broken down into small steps (i.e., task analyzed), a direction is given to the student, a student responds or is prompted to provide a correct response (i.e., errorless learning), and receives a reinforcer for providing a correct answer [8]. Then, an intertrial interval allows the child to access the reinforcer and the teacher to record data.

The second treatment was Project MIND (Math is Not Difficult), developed by the study's principal investigator, which was delivered in a more developmental, naturalistic manner [14]. This curriculum used embedded instruction, where teaching mathematics was integrated into various preschool activities, including music, movement, art, circle time, transition activities, and outdoor play utilizing strategies described in the Project MIND approach [16]. Project MIND used familiar concepts to build bridges to unfamiliar and abstract concepts. For example, an introduction to the base-10 concept began by demonstrating concepts with items that students already understood (e.g., people, food, classroom items, toys, and animals). The "best friends" concept was used to teach higher-level concepts for solving mathematical problems, which helped students with addition, subtraction, fractions, and other numeric operations.

F. Participants

Four preschool-aged students (3-5 years) with ASD classrooms were selected to participate in the study. These classrooms were chosen based on the characteristics of the

students. They included higher cognitive level (i.e., not intellectually disabled) and lack of challenging behavior (i.e., no aggression, high magnitude disruption, or interfering self-injurious behavior). Each classroom included nine-to-12 students, a staff, a Florida-certified teacher, and two or three aides. The four classrooms were randomly assigned to the BAU or Project MIND treatment. Each group had approximately 18-24 students. The selected classroom teachers and aides were then trained in Project MIND intervention.

III. Instruments

Each of the following standardized tests or curriculum-based assessments was administered to all the participants before the introduction of the interventions.

The STAR Assessment is a curriculum-based assessment for children with autism, designed for preschool and early elementary-aged students [24]. There are assessment strands in areas generally impacted by autism, including Receptive Language, Expressive Language, Spontaneous Language, Functional Routines, Pre-academic Concepts, and Play and Social Interaction. The Math items in the Pre-academic Concepts strand provided the instructional sequence for the group receiving the systematic instruction treatment.

The Test of Early Mathematics Ability, Third Edition (TEMA-3) is designed to assess the mathematical ability of children between the ages of 3 and 11. The purpose of the test is to identify young children with learning difficulties who are likely to develop problems in mathematics. The test also provides information about children's mathematical strengths and weaknesses, with or without learning difficulties. It suggests instructional practices for students who miss specific items. The test measures mathematics learned in everyday situations (informal) and more formal situations such as school, as well as concepts and skills [25].

The Woodcock-Johnson IV Tests of Achievement (WJ IV) is normed on children ages 2 to 19. Two subtests were used to measure pre-and post-test achievement in mathematics. They were Applied Problems and Calculations. Applied Problems measure a student's ability to analyze and solve math problems; for young children, the child needs to apply simple number concepts. The Calculation subtest requires a student to perform paper and pencil math computations beginning with writing numbers through simple numerical operations [26].

The Bracken Basic Concepts Scale-Third Edition-Receptive is designed for young children, ages 3 to 6-11. It evaluates the acquisition of basic concepts, including numerical concepts, and is strongly related to early childhood academic achievement [27].

Fidelity of implementation was measured bi-weekly against a checklist for each of the two interventions. The STAR implementation checklist comes with the curriculum. The sections on two teaching methodologies not utilized in this study were not completed. The author of the curriculum provided the implementation checklist for Project MIND.

A. Data Analysis

Power analysis for an independent two-group comparison was conducted in G-Power software to determine the sufficient sample size based on the following assumptions: (1) the median effect size of 0.60; (2) the expected power of 0.80; (3) the allocation ratio of 1; (4) *alpha* of 0.05; (5) one-tailed test, and (6) a 10% attrition rate. With a sample size of 18-24 per group, we would achieve the expected power of 0.80 to compare the differences between the intervention and control groups [28].

Descriptive statistics were computed and analyzed for all measures. Dependent samples *t*-tests were computed. Resultant *p*-values more minor than a critical value of .05 were used to reject each null hypothesis. Effect sizes for each of the comparisons were also calculated and analyzed.

B. Gained Scores for the Intervention Group

Prior analyses incorrectly identified one of the Intervention groups as a Comparison group. The three Intervention groups were combined in cleaning the dataset, leaving one Comparison group. Incomplete rows were removed; this included students with one or more missing scores. This resulted in 22 students in the Intervention group and two in the Comparison group. Because of the minimal number in the Comparison group, no consideration was given to including them for further analysis. Data from the Intervention group were analyzed for the Bracken RTC, the Bracken RSRC, and the TEMA; no data were provided for the WJ score.

TABLE I
PRE- AND POST-BRACKEN SCORES

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Bracken RTC	83.23	22	13.255	2.826
	Post Bracken RTC	85.32	22	14.361	3.062
Pair 2	Pre Bracken RSRC	103.95	22	15.825	3.374
	Post Bracken RSRC	104.09	22	13.341	2.844
Pair 3	Pre TEMA	100.59	22	17.813	3.798
	Post TEMA	106.55	22	16.989	3.622

There was minimal gain between the Pre-Bracken RTC and the Post-Bracken RTC scores (i.e., 2.09 points) and the Pre-Bracken RSRC and Post-Bracken RSRC scores (i.e., 0.14 points). Participants did show a 5.96-point gain on the Pre-TEMA and Post-TEMA scores.

Pre-intervention and post-intervention scores were compared using a dependent sample *t*-test. Results indicated no significant difference (i.e., p =.210) in pre-intervention and post-invention Bracken-RTC scores and no significant difference (i.e., p =.943) in pre-intervention and post-intervention Bracken-RSRC scores. A significant difference (i.e., p = .004) did exist between pre-intervention and post-intervention TEMA scores.

IV. Summary

Data were analyzed for the Bracken RTC, the Bracken RSRC, and the TEMA; no data were provided for the WJ score. In cleaning the dataset, incomplete rows were removed; this included students with one or more missing scores. Because of a lack of data, n = 2, students from the Comparison group were also eliminated. This resulted in a dataset with scores from 22 students from the Intervention group.

Results showed no significant difference in pre-intervention and post-intervention scores on the Bracken-RTC and Bracken-RSRC. A vital difference did exist between pre-intervention and post-intervention TEMA scores. However, care should be taken in interpreting this difference since such a small gain score may not indicate practical significance.

V. Challenges

The study is a replication with modifications of a previously successfully designed and implemented research at the Baudhuin Preschool implemented by NSU researchers [16]. A challenge of this study is to identify an adequate number of 3-to-4-year-olds with cognitive abilities above 70 on a measure of intelligence and development. A second challenge is ensuring that the teachers implement the interventions with fidelity. Observers from the research team monitored interventions bi-weekly and completed a fidelity checklist for the observed intervention. Additional training was provided as needed. As with any group of students with ASD, unexpected behavioral issues may interfere with the instructional period, negatively affecting each class's content delivery.

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Dr. Hui Fang Huang "Angie" Su is a Professor of Mathematics Education at Nova Southeastern University's Fischler College of Education and School of Criminal Justice. She holds an Ed.D in Early and Middle Childhood from Nova University in 1991.

She is the creator of *Project MIND - Math Is Not Difficult®*, a K-12 mathematics enhancement project currently implemented in hundreds of classrooms throughout the country. Project MIND has received numerous awards, including the Presidential Award for Excellence in Mathematics and Science Teaching from the National Science Foundation, for its innovation and ability to help students, especially preschoolers, become excited about math and improve their math skills. Angie is one of the authors of the Next Generation Sunshine State Standards for mathematics for the State of Florida.

Dr. Jia Borror is an Associate Professor at Nova Southeastern University's Fischler College of Education and School of Criminal Justice. She holds an Ed.D in Educational Leadership from Nova University and National Board Certification as an Early Childhood Generalist. She teaches Early Childhood Education, Curriculum and Instruction, and Educational Leadership courses.