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The Comparison of the Effects of Direct Instruction and Project-/Problem-Based Learning to Teach Basic Math Skills for Students with Low-Functioning Autism Spectrum Disorder

Maiko Hosokawa
St. Cloud State University, maiko.hoso@gmail.com

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Maiko Hosokawa

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Starred Paper Committee:
Marc Markell, Chairperson
Jerry Wellik
Susan Haller

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Chapter 1: Introduction

In 2014, the Center of Disease Control and Prevention (CDC)'s Autism and Developmental Disabilities Monitoring (ADDM) Network reported the population of Autism Spectrum Disorder (ASD) is about 1 in 68 or 1.5% of children. The prevalence of ASD has rapidly increased. In the 1960s, Lotter (1966) reported the prevalence was 0.04%; in the 1990s, the prevalence increased to 0.05% to 0.31% (Nordin & Gillberg, 1996). The percentage increased between 2002 and 2010 based on the previous report; however, there was not a significant increase seen between 2010 and 2012. Then, this most recent prevalence of ASD increased up 29% from 2012. More than 80% of children who are identified with ASD are eligible for the special education program at school or diagnosed with ASD from a community provider.

As the similar timeline of the increasing ASD prevalence, trends regarding U.S. students' math achievement on national and international assessments have changed in the 2000s (Przychodzin, Marchand-Martella, Martella, & Azim, 2004). On an international assessment program, Program for International Student Assessment (PISA), the U.S. students' performance in math has dropped over time. According to the most recent report on PISA (2015) with 73 countries by the National Center for Education Statistics (Kastberg, Chan, & Murray, 2016), the average score of math performance has been lower than the average score of 2009 and 2012. PISA assessed the application skills in science, reading, and mathematics literacy in real-life problems to compare the academic performance. The U.S. students have participated in PISA every 3 years since the first assessment in 2000. Improving U.S. students' math ability has been one of the necessary goals in education.

For higher mathematical achievement, 21st Century skills and problem-solving skills have been highly focused. The Problem-Based Learning, or Project-Based Learning (PBL), is an innovation of mathematical instructions that has gradually replaced traditional mathematical instruction, Direct Instruction (Bell, 2010; Merritt, Lee, Rillero, & Kinach, 2017).

The purpose of this paper was to review the literature that examines the effectiveness of Direct Instruction (DI) and Problem-/Project-Based Learning (PBL) for students with low-functioning ASD in math. Chapter 1 provides a description of these interventions as well as a description of the types of characteristics and needs of students with low-functioning ASD.

Focus of Paper

The focus of this paper is: characteristics of Autism Spectrum Disorder (ASD), instructional requirements or needs for students with low-functioning ASD, higher order of thinking, and the differences of effectiveness of Direct Instruction (DI) and Project-/Problem-Based Learning (PBL).

The studies I reviewed for Chapter 2 were published from 1997 to 2017. My initial focus was on the effectiveness of DI and PBL to teach basic math skills for secondary students with low-functioning ASD. Given the limited number of published studies on this narrow focus, I expanded my search parameters to include Intellectual Disabilities (ID) to a part of low-functioning ASD with the fact that low-functioning ASD has similar characteristics with ID, and reviews of interventions in other subjects such as Science, Technology, Engineering, and Math (STEM) for students with ASD. In addition to this adjustment, I expanded the age range of study participants, the target skills, and the levels of disability to include elementary students, functional math skills, and broad term of autism spectrum, correspondingly.

The Academic Search Perimeter, JSTOR, SAGE Journals Online, and ERIC were used for my literature review of peer-reviewed studies. I used several keywords and combinations of keywords to locate appropriate studies: *secondary, autism, special education, low-functioning, intellectual disabilities, math, academic needs, target skills, project-based learning, problem-based learning*, *direct instruction*, *intervention, instruction, Asperger's Syndrome,* and *high-functioning.*

Theoretical Implication/Importance of the Topic

Although the increasing prevalence of ASD and the high percentage of children who are eligible for the special education at school are reported, research of effective math interventions for students with ASD are limited. Additionally, most of the existing research of effective interventions for people with ASD focuses on behavior or communication interventions. Further research is needed focusing on students with ASD and their academic skills. Mathematics interventions for secondary students with ASD is one of the undeveloped subjects and age-level, whereas researchers have examined a lot in literacy interventions for students with disabilities. As a special educator, I teach mathematics to secondary students with ASD and have seen their struggles. At the same time, I have struggled to teach them and been looking for evidence-based effective interventions.

As an individual from Japan which is a high-performance country in math, I believe DI with repeated practice is the most effective instruction. However, innovative instructions and authentic math education to target students' motivation, application skills, and a higher order of thinking cannot also be ignored if there is evidence to support the effectiveness of instruction for students with low-functioning ASD.

Glossary

Autism Spectrum Disorder (ASD). ASD is a developmental disorder of brain function (American Psychiatric Association, 2016). Autism was described first time in 1943 by Kanner as deficits in communication skills and interpersonal relationships. The Centers for Disease Control and Prevention (CDC) and the most recent Diagnostic and Statistical Manual of Mental Disorders (DSM-V; American Psychiatric Association, 2013) defined the diagnostic criteria of autism spectrum disorder (ASD) as:

> (a) persistent deficits in social communication and social interaction across multiple contexts, (b) restricted, repetitive patterns of behavior, interests, or activities, (c) symptoms must be present in the early developmental period, (d) symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning, and (e) these disturbances are not better explained by intellectual disability (intellectual developmental disorder) or global developmental delay. (pp. 50-51)

Basic Math. Basic math is sometimes interchangeably used with basic calculation, including the basic mathematical four operations: addition, subtraction, multiplication, and division. Many colleges and universities in the United States offer students a pre-college math class prior to college algebra to review and improve their basic math skills. Based on course descriptions and syllabi at colleges and universities as well as textbook contents, the basic math classes mainly cover whole numbers, fractions and mixed numbers, decimals, percent, ratios, rates, proportions, graphing and the rectangular coordinate system, introduction to statistics, units, conversions, integers, basic geometry, measurement, equations, exponents, and introduction to algebra. As some textbooks and pre-college math classes describe, basic math can be described as elementary math.

Direct Instruction (DI). DI is a systematic, explicit, and teacher-centered instruction model developed in the 1960s by Siegfried Engelmann and his colleagues (Marchand-Martella, 2017). Gersten, Woodward, and Darch (1986) identified the critical elements of DI as an explicit step-by-step strategy, modeling, immediate and continuous teacher feedback, guided and independent practice with variety examples. DI has been examined with various target skills and across academic subjects, such as math, reading, history, and language, and many studies have shown its strong positive effects (American Federation of Teachers, 1998; American Institutes for Research, 1999; Borman, Hewes, Overman, & Brown, 2002; Shillingsburg, Bowen, Peterman, & Gayman, 2015). As a result of 45 studies examining Direct Instruction programs, 90% of the studies identified positive outcomes (Kinder, Kubina, & Marchand-Martella, 2005). DI is one of the traditional instructions in many research, compared to innovative instructions such as Project-/Problem-based Learning (Bell, 2010).

Functional Skills/Functional Math. Functional skills are life skills (King, Lemons, & Davidson, 2016). Webster (2017), a general and special education teacher as well as a Reading Specialist and a Board Certified Behavior Analyst, defined the functional skills as skills that students need to live independently and skills whose outcomes support the students' independence on education website ThoughtCo. Webster explained that the functional skills include self-care skills (e.g., tooth brushing, dressing, self-feeding, bathing, and toileting) and functional academic (math and literacy) skills (e.g., telling time, counting money, following directions, reading signs, balancing a check book, reading a bank statement, making change, and purchasing).

The functional skills are one of the most important and beneficial skills for students with disabilities, specifically for students with ASD within the cognitive range of intellectual disabilities or with significant cognitive disabilities (Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2008).

Intellectual Disability (ID). ID (previously named as Mental Retardation) is an overall disability of intellectual and adaptive functioning (American Psychiatric Association, 2017). Minnesota Department of Education uses the educational categories of Developmental Delay (DD) for children younger than 7 years old and Developmental Cognitive Disability (DCD) for students after 7 years old. "In DSM-5, intellectual disability is considered to be approximately two standard deviations or more below the population, which equals an IQ score of about 70 or below." (APA, 2013)

Many individuals diagnosed with ID frequently have other disability categories such as some mental health, neurodevelopmental, medical, and physical conditions, including cerebral palsy and epilepsy, as well as ADHD, ASD, and depression and anxiety disorders (American Psychiatric Association, 2017).

Low-functioning ASD. ASD causes a lot of different functions in various ways with various degrees. Pratt and Stuart (1997) said 70% of the ASD population has cognitive disabilities. In use of Gilliam Asperger's Disorders Scale in differentiating high and low functioning autism and ADHD, children below 80 on full-scale IQs in addition to a diagnosis of ASD were labeled as low-functioning ASD, and children at or above 80 on full-scale IQs with autism or Asperger's Disorder are labeled as high-functioning (Mayes et al., 2011). However, Su, Lai, and Rivera (2010) defined preschool students as high-functioning autism if children's IQs are at or above 70.

People who have a severe cognitive impairment are, in general, categorized in low-functioning and have great difficulties in social and academic skills. People with high-functioning ASD are relatively in or above average in terms of mathematical ability. In short, higher functioning group has higher social, language, and nonverbal abilities. Then, lower-functioning group has lower skills on these dimensions (Stevens et al., 2000).

Problem-based Learning. The initial target skills are motivation and the rate of students passing. In current education setting, PBL aims understanding and defining problems than resolving them (Warin, Talbi, Kolski, & Hoogstoel, 2016). Students can retain knowledge through this approach longer than traditional methods. However, strong effectiveness has not been found in studies related to elementary and middle school settings.

Project-based Learning. Project-based Learning has a longer history. Through this instruction, normally students work on projects (Warin et al., 2016). PBL is a student-driven facilitated and guided by teacher. Therefore, students are engaged in projects and become active learners, better researchers, problem solvers, and higher-order thinkers (Bell, 2010). Project-based Learning is more complex, more extensive, and more rational approach than Problem-based Learning, and it covers all six orders of thinking based on Bloom's Taxonomy (Merritt et al., 2017). Teachers assess the child's performance on projects based on rubrics. Self-evaluation and reflection work important roles in PBL (Bell, 2010).

Bloom's Taxonomy and Higher Order of Thinking. Bloom's Taxonomy is the definitions of the hierarchy of process that students use to perform their knowledge. Bloom's Taxonomy was originally published in 1956. The hierarchy consists of six categories from lower to higher: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Signe, 2003). In 2001, psychologists revised Bloom's original taxonomy to accommodate its weakness. The revised six categories of the taxonomy are: Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. (Rahbarnia, Hamedian, & Radmehr, 2014). In general, lower order of thinking are the first three categories (remembering, understanding, and applying), and higher order of thinking are the last three categories (analyzing, evaluating, and creating).

Summary of Chapter 2 Research to be Reviewed

Eleven studies were chosen for review that evaluated the effectiveness of effectiveness of Direct Instruction (DI) and Project-/Problem-Based Learning (PBL). Table 1 presents these studies in the same chronological order in which they appear in Chapter 2.

Chapter 2: Review of the Literature

The attention toward the mathematics achievement of U.S. students in general education, when they took the national and international assessments, has risen (Przychodzin et al., 2004). However, a limited amount of research focusing on effective mathematics instruction was completed (Baker, Gersten, & Lee, 2002).

Mathematics is an important academic area for students with disabilities, including autism, because people with disabilities can increase work or volunteering opportunities and enrich their post-secondary life if they perform functional math skills well (Brown & Snell, 2000). However, Su et al. (2010) described that few studies focusing on learning strategies to support students with autism have been done. Specifically, research on mathematics for students with autism is significantly limited, although some studies in reading were done (National Research Council [NRC], 2001).

The purpose of this paper was to review the literature that studied the effectiveness of Direct Instruction (DI) and Problem-/Project-based Learning (PBL) for students with low-functioning autism spectrum disorders (ASD) in math. Eleven studies were chosen for review that evaluated the effectiveness of DI and PBL. The foci of this paper are: characteristics of ASD, instructional requirements or needs for students with low-functioning ASD, higher order of thinking, and the differences of effectiveness of DI and PBL.

There is no study directly comparing the effects between DI and PBL as well as there is a limited number of published studies targeting students with low-functioning ASD and basic math through DI and PBL. Therefore, the review addressed the research questions with three main combinations: 1) ASD or ID and math/academic needs; 2) DI, math, and ASD or Special

Education; and 3) PBL and math. It specifically analyzed the characteristics of ASD including disabilities and instructional requirements or academic needs and what positive and negative effects DI and PBL have with students with low-functioning ASD to learn basic math.

Characteristic of Autism Spectrum Disorder

Disability categories and DSM-V. Autism spectrum disorder (ASD) is a neurodevelopmental disorder of brain function (APA, 2013; APA, 2016). The characteristics of ASD are “persistent deficits in social communication and social interaction” and “restricted, repetitive patterns of behavior, interests, or activities” (APA, 2013, p. 50).

In May, 2013, APA revised the diagnostic criteria of ASD in the Diagnostic and Statistical Manual of Mental Disorders and published the fifth edition (DSM-V). The previous edition, DSM fourth edition, text revision (DSM-IV-TR; APA, 2000), contained pervasive developmental disorders (PDD), which included autistic disorder (autism), Asperger’s disorder, pervasive development disorder–not otherwise specified (PDD-NOS), Rett’s disorder, and childhood disintegrative disorder. However, the new term of autism spectrum disorder (ASD) appeared as a broad term for autism, Asperger’s disorder, and PDD-NOS in DSM-V. Therefore, the terms regarding disorders or disabilities are different, depending on the published years.

In addition, there are various characteristics within ASD because of the differences of disorders among autism, Asperger’s disorder, and PDD-NOS. In order to clarify the differences of characteristics within ASD, DSM-V added a few categories, such as “with or without accompanying intellectual impairment” and “with or without accompanying language impairment” (APA, 2013, p. 51). Although, with these specifications, intellectual impairment does not mean that a student with ASD is also diagnosed with an intellectual disability.

According to DSM-V, an “intellectual disability is considered to be approximately two standard deviations or more below the population, which equals an IQ score of about 70 or below” (APA, 2013, p. 33). Therefore, some researchers clarified their participants’ disability categories based on records of medical diagnosis and DSM-V. In this paper, research targeting ID is also included because ID is a part of common deficits in individuals within the ASD population.

Furthermore, it has to be noted that medical diagnosis based on DSM-V and education criteria for special education, are slightly different. Therefore, the disability categories in research should be considered as a part of components describing the researches but should not be the main focus.

Prevalence of autism spectrum disorder. Although only 1% of population in the world is considered being on the spectrum based on DSM-V (APA, 2013), the U.S. Department of Education (2014) reported that 7.6% of students in special education are under ASD, and one of the most developing categories under the Individuals with Disabilities Education Act (IDEA). The Center for Disease Control and Prevention (CDC; 2014) also highlights the fact that 500,000 children with ASD will begin their adult life in next 10 years.

Outcome and adulthood of students with autism spectrum disorder. Oswald et al. (2016) stated that academic career and achievement strongly relates to vocational achievement in adult life in general. More than one-third of all college students with ASD are majoring in science, technology, engineering, and mathematics (STEM). More young learners with ASD major in STEM compared to populations without disabilities (Chen & National Center for Education Statistics [NCES], 2009) and other disabilities (Wei, Yu, Shattuck, McCracken, & Blackorby, 2013).

However, the adulthood of individuals with ASD are highly likely to be poor since these premises play into the population with disabilities as well (Oswald et al., 2016). Many young adults with ASD are still at risk of being unemployed, although the likelihood of being at-risk is less than the individuals with other disabilities (King et al., 2016). Mathematics is not only an academic subject, but also a tool for problem-solving in daily life and vocational achievement. Therefore, investigating mathematical achievements of students with ASD is needed. Investigation may more clearly guide teachers to help their students with ASD for higher education and society (Oswald et al., 2016).

Deficits and impacts in mathematics. Hart Barnett and Cleary (2015) stated that the difficulties that students with ASD face in school life are because of the deficits of executive function (EF). According to the report *Executive Function: Implications for Education* by Zelazo, Blair, and Willoughby (2016), the executive function is “a specific set of attention-regulation skills involved in conscious goal-directed problem solving” (p. 2) and includes working memory, impulse control, cognitive flexibility planning, organization, attention, and self-monitoring (Hart Barnett & Cleary, 2015; Rockwell, Griffin, & Jones, 2011; Zelazo. et al., 2016).

These deficits of executive functions, language impairment, and attention control severely impacts students’ math learning. The difficulties due to working memory deficits are using poor strategies and procedures for problem-solving so students may count with fingers rather than recalling math facts, or use modeling rather than performing conceptual understanding of operations. Poor attention and working memory cause errors in lining numbers up, procedures to calculate, problem-solving, and forming concepts (Rockwell et al., 2011).

Based on DSM-V diagnostic criteria (APA, 2013), students with ASD have significant difficulties with expressive and receptive language, social communication skills, and semantic use of information, which also negatively impacts their development in mathematical learning (Hart Barnett & Cleary, 2015; Rockwell et al., 2011). The areas that are impacted by language impairment include number-word sequence, calculation, and fact retrieval; however, the most affected area is problem-solving (Hart Barnett & Cleary, 2015) because students have to manipulate both semantic and numeric information (Rockwell et al., 2011). Additionally, students with ASD encounter difficulties with determining if given information is important to solve problems or irrelevant on specific problems (Rockwell et al., 2011).

Students with ASD may show struggles in math when they enter middle school because of content which requires students to solve more abstract and cognitively complex problems. Tasks emphasize problem-solving, targeting higher level thinking, and developing mathematical reasoning. These tasks and problems require executive functions and language skills, which are the deficits of students with ASD (Hart Barnett & Cleary, 2015).

Math performance of population with autism spectrum disorder. Many students with high functioning ASD (HFASD) perform mathematics at an average level; nevertheless, many students show overall deficits in mathematics, which is an unexpected level of their intellectual abilities (King et al., 2016).

Only 20% of students in this population perform mathematics in or above average range with below average performance on national assessments, although about 40% of the students in this population perform in the average range or above average across subjects (Wei, Christiano, Yu, Wagner, & Spiker, 2014). Although there are researchers who indicated that people with

ASD have difficulty in math, society holds the idea that most people with ASD are gifted in math, going on to major in a STEM field, and good at systemizing. However, less than 15% of students with high functioning ASD can perform at the level of giftedness in math (Oswald et al., 2016).

Oswald et al. (2016) stated that the difficulties students with ASD struggle with are more complex. Recently, the relationships between ASD and mathematical ability was studied and it was discovered that 17% to 40% of students with high-functioning ASD perform expressively worse than expected based on their IQ (Oswald et al., 2016). Wei, Lenz, and Blackorby (2012) focused on the specific skills in mathematics and found that calculation and applied math problems are the distinct areas in which students with ASD perform lower than students with learning disabilities (LD). Moreover, Wei et al. (2013) found that the growth rates of students with ASD in calculation skills is slower, compared to students with learning disabilities.

In the other study, students with ASD without ID perform above average on basic calculation skills and at average on mathematical reasoning skills (Iuculano et al., 2014). The other study examined the discrepancy of mathematical skills of students with ASD whose intellectual ability is IQ of 50 to 119. This group of students showed that their struggle was mathematical reasoning rather than numerical operations (Jones et al., 2009).

There are studies that found a prevalence of mathematics learning disabilities in the high-functioning population of ASD students. The prevalence of mathematics learning disabilities in the general population is 5% to 7%, which is significantly less than the population with high-functioning ASD (Oswald et al., 2016). Another study found that nearly one in every four students with ASD may have a mathematics learning disability (Hart Barnett & Cleary, 2015).

Even though most students with ASD struggle with mathematics, interventions and studies have been predominantly focused on reading. A lack of instructions in math considering students' deficits may contribute their difficulties in mathematics (Hart Barnett & Cleary, 2015). Therefore, researching mathematical achievements of struggling students with ASD and interventions for these students is an essential process (Oswald et al., 2016).

Essential Components in Instruction for Students with Autism Spectrum Disorder

Iovannone, Dunlap, Huber, and Kincaid (2003): Six essential components.

Iovannone, Dunlap, Huber and Kincaid (2003) reviewed four studies between 1992 and 2002 which experimented interventions for students with ASD to identify effective elements in educational settings and in instructions for any student with ASD in any age range. Six common areas across the four studies are:

1. Individualized supports and services for students and families
2. Systematic instruction
3. Comprehensible and/or structured environments
4. Specialized curriculum content
5. A functional approach to problem behaviors, and
6. Family involvement (p. 153)

Iovannone et al. (2003) reviewed a total of 39 studies of strategies between 1992 and 2002 that integrated at least one of the components effectively. Table 1 summarizes the six core elements, sub elements, keys, strategies, and examples for each core element which Iovannone et al. (2003) found.

Table 1

Six Core Elements, Sub Elements, Keys, Strategies, and Examples in Educational Settings for Students with ASD

CORE ELEMENTS	SUB ELEMENTS	KEYS AND STRATEGIES
1. Individualized supports and services for students and families	Should consider: - family preferences in goal setting and instructional methods - child's preferences, interests, needs, and unique learning styles in instructions child's strengths and the areas to improve in instructions and services	Increase/promote: - students' participation and motivation - students initiate questioning - generalization - on-task/schedule behaviors Decrease: - problem behaviors Examples: - individual discrete trial training (DTT) - naturalistic teaching instructions - pivotal response training (PRT) - one-to-one instruction with an adult - independent work time with planned activities - group instruction with a peer tutor or an adult general instruction throughout a day

Table 1 (continued)

CORE ELEMENTS	**SUB ELEMENTS**	**KEYS AND STRATEGIES**
2. Systematic instruction	Should: - be both comprehensive and systematic instructions - be at level and intensity meeting students' needs and characteristics in the specific environment - carefully plan instructional methods and when students are instructed	Increase/promote: - attainment of competencies and novel skills - generalization and maintenance of learned skills - students' engagement - functioning assessing cognition, language, and adaptive skills - independence in academic tasks and behavior - on-task behavior Decrease: - inappropriate behavior and verbalizing Examples: - using applied behavior analysis (ABA) principles - discrete trial training (DTT) - naturalistic teaching instructions - pivotal response training (PRT) - self-management procedure in viro training (including constant time delay and visual aids)

Table 1 (continued)

CORE ELEMENTS	SUB ELEMENTS	KEYS AND STRATEGIES
1. Comprehensible and/or structured environments	Should be able to: - predict what is currently happening and what will happen next - expectation and requirements of settings - learn and generalize various skills Should be considered: - with clear curriculum, activities, schedule, and environment not only to students but also to educational personnel	Increase/promote: - organize learning environment - a schedule of activities - choice-making opportunities - on-task behavior - areas of the classroom and school setting for specific purposes - temporal and better relations - transitions, flexibility, and change - competencies in communication and independence behavior - generalizing to new skills Decrease: - the latency time of transitioning - disruptive transition behavior Examples: - video priming - visual supports - minimal supports (visual schedule, planner) - extensive supports (labeling, sub-schedules, boundaries defined)

Table 1 (continued)

CORE ELEMENTS	SUB ELEMENTS	KEYS AND STRATEGIES
2. Specialized curriculum content	Should: - include systematic instruction - include communication and social skills, recreational or leisure skills, and language comprehension skills - be based on assessment - consider student's and family's preferences, needs, and interests - focus on meaningful skills in student's life and in the environment where student is belonged, increasing quality of life and competent performance	Increase/promote: - acquisition in language ability - generalize across novel questions and people - conversational exchange - functional communication - requesting, commenting, and sharing behavior - play behavior - verbal utterances Decrease: - inappropriate social behaviors Examples: - ABA principles - augmentative communication (AAC) and assistive technology (AT) strategies (picture communication systems, switches)voice output communication aids (VOCAs) - Picture Exchange Communication system (PECS) - discrete trial training (DTT) with gestures and verbal communication - fading procedures - combinations of visual cues and texts - naturalistic teaching procedures - incidental teaching - pivotal response training - Social Stories, - self-management packages - peer mediated strategy - monitoring strategies - free play Integrated Play Group Model

Table 1 (continued)

CORE ELEMENTS	SUB ELEMENTS	KEYS AND STRATEGIES
3. A functional approach to problem behaviors	Should: - focus not only on decreasing but also replacing the problem behavior with an appropriate or alternative behavior - identify and understand the function and factors of problem behaviors - be comprehensive focus on antecedent manipulations	Increase/promote: - quality of life - expanding existing behaviors - learning environment Decrease: - effectiveness, efficiency, and relevancy of problem behavior Examples: - functional communication training - positive behavior support (PBS) - functional behavior assessment (FBA) - contingency management approaches
4. Family involvement	Should include: - parents in developing educational plan and delivery services	Increase/promote: - the effectiveness of interventions and programming - generalizing skills Examples: a social story as an antecedent intervention to prevent problem behaviors in the home setting

Iovannone, Dunlap, Huber, & Kinkaid (2003)

Iovannone et al. (2003) concluded that the elements can guide educators of any-aged students, although the studies they reviewed were mainly with children younger than 8 years old, based on the fact of knowledgeable experts in the field of autism.

Knight and Sartini (2015): Strategic instruction, response prompting, and visual supports. Knight and Sartini (2015) reviewed 13 studies and summarized comprehension strategies in content areas for students with ASD. Students with ASD have significant difficulties in expressive and receptive language and social communication skills based on diagnostic criteria (APA, 2013). Woolley (2011) stated that early decoding ability and listening comprehension are indicators of reading achievement. The reading comprehension skills of individuals with ASD is significantly lower compared to their typically developing same-age peers, and the listening comprehension is challenging, although they can decode well enough. Knight and Sartini examined and focused on oral language, prior knowledge, skills that inference from texts, and social skills as factors influencing on reading comprehension.

The authors chose the strategies that designed a single case or group research design, examined with one or more students with ASD, have been peer-reviewed, have comprehensive results, used interventions targeting of text-based comprehension skills, and interventions for comprehension skills in any content area and instruction in a school setting. Based on criteria of quality analysis, the authors reviewed thirteen studies, where achievement level was between strong to adequate, with students between 7 and 15 years old.

The 13 studies included students with IQ in the average to below average range, low average range (1SD below), low range (2SD below), and very low range (3SD below). The interventions were implemented predominately in special education settings, across ELA, math and science areas. Target skills included story comprehension, reasoning and language skills, making inferences, using facts, and comprehension and vocabulary words within the content areas. Math instruction was examined in two out of 13 studies and included skills of determining correct math operations and solving words problems.

All 13 studies showed positive achievement outcomes, including the two studies that were implemented in math (Burton, Anderson, Prater, & Dyches, 2013; Rockwell et al., 2011). The two studies concluded that their participants improved comprehension on word problems with three different types of problems, generalized the skills, and the number of correctly completed steps. The reliability for inter-observer agreement was at least 90% and the procedural reliability was 92% or above. Eight studies including Burton et al. (2013) measured social validity, using Likert scales, interviews, or questionnaires, and gained positive results.

The authors also used Reichow's (2011) evidence-based practice criteria and concluded that response prompting strategies and visual supports are evidence-based effective strategies to teach comprehension skills in math story problems for children with ASD. In addition, model-least-test (MLT) was used in many strategies, followed by time delay, task analysis, modeling of examples and non-examples, direct instructions, and simultaneous promptings across studies. The MLT is the strategy which is systematic and explicit based on direct instruction, and provides modeling of skills and practice opportunities with minimal errors. Randi, Newman, and Grigorenko (2010) also suggested DI, not specifically MLT; Rockwell et al. (2011) used DI including MLT to teach a student with ASD on math word problems.

Although this literature review presented positive outcomes with reliability and includes individuals with the wide range of ASD, some studies did not examine a social validity or did not measure generalization and maintenance of skills. Additionally, the authors found no studies met the criteria and designed a group research.

Su, Lai, and Rivera (2010): Systematic instruction, early intervention through DI. Su et al. (2010) examined systematic instruction and early intervention, two of the six core elements of Iovannone et al. (2003) in mathematics for 25 preschool students with high-functioning ASD (70 or higher IQ), and 10 typical developing same-age peers. The study group and the control group each included one exclusive class for students with autism, and one inclusive class. The examiners implemented the systematic instruction, The Project MIND–

Math Is Not Difficult®, for 3 months. The Project MIND is a multi-sensory math curriculum based on direct instruction and was implemented through 15-minute direct instruction daily sessions. The examiners used a quasi-experiment and a group research design with pre- and post-mathematics achievement tests. Hawaii Early Learning Profile (HELP) assessed skills of mathematical reasoning and problem-solving. Mullen Scale of Early learning (MSEL) assessed cognitive functioning. Beery Development Test of Visual Motor Integration (VMI) assessed visual-spatial ability. The Bracken Basic Concept Scale–Revised (BBCS-R) evaluated students' knowledge of mathematical terms. VMI and MSEL identified the relative effects on acquisition of mathematical concepts such as number sense and numerical operations.

Mann-Whitney U test was used to analyze the results based on the small sample size in this study for continuous data, and the Chi Square test was used for discrete data. The Mullen test score (Mann-Whitney U, P=0.000) was significantly different between the pilot group with the interventions and the control group without the interventions on all subtests. The subtests are visual, fine motor, expressive language, and receptive language, and its P values were between 0.000 and 0.002. On the HELP mathematical test (Mann-Whiney U, P=0.036), there was also a statistically significant difference between the study group and the control group. These results showed that a systematic instruction in math promotes learning in inclusive class settings with typical preschool curriculum.

In addition, the Wilcoxin Signed Ranks Test determined a statistically significant difference between pre- and post-test scores in mathematical concepts, cognitive ability, and visual spatial ability of children with autism in the study group (Su et al., 2010). The result showed that the children in the study group significantly improved on the HELP test (Wilcoxin

Signed Rank, P=0.007). This result indicated that students with high-functioning autism were able to improve their knowledge of math concepts through the systematic instruction.

The examiners concluded that this study helps educators restructure the mathematical instruction in general education and special education classrooms. However, this study included only young children. Therefore, the experiment with older students with autism and students with low-functioning autism are needed.

Rockwell, Griffin, and Jones (2011): Strategic instruction on math word problems. Rockwell, Griffin, and Jones (2011) implemented schema-based strategy instruction for a fourth-grade student with autism. The instruction was used to teach solving addition and subtraction word problem. Schema-based strategy instruction (SBI) integrates visual representations, heuristics, and direct instruction to teach word problems. The authors mentioned the schematic diagrams may help students reduce the language and working memory demands required to solve word problems by representing the semantic structure of word problem (Rockwell et al., 2011).

The student in this study was 10 years and 3 months old and was clinically diagnosed with ASD. The student was not on any medications, under any dietary constraints, or in any private therapy. Her nonverbal intellectual abilities were in the low average range and her language abilities were below average. However, her mathematical abilities were in the very low range (SS 63) based on KeyMath Diagnostic Assessment, Third Edition (Connolly, 2007). Her problem-solving skills were significantly low (SS 55), and the result was because of her difficulty with determining which operation she needed to use in word problems. The intervention was the SBI one-to-one individual sessions for 8 weeks during summer. The instruction included teaching problem-types (group problems, change problems, and compare problems) following a 4-step heuristic to solve problems, using the mnemonics, sorting problems in types and lessons on generalization.

This study used a single-case, multiple probes across behaviors design. Performance on each type of problems were considered as separate behaviors. The behaviors were group problems, change problems, and compare problems. The performance was evaluated at a maximum of 6.0 points. The girl improved by 2.0 points (33.3% increase) on group problems, by 1.0 point (16.7% increase) on change problems, and by 6.0 points (100% increase) on compare problems. The girl performed 6.0 points (100% accuracy) on group and compare problems and 5.0 points (83.3% accuracy) on change problems. Additionally, she earned 6.0 points on maintenance group and change problems, and 5.67 points (94.5% accuracy) on maintenance compare problems. Based on the results, the authors concluded that SBI may be an effective instruction for children with ASD. SBI provides direct instruction, including teacher modeling, guided practice, independent practice, and spontaneous positive and corrective feedback. SBI also reinforces the correct response and minimizes errors. Given SBI with visual diagram, a child with ASD can improve problem solving skills on addition and subtraction word problem, maintain the skills, and generalize the skills.

The authors mentioned some limitations of this study, although this examination showed the effectiveness of SBI, as well as the SBI is useful instruction for students with ASD. The limitations were a fewer number of the participants, which causes less generalizing; and the design of a multiple probe across behaviors may not be the best design to present with this study. A single-step addition and subtraction were assessed in this study; however, this was only a small part of the skills needed for academic success in mathematics. The SBI intervention in this study took place in a one-to-one setting, unlike the classroom setting at school. Therefore, to expand this study results for future use of SBI, more examinations with more participants, different skills such as multiplications and divisions, in different learning environments are needed.

Hord and Bouck (2012): Visuals, models, and cognitive/metacognitive prompts. Hord and Bouck (2012) reviewed studies which focused on academic mathematic interventions, since students with disabilities need to develop conceptual understanding for success in middle school and high school with higher mathematics. In seven studies that were reviewed, 66 students and adults from elementary school age to 23 years old had math instructions. In the process of selecting studies, studies focused on functional math skills and other skills rather than academic math skills, and studies between 1999 and 2010 were excluded. Students who were identified as MID by authors but not in the range between IQ 55 and 70 were also excluded.

Six studies of the seven focused on interventions for procedural understanding, computations, math facts, and basic arithmetic. More than half of the studies used flashcards for basic math facts, a single subject research design, and multiple baselines across participants were mainly used. The other studies focused on computations with a single subject research design. On the other hand, only one study focused on conceptual understanding with the use of strategies such as models, cognitive or metacognitive prompts, word problems, and algebraic procedures. All seven studies improved students' basic math facts accuracy, performance in computation, and performance in solving word problems.

The reviewed indicated that limited academic math interventions predominantly focuses on procedural instructions more than conceptual understanding. The limitations of research in mathematical interventions for students with MID makes evidence-based teaching practices difficult. Woodward (2004) recommended that focusing on "critical thinking skills about mathematics and deeper conceptual understanding of mathematical ideas to empower students with knowledge that is transferable to various situations rather than knowledge of procedures specific to certain mathematical situations" (pp. 395-396), which may help students perform better in schools. Students with MID generally struggle due to working memory, memorizing procedures and math facts being their struggle areas. Rather than focusing on procedure instruction, students can succeed by developing a deeper conceptual understanding with a use of a calculator. Neef, Nelles, Iwata, and Page (2003), who intervened with math word problems, showed that visualizing the word problems is a beneficial and helpful instruction for students. Due to low level of working memory, students with MID will benefit from organizing and sorting information and analyzing multi-steps by diagramming.

There are a few limitations on this review. The characteristics of MID were not clearly described or identified in many studies, which caused the exclusion of many studies. In addition, it is important to examine qualitative rather than quantitative results of a student's performance due to a limited number of research focusing on math and MID. Qualitative research analyzes how students with MID understand concepts and solve with mathematical reasoning. To establish the evidence-based instructions that guide teachers to teach students effectively, more researches are needed with students with MID in math.

Hart Barnett and Cleary (2015): Visual representations, concreate manipulatives. Hart Barnett and Cleary (2015) reviewed 11 studies, which examined mathematical interventions for students with ASD as shown in Table 2. The 11 studies included wide ranges of students' ages, disabilities, instruction settings, experimental designs, and target skills.

Table 3 shows the disability categories of 34 students participated in the 11 studies. The 34 students included several combinations of disabilities, such as severe LD/ADHD (1 student, 2.94%), intellectual disabilities (ID; 1 student, 2.94%), ASD (28 students, 82.35%), mild intellectual disabilities (MID; 2 students, 5.88%), and mental retardation (MR; 2 students, 5.88%). The students in the ASD category included the various combinations of categories which are autism, Asperger syndrome (AS), and pervasive developmental disorder (PDD). The individuals were from 6 to 22 years old, and they were in elementary school through post-secondary programs for youth with disabilities.

Notably, six studies integrated visual representations such as manipulatives, pictures, and number lines for abstract concepts. Specifically, the visual representations in this review were touch point (3 studies), video self-monitoring (1 study), virtual and concrete manipulatives (1 study), and schematic diagrams (1 study). The other five studies integrated cognitive or metacognitive strategies. According to Simpson (2005), instructions in math problem-solving often use cognitive strategies. Its definition is "a series of sequenced procedures that permit a student to complete a task effectively using rules, processes, and steps that are applied systematically to obtain a problem solution" (p. 174). Cognitive strategies provide "when and where to apply specific strategies in the implementation and evaluation of the process and outcome" (p. 174). The authors identified both visual and cognitive approaches are evidence-based, effective math instructions, specifically for students with low performance and with learning disabilities.

Table 2

Revised Studies by Instructional Intervention Type

Author(s)	*Participants in Experiment (Total Number of Participants*, Number of Participants with ASD, Ages)*	*Setting*	*Intervention*	*Intervention Testing*	*Design*	*Dependent Variables*	*Independent Variables*	*Results*
Visual Representation Interventions								
Bouck, Satsangi, Doughty, Courtney (2013)	*N* = 3 *N*(ASD) = 3 Ages = 6, 7, 10	Autism Clinic	Using concrete (physical objects) and virtual (3-D objects on computer) manipulatives to help students acquire single-digit and double-digit subtraction skills	Virtual or concrete manipulative sessions consisting of ten trials with five subtraction problems each	Single Subject Alternating Treatment Design	Percentage of accurately completed subtraction problems and percentage of subtraction problem steps completed individually	Use of concrete and virtual manipulatives	All three participants demonstrated an increase in correctly completed subtraction problems using both the concrete and virtual manipulatives (the virtual manipulatives proved slightly more effective), as well as an increase in independent completion of problems
Burton, Anderson, Prater, and Dyches (2013)	*N* = 4 *N*(ASD) = 3 Ages = 13, 13, 14, 15	Junior High School	Using a video self-modeling technique to teach money estimation of a given item and estimation of the amount to receive in change	Two daily sessions of intervention testing to complete five math problems with the iPad, occurring four days each week	Multiple-Baseline-Across-Participants Design	Percentage of accurately completed money computational problems	Use of video self-modeling on the iPad	All four of the participants demonstrated an improvement in math skill performance after implementation of the video self-monitoring
Cihak and Foust (2008)	*N* = 3 *N*(ASD) = 3 Ages = 7, 7, 8	Resource room at Elementary School	Using number line and touch-point strategies to solve single-digit addition math problems	Two daily 5–20 minute sessions to complete a worksheet of ten single-digit mathematics problems using either touch points or a number line	Alternating-Treatments Design	Percentage of correct single-digit addition math problems completed	Use of a touch points and use of a number line	All three students demonstrated that touch-point strategy was more successful in teaching single-digit addition skills than the number line strategy
Fletcher, Boon, and Chihak (2010)	*N* = 3 *N*(ASD) = 2 Ages = 13, 13, 14	Self-contained classroom at Middle School	Teaching single-digit mathematics problems using *TOUCHMATH*, a multi-sensory mathematics program, and a number line	Two daily 5–15 minute sessions to complete a worksheet of ten single digit mathematics problems using either the "touch points" or number line strategy	Alternating Treatments Design	Percentage of single-digit mathematics problems answered correctly	Use of the *TOUCHMATH* program using "touch points" and the number line strategy	*TOUCHMATH* strategy was more effective and efficient in teaching single-digit addition problems compared to the number line strategy
Rockwell, Griffin, and Jones (2011)	*N* = 1 *N*(ASD) = 1 Age = 10	Author's Home Office	Using schematic diagrams to solve group, change, and compare addition or subtraction word problems	Problem solving probe sessions containing two group, two change, and two compare word problems	Multiple Probes Across Behaviors Single-Case Design	Percentage of word problems completed accurately	Use of schematic diagrams to solve group, change, and compare problems	The participant successfully increased her ability to complete single-step addition and subtraction word problems

Table 2 (continued)

Author(s)	*Participants in Experiment (Total Number of Participants*, Number of Participants with ASD, Ages)*	*Setting*	*Intervention*	*Intervention Testing*	*Design*	*Dependent Variables*	*Independent Variables*	*Results*
Waters and Boon (2011)	*N* = 3 *N*(ASD) = 1 *N*(AS) = 1 Ages = 14, 15, 16	Self-contained special education mathematics classroom at Public High School	Teaching 3-digit money computational subtraction problems with regrouping using the *TouchMath* program	Ten 3-digit money computational problems solved by regrouping using the touch-point strategy	Multiple-Probe Across Participants Design	Percentage of correct 3-digit money computations performed	Use of *TouchMath* program using "touch points" and regrouping	All three participants increased acquired skills to subtract 3-digit mathematics operations using money computations
Congnitive Strategy Interventions								
Banda and Kubina Jr. (2010)	*N* = 1 *N*(ASD) = 1 Age = 13	Resource room at Middle School	Using high preference math tasks to increase academic compliance and completion of low-preference math tasks	Ten cards containing two high-preference problems to be completed prior to one low-preference problem	ABAB Design	Lack of initiation of a three-digit by three-digit missing addend problem	Using a high preference intervention to complete ten test cards containing two three-digit by three-digit addition problems followed by one missing addend problem	The student took less time to begin low-preference math problems that were stated after high-preference math problems
Cihak and Grim (2008)	*N* = 4 *N*(ASD) = 4 Ages = 15, 16, 16,17	Resource room at High School, school bookstore, and local department store	Using counting-on math technique with the next-dollar strategy to increase independent purchasing skills	1) Classroom Phase: Two daily sessions containing ten trials of ten problems to be completed using the counting-on strategy 2) Bookstore and Community Phases: One daily session containing three purchasing trials	Multiple-Probe Design	Percentage of independent purchases completed accurately	Use of counting-on and next-dollar math strategies to enhance purchasing skills	All four students successfully learned the counting-on and next-dollar techniques and were able to apply these skills to community settings
Hua, Morgan, Kaldenburg, and Goo (2012)	*N* = 5 *N*(ASD) = 3 Ages = 18, 18, 21, 22, 22	University classroom	Using a three-step cognitive strategy (TIP) for calculating tip and total bill for young adults with intellectual disabilities	Six instructional stages including a final stage of ten tip and total bill problems to be completed independently by the students	Pre- and Posttest Nonequivalent Groups Design	Total number of tip and total bill calculations completed accurately	Use of TIP method	The experimental group successfully increased their ability to calculate tip and total bill using the TIP strategy, showing much higher posttest results than the comparison group

Table 2 (continued)

Author(s)	*Participants in Experiment (Total Number of Participants*, Number of Participants with ASD, Ages)*	*Setting*	*Intervention*	*Intervention Testing*	*Design*	*Dependent Variables*	*Independent Variables*	*Results*
Rapp, Marvin, Nystedt, Swanson, Paananen, and Tabatt (2012)	*N* = 4 *N*(ASD) = 2 *N*(AS) = 1 *N*(MMR) = 1 Ages = 7, 8, 9, 12	Individual classroom at School or at Home	Using response repetition as an error-correction technique to increase students' ability to complete math facts and math computation	Two to four weekly sessions ranging from 15–20 minutes each, containing 2–5 sets of flash cards or worksheets per session	Nonconcurrent and Concurrent Multiple Baseline Designs	Percentage of mathematic problems solved accurately	Use of Response Repetition technique	Three of four participants demonstrated improvement on targeted math problems, and two of two participants showed improvement on other forms of math problems
Whitby (2013)	*N* = 3 *N*(ASD) = 3 Ages = 7th grader, 7th grader, 8th grader	Individual Public Middle School classrooms	Teaching math word problems using the 7 cognitive strategies and 3 meta-cognitive strategies from the *Solve It!* Problem Solving Routine	Minimum of five training sessions containing 3–5 math words problems; five acquisition condition sessions containing five math word problems	Multiple Baseline Across Participants Design	Percentage of correct word problems completed	Use of *Solve It!* Problem Solving Routine curriculum	All three participants learned to use problem-solving skills to accurately complete math word problems, as demonstrated through the increased percentage of correct word problem responses

Hart Barnett & Clary (2015)

Table 3

Participants' Disability Categories

STUDENT DIAGNOSIS	NUMBER OF STUDENTS WITH DIAGNOSIS	
Severe LD/ADHD	1	
ID	1	
ASD and ID	2	
ASD	26	
-Autism		9
-Autism and MID		7
-Autism and PDD		1
-AS		1
-AS and ID		1
-AS and MID		1
-ASD		6
MID	2	
MR	1	
MR and ID	1	
Total Number of Participants	34	

Table Abbreviations:
LD: Learning Disabilities
ADHD: Attention Deficit Hyperactivity Disorder
ID: Intellectual Disabilities
ASD: Autism Spectrum Disorder
MID: Mild Intellectual Disabilities
MR: Mental Retardation
PDD: Pervasive Development Disorder
AS: Asperger Syndrome

Although the level of intellectual disability in individuals with ASD is a wide range depending on studies, it is also true that approximately half of individuals with ASD are in the borderline range or below average. In fact, experts of autism also share information with developmental disabilities and mild intellectual disability (MID) as many articles were published by research groups of autism or published in journals of autism such as Hord and Bouck (2012).

Intellectual ability of students with MID is typically in the IQ range of 55 and 70 and have characteristics of low academic performance, slower academic growth, and low working memory (Hord & Bouck, 2012). Alwell and Cobb (2009) stated that mathematical instructions for students with ID have mainly a functional skill approach and an academically oriented approach. Butler, Miller, Lee, and Pierce (2001) also found changes in mathematic instruction over time. The changes in instructional attentions were from basic skills to computational fluency and problem-solving, more attention to developing procedural and conceptual understanding, strategies for problem-solving, and the concrete-symbol (representational)-abstract teaching process. National Council of Teachers of Mathematics (NCTM; 1989) supported the changes and emphasized the importance of developing problem-solving skills and conceptual understanding.

Direct Instruction

History of direct instruction. Direct Instruction (DI) is one of traditional instructions that has been used for a long time in education. "Direct Instruction (DI) is an empirically supported curriculum designed to teach complex language skills to children with and at risk of learning disabilities" (Shillingsburg et al., 2015, p. 44). DI integrates "behavioral principles including short, clear and sequenced instructions, immediate reinforcement, and error correction procedures to enhance learning outcomes" (Shillingsburg et al., 2015, pp. 44-45). Many researchers have examined DI with students in special education settings. Watkins and Slocum (2003) researched the effectiveness of DI with diverse learners including students in special education, and Flores and Ganz (2007) studied the effects of DI for students with autism and with developmental disabilities. However, Shillingsburg et al. stated that evidencing the effectiveness of DI for children with autism has been recently evolving.

One initial study investigating DI, the 1968 nation-wide project "Project Follow Through," compared the effectiveness of nine teaching methods, including DI. The project involved students in kindergarten to third grade who were "at-risk" or from low-income families (Watkins, 1997). Project Follow Through concluded that DI is a significantly positive instructional method to teach reading, language usage, and arithmetic. It positively impacts basic skills, conceptual understanding, and affective skills (Watkins, 1997). DI is one of the seven effective and strong evidence-based interventions for students with disabilities in special education (Forness, Kavale, Blum, & Lloyd, 1997). Gersten, Becker, Heiry, and White (1984) investigated the data of Project Follow Through, focusing on the participant's intellectual and cognitive abilities. Gersten et al. (1984) found the same patterns of improvement in all IQ ranges. Participants with low IQs showed consistent growth and progressed as much as others with higher IQs. Therefore, research topics of special education intervention often refer to DI (Watkins & Slocum, 2003).

Effectiveness of direct instruction.

Watkins (2008). Watkins (2008) identified five essential components of DI, which work well for students with ASD: general case programming, track organization, scripted presentation, predictable formats, and pacing. Table 4 shows the five identified components of effective DI and what is promoted by each component.

Table 4

Five Essential Components of Direct Instruction

<table>
<tr><th>COMPONENTS</th><th>PROS/WHAT IS PROMOTED</th></tr>
<tr><td>General case programming</td><td>• Generalization</td></tr>
<tr><td>Track organization</td><td>• Maintenance</td></tr>
<tr><td>Scripted presentation</td><td rowspan="2">• Consistency, predictability, and systematic instruction
• Increase engagement, speed, and accuracy</td></tr>
<tr><td>Predictable formats</td></tr>
<tr><td>Pacing</td><td>• Decrease off-task behavior
• Increase engagement and accuracy</td></tr>
</table>

Watkins (2008)

Thompson, Wood, Test, and Cease-Cook (2012). Thompson, Wood, Test, and Cease-Cook (2012) stated that the amount of research regarding effective math interventions with students with ASD is very limited. Although there is much research with students with disabilities, including students with ASD and including broad math skills relevant to their lives in post-secondary education, they have not been done adequately (Browder et al., 2008; Przychodzin et al., 2004). One of the functional, as well as academic math skills, is telling time (Krustchinsky & Larner, 1988). Therefore, Thompson et al. studied the effects of DI for students with ASD to teach time telling to the 5-minute increment.

In this study, one 6-year-old and two 8-year-old boys with ASD had instructions on telling time. All three young students were racially identified as African American and their disabilities for special education services were categorized as moderate intellectual disability (ID). All three students were able to identify numbers up to 12, understand the concepts of the word "before," count numbers by five up to 60, and have been diagnosed with ASD. The intervention integrated Connecting Math Concepts (CMC) published by McGraw-Hill Education with one-to-one DI. The CMC curriculum has scripts that teachers should say and how students are expected to respond. In addition to the scripts, interventionists integrated visual, verbal, and behavioral prompts to guide students, provided immediate feedback, and praise for expected behaviors.

Thompson et al. (2012) used a multiple probe across participants and measured the number of correct responses. After the intervention, all three students improved their skills from baseline. The mean before the intervention were 0.2, 0, and 0.2. After 16 CMC lessons, the students were administered the probes for maintenance which showed that all students maintained the skills at 6.6, 5.7, and 7, respectively. Generalization and maintenance were also examined in addition to the improvement of each student, as well as compared to same-aged peers' performances. The participants showed that their time-telling skills dropped with generalization probes; however, the scores were in the same range of the control group.

This time-telling study had several limitations, according to the authors. The students were taught with only one analog clock through the instructions. The generalization to various types of clocks was limited. In addition, the immediate feedback and the number of drills may have influenced the students' performance in terms of generalizing to the probes. The generalization data indicated that the intervention period, tools, and settings were not enough for students with ASD. CMC is not instruction designed for students with disabilities and might be difficult to generalize to students with ASD who have difficulties to generalize pre-taught skills in various settings and with different tools.

Although there were some limitations stated by the researchers, this study revealed that DI can be an effective and helpful instructional method in teaching students with ASD to tell time and to support young students with ASD. DI may promote maintenance and generalization of specific math skills and academic math skills. In addition, DI can enhance math skills of not only younger students but also older students.

Kinder, Kubina, and Marchand-Martella (2005). Kinder et al. (2005) reviewed 45 studies, which were published between 1975 and 2005, and investigated DI used with students with special needs. Among the 45 studies, almost all studies documented positive outcomes of DI programs. The two main disabilities of the studies were high-incidence and low-incidence disabilities. In this review, 37 studies were conducted with students with high-incidence disabilities, and eight studies were conducted with low-incidence disabilities.

Friend and Bursuck (2012) defined high-incidence disabilities (HID) as disabilities represented by about 80% of all students who have a disability. They include speech and language impairment (SLI), learning disabilities (LD), emotional/behavioral disorders (EBD), mild to moderate intellectual disability (MID). The author of Teaching Students with High-Incidence Disabilities: Strategies for Diverse Classrooms, Prater (2017), defined HID as the disabilities, to which more than 100,000 people in the United State are diagnosed. HID includes LD, EBD, intellectual disability (ID), high-functioning autism (HFA), and attention-deficit/hyperactivity disorder (ADHD). On the other hand, low-incidence disabilities are the disabilities whose numbers are low. In Minnesota, blind/visually impaired (BVI), deaf/hard of hearing (DHH), deafblind (DB), developmental cognitive disability-severe/profound (DCD-SP), physical impairment (PI), traumatic brain injury (TBI) and severe/multiple impairments (SMI) are identified as low-incidence disabilities (Minnesota Department of Education, 2017).

Among the 37 studies with high-incidence disabilities, 36 studies targeted language (reading, writing, and/or spelling) skills; six of the eight studies with low-incidence disabilities targeted language. Only one study with high-incidence and two studies with low-incidence disabilities were math interventions. One of the math interventions with high-incidence disabilities was administered by McKenzie, Marchand-Martella, Moore, and Martella (2004). The examiners used Connecting Math Concepts (CMC) with three 3- to 5-year-old students with developmental delay and 13 same-aged peers. Kinder et al. (2005) summarized the result of this investigation; the CMC programs with 60 lessons showed positive outcomes on numerous math skills. The authors mentioned other investigations, which integrated Distar Arithmetic and Corrective Mathematics by such as Cole, Dale, Mills, and Jenkins (1993), Glang, Singer, Cooley, and Tish (1992), Young, Baker, and Martin (1990). With these direct instruction programs. Kinder et al. (2005) also found positive outcomes with students who have low-incidence disabilities.

The summary of the language-focused studies by Kinder et al. (2005) stated that students' performance in the DI interventions showed they had benefited from DI, although their disabilities were mostly learning disabilities; the other disabilities included mild cognitive disabilities and behavior disorders.

Among the eight studies with low-incidence disabilities, Young et al. (1990) using Distar Arithmetic I and Glang et al. (1992) using Corrective Mathematics conducted research about the effects of DI. Students were in the range of early elementary school age, and in the disability categories of intellectual disabilities (ID) and traumatic brain injury (TBI). In the first study, participants performed better academically and were more engaged when they were instructed through the combination of Distar Arithmetic and DI with the addition of Discrimination

Learning Theory (DLT). In the second study, two students with TBI had instructions on math word problems and math facts with Corrective Mathematics. They answered more problems correctly and improved their math fact fluency. Among the 45 studies, over 90% of the studies with documented positive outcomes of DI programs. Kinder et al. (2005) concluded that DI programs are effective for students with high- and low-incidence disabilities. DI is designed for the needs of individual students and various research has supported its validity. Students with more severe disabilities can learn at high levels when provided with systematic, research-validated programs such as Direct Instruction.

Project-/Problem-Based Learning

History of project-/problem-based learning. Project based learning (PBL) was first systematically implemented in the 1970s in the medical field at a university (Barrows, 1996). Students in the medical field had experiences in making diagnoses, clinical reasoning, and prescribing medications and treatments in a simulated learning environment and actual medical environments (Barrows & Tamblyn, 1980). Other occupational fields such as advertising, engineering, nursing, architecture, and physical therapy, also implemented PBL as an effective learning method to hone student's skills in the professional learning environment (Barrows, 1996). Strobel and Barneveld (2009) mentioned that PBL is a more effective method compared to teacher-centered lectures, a traditional instructional method, in terms of retaining skills in the long term.

In addition to improving long-term retention, Capraro and Slough (2013) also stated that solving problems and applying knowledge in real-life situations through PBL aids students' 21st century skills. Warin et al. (2016) stated transformations of PBL's purpose. The initial target of

PBL were increasing motivation and the rate of students with passing grades. In current education settings, PBL works with understanding and defining problems rather than solving problems. Although the effectiveness of PBL has been researched in higher education, its effectiveness with students younger than 15 years old has not been researched yet (Capraro & Slough, 2013). In mathematics education, the National Council of Teachers of Mathematics (NCTM; 1989) promoted and emphasized the need for changing math instruction from memorization to authentic use and application. In this way, students build problem-solving skills and apply the learned skills in real life. One of the focused teaching instructions is project- or problem-based learning (Meyer, Turner, & Spencer, 1997).

Definitions of project-/problem-based learning. Warin et al. (2016) clarified the definitions of problem-based learning and project-based learning referred to by Larmer (2013).

Table 5

Definitions of Problem-Based Learning and Project-Based Learning

PROJECT-BASED LEARNING VS. PROBLEM-BASED LEARNING	
SIMILARITIES	
Both PBLs: - Focus on an open-ended question or task - Provide authentic application of content and skills - Build 21st century success skills - Emphasize student independence and inquiry - Are longer and more multifaceted than traditional lessons or assignments	
DIFFERENCES	
Project-Based Learning	Problem-Based Learning
Often multi-disciplinary	More often single-subject
May be lengthy (weeks or months)	Tend to be shorter
Follows general, variously-named steps	Follows specific, traditionally prescribed steps
Includes the creation of a product or performance	The "product" may simply be a proposed solution, expressed in writing or in an oral presentation
Often involves real-world, fully authentic tasks and settings	More often uses case studies or fictitious scenarios as "ill-structured problems"

Larmer (2013)

Warin et al. (2016) stated that problem-based learning lacks pedagogical methods with learning tools teachers can use efficiently. On the other hand, project-based learning is a pedagogical method. Project-based learning has a longer history than problem-based learning. Through project-based learning, students typically work on projects (Warin et al., 2016). Project-based learning is student-driven instruction, facilitated and guided by the teacher. Therefore, students are engaged in projects and become active learners, better researchers, problem solvers, and higher-order thinkers (Bell, 2010).

Project-based learning is more complex, more extensive, and a more rational approach than problem-based learning, and it covers all six orders of thinking based on Bloom's Taxonomy (Merritt et al., 2017). Teachers assess a child's performance of projects graded on rubrics. Self-evaluation and reflection of their planning, organizing information, and applying strategies, play important roles in PBL (Bell, 2010).

There are some differences between project-based learning and problem-based learning; however, Merritt, et al. (2017) clearly stated that the definition of problem-based learning is not consistently defined among researchers. Therefore, in this review, project-based learning and problem-based learning are both referred to as PBL for this reason.

Effectiveness of Project-/Problem-Based Learning.

Meyer, Turner, and Spencer (1997). Meyer et al. (1997) researched students' motivation and strategies through PBL instruction. Meyer et al. said challenges can build higher knowledge and self-monitoring and self-regulation skills, metacognitive and cognitive strategies, and the feeling of competence. However, academic challenges also can develop frustrations. The authors added that:

> students must use and adapt strategies to attain these goals, basing their choices on their personal preferences, strengths, weaknesses, and opportunities. In turn, the strategies they choose affect not only their learning but their future goals, efficacy, strategy choice, attributions, and emotions. This reflects how motivation, volition, and affect are essential and inseparable components of learning. (p. 502)

The authors introduced Entwistle's (1988) research on students' attitudes, motivations, and behavior toward learning. Entwistle's theory is that learning will be affected by types of quality and quantity in motivation, and there are three different types: deep, surface, and strategic styles, as shown in Table 6.

People in the deep learning style are conceptual learners and motivated by making connections and showing evidence. People in the surface learning style are motivated by work completion and meeting requirements; failing coursework is their fear, which works as a motivator. Surface learners tend to memorize content. Strategic style learners use any kind of tools that they can find, from memorizing to conceptual understanding. Learners with this type of motivation, usually receive good grades and are often overachievers. Other experts, Lehtinen, Vauras, Salonen. Okinuora, and Kinnunen (1995) found similar patterns: task-oriented coping, ego-defensive coping, and social-dependence-type coping.

Table 6

Summary of Three Learner Types

TYPES	DEEP LEARNER	SURFACE LEARNER	STRATEGIC LEARNER
Description	Conceptual understanding	Memorizing contents	Using any tools including memorizing connections, evidencing, conceptual understanding
Motivation	Making connections and evidencing	Work completion and meeting requirements, fears of being failed	Receiving good grades, overachieving
Learning Outcome	Deeply understanding applying the principles with facts, making statements with evidence	Wide range of learning outcome Little or no understanding—superficial understanding with substantial knowledge of facts	Ties the emphases of assessments Knowledge reproduction to conceptual understanding

Meyer, Turner, & Spencer (1997)

These patterns between motivations and behavior are caused by: 1) mastery vs. performance orientations, 2) risk-taking vs. risk-avoiding postures, 3) volition, 4) self-regulation, and 5) affect. Therefore, Meyer et al. (1997) examined the relationships among these five areas.

The first three areas are essential components of the motivational perspective, and the rest are vital and devoted components of learning. The authors examined how these elements characterize students in project-based learning instruction due to the requirements of PBL, which can create a deep and valuable learning setting for examining the students' characteristics. Fourteen Caucasians were examined in the PBL. The participant group consisted of eight 5th-grade and six 6th-grade students, and the students' genders were even. Students were in the average-ability math class, but the lowest group of students among all fifth- and sixth-graders.

Students worked on building a kite with applications of geometry concepts. Meyer et al. (1997) gave two surveys to eight 5th-grade and six 6th-grade students before and after the project: School Failure Tolerance Scale (SFT; Clifford, 1984) and Patterns of Adaptive Learning Survey (PALS; Maehr & Midgley, 1991). SFT measured the student's learning in three areas: 1) how failure affects students, 2) how much students prefer difficult math tasks, and 3) what students do after failure. PALS measured three different dimensions: a) mastery goals or performance goals, b) students' self-efficacy, and c) surface strategy users or deeper strategy users. Students answered with a 6-point scale on SFT and a 5-point scale on PALS. In addition to the pre- and post-surveys, examiners also interviewed all participants before, after, and throughout the project, which added rich information to the qualitative analysis.

The researchers found significant correlations among the SFT subscales and patterns of students' characteristics. Affect negatively correlated with preference of difficult tasks ($r = -.63$, $p < .05$) and action ($r = -.84$, $p < .01$); preference and action positively correlated ($r = .87$, $p < .01$). These results indicate students, who do not prefer challenging tasks, tend to have more negative affect due to failure. This was the same as the examiners' hypothesis. Table 7 shows the two main patterns of students.

In addition to conducting the observations and interviews, the researchers identified the groups, which rated high on negative affect as challenge avoiders, and the other group, as risk takers.

Table 7

Patterns on SFT Subscales between Challenge Avoiders and Riskers

	SFT SUBSCALES	
High negative affect	1) Affect after failure	Low negative affect
Low preference	2) Preference of difficult math tasks	High preference
Low action	3) Action after failure	High action
Challenge Avoiders		**Risk Takers**

Meyer, Turner, & Spencer (1997)

The researchers also found correlations between the SFT subscales and PALS. High negative affect raters on SFT also rated high on ability focus learning goals ($r = .67, p < .01$) and surface strategy use ($r = .64, p < .05$); on the other hand, they rated low on self-efficacy ($r = -.77, p < .01$). The ratings of risk takers were significantly different from challenge avoiders. Risk-takers rated high on mastery focus goals, self-efficacy, and deeper strategy use. Table 8 shows the summary of ratings on PALS, grouped by the ratings on SFT.

Table 8

Correlations between SFT and PALS Subscales

High Negative Affect on SFT	PALS Subscales	PALS Subscales
High ratings on ability (performance) focus goals	a) mastery goals or performance goals	Low negative affect
Low self-efficacy	b) students' self-efficacy	High preference
High ratings on surface strategy use	c) surface strategy users or deeper strategy users	High action
Challenge Avoiders		**Risk Takers**

Meyer, Turner, & Spencer (1997)

The authors identified six students as challenge avoiders and eight students as risk-takers in their student group. Both groups of students showed similar patterns. Seven of eight risk-takers had negative affect after failure at lower rates, but held higher self-efficacy, focused more on mastery of academic goals and used deeper strategies more. These results on PALS statistically distinguish these two groups, excluding the use of deeper strategy. The statistical power supported the result, despite the small sample size. Table 9 shows the means of SFT and PALS subscales of each group.

Table 9

Analysis of Variance for Challenge avoiders (N=6) and Risk Takers (N=8) on School Failure Tolerance Scale and Patterns of Adaptive Learning Scale Subscales

Mean on SFT subscales 6 point scale	**Challenge Avoiders**	**Risk Takers**
1) Negative affect after failure	4.00	1.75
2) Difficulty Preference	3.06	4.91
3) Action after failure	3.61	5.47
Mean on PALS subscales 5 point scale	**Challenge Avoiders**	**Risk Takers**
a) mastery goals or performance goals	mastery goals: 3.43 performance goals: 2.29	mastery goals: 4.09 performance goals: 1.61
b) students' self-efficacy	2.83	4.19
c) surface strategy users or deeper strategy users	surface strategy: 2.69 deeper strategy: 3.37	surface strategy: 2.00 deeper strategy: 3.83

Meyer, Turner, & Spencer (1997)

Meyer et al. (1997) found an unexpected pattern regarding gender differences. The ratio of boys to girls in challenge avoiders was 5 to 1, but 2 to 6 in risk-takers. In other words, the ratio of challenge avoiders to risk takers in each gender group was 5 to 2 among boys and 1 to 6 among girls. In addition, the six highest ratings on the negative affect after failure was made by boys, and the seventh highest rating was by the girl who was considered as a challenge avoider. Meyer et al. (1997) referred to Clifford (1991) who reported that upper elementary girl students tend to avoid taking risks on experimental math, spelling, and vocabulary tests because they feel inferior by making errors. In addition, the girls of these ages in math classes are peer-based rather than being adult-based (Newman & Goldin, 1990). Boys in this range of ages may take higher risks when they are encouraged by adults. However, the authors also explained that boys in this age range may have higher expectations on themselves, and established the hypothesis that this causes them avoid taking risks in front of peers.

SFT and PALS gave the researchers the quantitative results and the interview was able to add rich qualitative context. In summary of both the quantitative and qualitative results, the authors concluded that the risk-takers were more tolerant to the errors they made, more persistent, more flexible, and better able to manipulate cognitive, metacognitive, emotional, and environmental factors. To implement PBL effectively in the classroom, the authors pointed out that the classroom and context should focus students on mastering learning goals and reacting positively toward errors. The instructions may include discussion time for problem-solving, time to reflect on errors (which helps students describe what they learn from errors) and emphasis on quality of work instead of completion of work with an established rubric. Collaborations with peers can encourage students to think outside of the box, try their ideas, be persistent, and learn from errors, as well as decrease fears, stress, and negative affect to errors. However, this experiment involved only 14 fifth- and sixth-grade students in one setting. Regarding the sample size, the range of students' ages, and the academic subjects, more experiments are needed for generalization of patterns of challenge avoiders and risk-takers.

Göransson, Hellblom-Thibblin, and Axdorph (2016). Göransson, Hellblom-Thibblin, and Axdorph (2016) pointed out the trends of education for students with special needs in the world. Normalization was the trend of the 1970s, focusing on skills in self-care, socialization, and recreation (Fisher, Frey, & Thousand, 2003). Normalization was followed by the popularization of inclusive education. However, less attention to academic curricula, such as math and literacy, has been seen in educational trends. Furthermore, instructions in general education classrooms, targeting conceptual understanding of mathematics, and traditional math instructions in special education, emphasizing direct instruction, are contradictory regarding inclusive education and equal access to education for all. As the National Council of Teachers of Mathematics (NCTM, 2000) strongly supported, general education math instruction increased its focus on conceptual understanding and shifted from a procedural competency. Contrarily, special education has focused and practiced direct instruction for procedural fluency (Woodward, 2004).

Göransson et al. (2016) referred to a study by Jackson and Neel (2006) regarding the instructional differences in math between general education and special education. The proportion of instructional time of procedural (algorithmic) instructions and conceptual instructions were completely opposite. In general education class, students have less time through DI but more PBL, targeting more application abilities rather than procedural instructions. In special education class, students get more DI instructions than PBL, and more procedural focus than conceptual understanding.

Merritt, Lee, Rillero, and Kinach (2017). Merritt et al. (2017) investigated PBL by researching its effectiveness with younger students from kindergarten (3-years-old) to eighth grade (14-years-old) in the content areas of mathematics and science. The research also focused on effective components of PBL. The researchers' focus was the effectiveness of PBL compared to traditional educational instruction with quantitative research. Although the researchers initially targeted science and mathematics using PBL, only nine articles focused on science went through the elimination process of criteria. In other words, no studies with math instruction passed the elimination process. The remaining nine studies instructed mainly sixth- to eighth-grade students.

The authors identified eight components of PBL found through the nine studies: existence of a problem, use of small groups, student-centered iterative inquiry process, communication of findings, use of resources, incorporation of technology, and teacher as facilitator. While the nature of problems varied in each PBL example, identifying problems was an important component in all nine studies, especially studies with secondary students. With PBL for older students, students were given less-structured instructions compared to younger students. The authors indicated that both well- and less-structured approaches can be used, but teachers need to consider a student's ability in literacy comprehension. In addition, in all studies, small group instruction was used to promote collaboration and teamwork to solve problems. The other component that most studies emphasized as an important component was an interactive inquiry process such as analyzing options, deciding what to do, and how to do it. Providing resources, such as the school library, was observed in five of the studies, and the other components were found in four or fewer of the studies.

The authors measured the effectiveness of PBL instruction in four areas: academic achievement, knowledge retention, conceptual development, and attitudes. Eight out of the nine studies measured student's academic achievement. Seven out of those eight studies concluded that students given PBL instruction performed better than students in the control group. One study did not find a significant difference in student's performance between PBL instruction and traditional instruction, while students in a control group performed slightly lower. Four studies measured students' knowledge retention through the use of a delayed posttest. Three of those four studies showed that students in the PBL group performed better than in the control groups, which indicated that PBL helps students retain knowledge overtime more than a traditional method. Another one of the four studies showed almost identical results in both groups.

Four studies examined students' conceptual understanding with which students can understand scientific theory and apply the theory to occurrences. All studies found that there was a significant difference between the PBL group and the control group. The four studies measured the student's attitude toward the content, teachers (scientists), and PBL. Three studies showed that students had a positive attitude toward the content and teachers, but one showed that students' attitude was not significantly different toward PBL. Overall, students showed positive outcomes in academic achievement, knowledge retention, conceptual understanding, and attitudes through PBL.

The authors concluded that few studies were done with PBL in science and math with younger students, especially studies in math with PBL are very limited. However, the authors believe that PBL will work more effectively and efficiently in math, so more studies will be needed. The authors added that the definitions of PBL was not consistent among articles. For future studies, PBL has to have a more clear and consistent definition in order to evaluate the effectiveness of PBL. In most of the seven studies with positive outcomes, students in sixth- to eighth-grade were involved, but not a wide range of ages, which means that future research should also address this limitation.

Higher Order Thinking and ASD

One of the most important aspects in education is higher order of thinking (Tanujaya, Mumu, & Margono, 2017). The positive outcomes of PBL include retaining knowledge for extended periods of time (Strobel & Barneveld, 2009), improving problem-solving abilities, applying knowledge in real-life situations, and increasing 21st century skills (Capraro & Slough, 2013). These abilities are also considered as higher order of thinking. Therefore, PBL and higher order thinking are often discussed together.

Higher order thinking skills often refer to the highest three areas of the revised Bloom's Taxonomy: analyzing, evaluating, and creating. The revised Bloom's taxonomy includes three more categories (remembering, understanding, and applying), which are referred to, in general, as lower order of thinking skills (Rahbarnia et al., 2014). The skills of higher order thinking are the abilities that students activate when they are involved with unfamiliar problems, uncertainties, questions, or dilemmas (King, Goodson, & Rohani, 2013).

Researchers have studied higher level thinking throughout the world. One group of researchers, Ramos, Dolipas, and Villamor (2013), summarized that higher order thinking skills are thinking creatively and critically, analyzing, problem-solving, visualizing, categorizing, comparing, and contrasting. Based on the ideas of previous researches, Tanujaya et al. (2017) concluded that higher order thinking consists of three components: critical thinking skills, creative thinking skills, and systems thinking skills. Additionally, there are nine elements within two main skill indicators (Tanujaya, 2016; Tanujaya et al., 2017).

Table 10

Nine Elements in Two Skills Indicators

CRITICAL THINKING SKILL	CREATIVE THINKING SKILL
1. The use of mathematical concepts 2. Principles comprehension 3. Impact predicting 4. Problem-solving 5. Decision-making	1. Working in competence limit 2. Coping with new challenges 3. Divergent thinking 4. Imaginative thinking

Tanujaya, Mumu, & Margono (2017)

Mayes and Calhoun (2003) stated that once students start middle school, math content becomes more abstract and cognitively complex, as well as focused on problem-solving and mathematical reasoning skills, and higher level thinking. However, students with ASD struggle more in middle and high school due to their dominate deficits of executive functioning such as working memory, impulse control, cognitive flexibility planning, organization, attention, and self-monitoring (Hart Barnett & Cleary, 2015; Mayes & Calhoun, 2003; Rockwell et al., 2011). Therefore, Cleary and Hart Barnet (2015) concluded that students with ASD need to be taught math and higher order thinking skills with strategies, which are research based and easily implemented by teachers in a classroom.

Table 11

Summary of Chapter 2 Findings

Author(s)	Study Design	Effect Sizes/ Participants	Procedure	Findings
AUTISM AND EFFECTIVE INSTRUCTIONS				
Iovannone, Dunlap, Huber, & Kincaid (2003)	Qualitative • Metanalysis	39 studies (177 students)	Identified 6 essential components of effective interventions for students with ASD from 4 recent reports (1992-2001). 6 core components are: 1. individualized support and services for students and families, 2. systematic instruction, 3. comprehensible and/or structured environments, 4. specialized curriculum content, 5. a functional approach to problem behaviors, and 6. family involvement Inclusion Criteria: (a) any age range but including individuals with autism older than 5 years old, (b) address at least one component, (b) within the last 10 years (1992-2002), and (c) effective interventions.	• This study gathered the reports of effective interventions focusing on 6 core components.

Table 11 (continued)

Author(s)	Study Design	Effect Sizes/ Participants	Procedure	Findings
Knight, & Sartini (2015)	Quantitative • Metanalysis	13 studies (37 students; 31 males, 6 females; 8-15 years old)	Inclusion Criteria: (a) single case or group research design, (b) at least one participant with ASD, (c) a peer-reviewed journal, (d) comprehension results, (e) an intervention to increase text-based comprehension skills, and (f) comprehension skills in any academic content area in a school setting. Quality Analysis Using Reichow (2011) Criteria The descriptive characteristics of a strong and adequate study: (a) reference, (b) participants, (c) setting, (d) targeted skills, (e) dependent variable/ measure, (f) independent variable / intervention, (g) research designs, and (h) results.	• All 13 studies showed positive outcomes. • Response prompting strategies and visual supports are effective interventions across content areas (ELA, Math story problem, and Science). • Time delay, modeling of examples and non-examples, direct instruction, and simultaneous prompting can produce positive outcomes.

Table 11 (continued)

Author(s)	Study Design	Effect Sizes/ Participants	Procedure	Findings
Su, Lai, & Rivera (2010)	Quantitative • A quasi-experimental, pre- and post- with control group de-sign.	25 students with autism (high-functioning autism >70) and 10 typically developing peers.	Pre-training: Training of The Project MIND approach, a multi-sensory math curriculum, and direct instruction on math were provided to all teachers for 5 months. Treatment: Systematic instruction was using direct and embedded instructions integrating The Project MIND approach. The study group had 3-month instruction. Mullen Scale of Early Learning (MSEL) and Test of Visual Motor Integration (VMI) were used for effectiveness identifications.	• Students with high-functioning ASD performed significantly different from students without ASD. • Systematic instruction supported students with high-functioning ASD learn math. • All students with interventions showed the differences between pre- and post-tests on all subtests including: visual test, fine motor test, expressive language test, receptive language test, and the H.E.L.P. math scale.
Rockwell, Griffin, & Jones (2011)	Quantitative • Single-case, multiple probes across behaviors design	10-years-3-month-old female with autistic disorder. No medications.	Using Schema-based strategy instruction (SBI). Four one-to-one sessions per week, for 8 weeks during the summer. Instructions included the sequential steps with mnemonics, schematic diagrams, problem sorting activity, and generalization instructions. Sessions were video-taped for treatment integrity.	• SBI can be an effective way to teach a child with autism. • SBI can support children maintain skills over time and generalize skills within the school setting. • SBI can improve math problem-solving performance of children with ASD and be modified to meet children’s needs.

Table 11 (continued)

Author(s)	Study Design	Effect Sizes/ Participants	Procedure	Findings
Hord & Bouck (2012)	Qualitative • Metanalysis	7 studies (66 students; elementary to 23 years old)	Inclusion Criteria: studies focused on (a) functional math skills and other skills rather than academic math skills, (b) between 1999 and 2010, (c) mild intellectual disabilities	• 6 out of 7 studies focused on procedural understanding, computations, math facts, and basic arithmetic. • Flashcards is used in a half of the studies. • Only 1 studies focused on conceptual understanding. • Using models, cognitive or metacognitive prompts. • All 7 studies improved student's basic math facts accuracy, performance in computation and solving word problem.
Hart Barnett, & Cleary (2015)	Qualitative • Metanalysis	11 studies (34 students: 1 Severe LD/ADHD, 1 ID, 2 ASD & ID, 26 ASD, 2 Mild-ID, 1 MR, and 1MR&ID)	Inclusion Criteria: (a) a peer-reviewed journal, (b) students of any age ranging (K-post secondary), (c) participants identified with an ASD, (d) any educational setting, and (e) evaluating the effectiveness of academic or functional interventions targeting mathematical content standards and/or process standards Exclusion: (a) lacking an empirical research design and (b) did not use the study of mathematics interventions as the primary goal of the experiment.	• Visual representations were effective strategies in teaching students with ASD mathematic skills. • Cognitive strategy interventions had positive outcomes with increasing mathematic skills. • Many students with ASD are included in general education classes. However, math instructions for most of them are outside of the general education setting. • The academic interventions mainly targeted low-level mathematical content.

Table 11 (continued)

Author(s)	Study Design	Effect Sizes/ Participants	Procedure	Findings
DIRECT INSTRUCTION				
Thompson, Wood, Test, & Cease-Cook (2012)	Quantitative • Multiple probe across participants design	3 elementary students with ASD (8-year-old African-American male, with moderate ID; 8-year-old African-American male, with moderate ID; and 6-year-old African-American male, with moderate ID)	Baseline was collected, and a generalization probe was conducted in five consecutive days prior to the intervention. One-to-one Direct Instruction Connecting Math Concepts (CDC) used. Intervention contains 10 lessons in the first phase and 6 lessons in the second phase. Duration varies for each student by using error-correction. Maintenance and generalization were measured.	• DI is effective instruction in teaching students with ASD to tell time. • DI is effective to support young students with ASD maintain and generalize specific math skills. • DI is effective in teaching younger students to extend previous studies with older students. • DI might be effective in teaching specific math skills.
Kinder, Kubina, & Marchand-Martella, (2005)	Qualitative • Metanalysis	37 studies with high-incidence disabilities and 8 studies with low-incidence disabilities	Inclusion Criteria: (a) only articles appearing in education journals, (b) ancestral searches of references in DI texts, (c) computerized searches using various search terms related to DI, and (d) examination of references listed in SRA-produced research overviews Exclusion: (a) grant reports, dissertations, technical reports, and paper presentations at conferences,	• Direct Instruction programs show clear evidence of their efficacy with students with low-incidence disabilities. • DI are designed with the needs of individual students in mind and have strong research support validating them for instruction of students with disabilities. • Students with more severe disabilities can learn at high levels when provided with systematic, research-validated programs such as Direct Instruction. • Of the 45 studies reviewed, over 90% identified positive effects for Direct Instruction programs.

Table 11 (continued)

Author(s)	Study Design	Effect Sizes/ Participants	Procedure	Findings
PROJECT-/PROBLEM-BASED LEARNING				
Meyer, Turner, & Spencer (1997)	Qualitative and quantitative • Experimental treatment control group design	14 Caucasian 5th- and 6th-grade students (8 fifth graders, 6 sixth graders; 7 girls 7 boys) Average-ability math class participants.	The Kite Project: working on a geometry unit incorporated PBL. 2 surveys approximately 6 weeks before the project. School Failure Tolerance Scale (SFT) for students' constructive responses to failure and Patterns of Adaptive Learning Survey (PALS) for (a) learning-focused academic goals, (b) ability-focused goals, (c) student self-efficacy, (d) use of surface learning strategies, and (e) use of deeper learning strategies. Observation of daily instruction and interviews of 14 students before, during, and after the project.	• 3 theoretical frameworks on motivation and challenges: academic risk taking, achievement goals, self-efficacy • Challenge seekers were tolerant, persistent, flexible, and easily manipulated cognitive, metacognitive, emotional, and environmental factors. • Challenge seekers supported the ideals of deep strategy users, and challenge avoiders reflected both the strategic and surface patterns. • Proportionately more girls than boys are challenge seekers (6 out of 8 were females).
Göransson, Hellblom-Thibblin, & Axdorph (2016)	Qualitative • Content analysis approach	6 classes 31 students within general Swedish compulsory schooling for students with ID (CSSID). 7-18 years.	Two types of data were collected: (a) filmed mathematics lessons and (b) interviews with teachers. Mathematical Competency Research Framework (MCRF) to understand the factors involved in mathematical competence	• 3 major teaching strategies were found: aspects of mathematics activities or the instructional material, students' thought processes or metacognitive processes, and dialogue and interaction between students • Conceptually-based mathematics curriculum can add meaningful knowledge to basic procedural skills. • Contents in various modes of math competence may help students conceptually understand.

Table 11 (continued)

Author(s)	Study Design	Effect Sizes/ Participants	Procedure	Findings
Merritt, Lee, Rillero, & Kinach (2017)	Qualitative • Metanalysis	9 studies (K-8)	Inclusion Criteria: (a) peer-reviewed journal articles, (b) problem or project-based learning, (c) studies related to mathematics and/or science education, (d) pre-K to high school, (e) quantitative analysis, (f) interrater reliability ranged from 0.80 to 0.90, (g) experimental or quasi-experimental design, (h) definitions of PBL stated, (i) PBL components stated, and (j) effectiveness of PBL Studies related to mathematics were eliminated with these criteria.	• No consistent definition of PBL. • PBL has 8 components: nature of problems, small group, student-centered iterative inquiry process, communication of their findings to whole class, resources, technology, partnership with community, and teachers' role as facilitators. • PBL is an effective method for improving K-8 students' science academic achievement.

Chapter 3: Conclusions and Recommendations

Basic mathematics is one of the essential skills for students with disabilities in order to be employed and independent in their adulthoods. In other words, teaching mathematics with effective methods at school has essential roles. Although there is some research of effective instructions, focusing on communication and reading for students with ASD, mathematics instructions have been limitedly examined (National Research Council [NRC], 2001).

Moreover, there are educational trends and innovative instructions, which special education teachers may also implement in their classroom. However, teachers must practice evidence-based instruction as required in the Individuals with Disabilities Education Act (IDEA) and the No Child Left Behind Act of 2001 (NCLB; Rockwell et al., 2011).

The purpose of this paper was to review the literature that examines the effectiveness of a traditional instruction and an innovative instruction for students with low-functioning ASD in math. Direct Instruction (DI) is the most practiced traditional instruction, and problem-/project-based learning (PBL) is chosen as the most recent innovative and focused instruction in education. Two questions guide this review:

1. Is Problem-/Project-based learning (PBL) as effective as Direct Instruction (DI) to teach basic math skills for students with low-functioning Autism Spectrum Disorder (ASD)?
2. Can students with low-functioning ASD develop the basic math skills through instructions targeting higher order thinking?

Conclusions

The conclusions of this literature review are discussed along with the foci of this paper: characteristics of ASD, instructional requirements or needs for students with low-functioning ASD, the effectiveness of DI and PBL, and higher order thinking.

Characteristics of ASD

Students with ASD face a lot of difficulties in academic situations due to deficits of executive functioning, language impairment (communication), and attention control (Hart Barnett & Cleary, 2015; Rockwell et al., 2011; Zelazo et al., 2016). In math, students struggle with identifying and isolating irrelevant information, organizing information, categorizing, using appropriate and useful strategies, comprehending word problems, conceptually understanding abstract and cognitively complex concepts, and developing mathematical reasoning skills (Hart Barnett & Cleary, 2015; Rockwell et al., 2011; Zelazo et al., 2016).

The overall outcomes and adulthood of this population are highly likely to be poor because academic career and achievement strongly relate to vocational outcomes (Oswald et al., 2016). Compared to the populations with other disabilities, students with ASD are at risk of being unemployed (King et al., 2016). Mathematics is an academic subject, as well as an essential functional and vocational skill for students with ASD (Oswald et al., 2016).

Although some students with ASD do not have an intellectual disability, one of the comorbid disabilities of intellectual disability is ASD. Only 20% of students with ASD perform mathematics at or above average (Wei et al., 2014). Their struggle in math is unexpectedly more severe than students with learning disabilities; their performance is lower than expected, based on their intellectual abilities (Hart Barnett & Cleary, 2015; Jones et al., 2009; Oswald et al., 2016).

Instructional Requirements or Needs

Among the eight essential components in instructions for students with ASD identified by Iovannone et al. (2003), comprehension strategies (Knight & Sartini, 2015), systematic instruction (Su et al., 2010), and visual representations (Hart Barnett & Cleary, 2015; Rockwell et al., 2011) are some of the evidence-based effective instructions. Most of the interventions targeted language improvement (NRC, 2001), but fewer interventions focusing math also improved students' target math skills, such as determining math operations on word problems (Kinder et al., 2005) and telling time (Thompson et al., 2012) which can be both functional and basic math.

Although many studies examined the effective math interventions, most studies targeted procedural achievement rather than conceptual understanding (Hord & Bouck, 2012). The effective instruction also should include the strategies regarding behaviors and communication and language skills (Iovannone et al., 2003), which also affect math performance.

Effectiveness of DI

The five essential components of DI identified by Watkins (2008) are: 1) general case programming, 2) track organization, 3) scripted presentation, 4) predictable formats, and 5) pacing. These five components promote generalization, maintenance, consistency, systematic instructions, engagement, speed, accuracy, and on-task behavior. These are the common areas that students with ASD struggle with, due to deficits of executive functioning (Hart Barnett & Cleary, 2015; Hord & Bouck, 2012; Rockwell et al., 2011; Zelazo et al., 2016). DI has "behavioral principles including short, clear and sequenced instructions, immediate reinforcement, and error correction procedures to enhance learning outcomes" (Shillingsburg et al., 2015, pp. 44-45). This shows that DI is a systematic and strategic instruction.

The effectiveness of DI has been studied and has shown positive outcomes with students with other disabilities (Kinder et al., 2005). Kinder et al. reviewed 45 studies using DI with students diagnosed with various disabilities in a wide range of age levels (students in preschool to middle school). More than 90% of the reviewed article showed positive outcomes. More studies using DI targeted procedural skills than understanding concepts and improving problem solving skills. Thompson et al.'s (2012) study showed the effectiveness of generalization and maintenance with academic and functional math skills with early elementary students. DI can also use to target conceptual understanding (Hord & Bouck, 2012), although the number of studies is limited.

The studies generally examined effective instructions for students with ASD instructed through DI with more specific strategies, such as visual aids, modeling, and prompting. One of the strategies used in many articles was model-least-test (MLT), which is systematic and explicit, and based on direct instruction (Knight & Sartini, 2015). Therefore, many studies that examined effective strategies for students with ASD include one or more elements of DI. In other words, DI is used and valued as effective instruction with researched evidence, even after innovative instructions are gained social attentions. DI can meet instructional requirements to approach students' needs and provide support to cover impairments of executive functioning.

Effectiveness of PBL

Although PBL is one of the new trends in education, no studies examined effectiveness of PBL with students who have been diagnosed with ASD in math class. In addition, its definitions among researchers are unclear; main elements of the instruction are undefined. However, its target skill is common in many studies. PBL targets higher order of thinking and provides students with more authentic environments, in which students can activate and practice their problem-solving skills. Increasing students' motivation and giving students freedom in their own learning are the other purposes of PBL, which are greatly different from DI (Warin et al., 2016). Meyer et al.'s (1997) study indicated that risk takers will activate their skills and learn from errors through PBL, which help students in their real life. They are also more tolerant to mistakes, more persistent and flexible in academic environments. Meyer et al. (1997) suggested that the instructions have allocated time of discussion and collaboration with peers. However, teachers need to carefully plan and guide challenge avoiders during PBL. This study did not indicate if it included students with disabilities.

The studies which examined the PBL's effectiveness are limited, especially with students who have disabilities. In fact, Merritt et al. (2017) started their researches in math and science classes, but did not include studies in math class. The large parts of struggles are due to a lack of four criteria that the reports: used either experimental or quasi-experimental design; included definition of PBL; included elements of PBL; and included results of effectiveness of PBL. Therefore, the studies of PBL are not able to provide evidence and essential components of instructions, which could guide teachers to easily use the methods in their classrooms.

Higher Order Thinking

The higher order of thinking activates students' critical and creative thinking skills, improves long-terms retentions, and enhances problem-solving skills in life (Capraro & Slough, 2013; Ramos et al., 2013; Strobel & Barneveld, 2009). The skills of higher order thinking are also described as the abilities that students activate when they are involved with unfamiliar problems, uncertainties, questions, or dilemmas (King et al, 2013).

As synchronized with the emphasis of higher order thinking, students with ASD show more struggles in middle and high school due to their dominate deficits of executive functioning, such as working memory, impulse control, cognitive flexibility planning, organization, attention, and self-monitoring (Hart Barnett & Cleary, 2015; Mayes & Calhoun, 2003; Rockwell et al., 2011).

Recommendations for Future Research

Almost all studies mentioned that research focusing on academic skills of students with ASD is limited. Among a limited number of studies, most of them have focused on communication, language, and reading comprehension rather than math. Within math interventions, computations and procedures a bigger focus than conceptual understanding and problem-solving. However, mathematics is not only an academic subject, but also a tool for problem-solving in daily life and vocational achievement. Therefore, investigating mathematical achievements of students with ASD is needed. Investigation may more clearly guide teachers to help their students with ASD for higher education and contribution in society (Oswald et al., 2016).

In addition, the limited existing research of conceptual understanding only included basic math operations (addition, subtraction, multiplication, and division) with word problems. However, to seek higher education and success in middle and high school, fractions, decimals, percentages, higher money skills, and basic algebra are the skills students need to be taught with evidence based strategies. Therefore, further researches targeting these skills are needed to improve instructions, and academic outcomes of students with ASD.

Implications for Practice

According to the impacts on academic skills due to students' deficits, clear and well-structured instruction is critical for students with ASD. In terms of the clearness of instructions, DI is clearer and has less clutter. Students get more expected responses and results than PBL. In terms of working memory, DI requires less working memory than PBL. Students through PBL have to use multi-tasks such as experimenting with math reasoning, observing, writing, checking, reflecting, and correcting. Since a lot of students with ASD struggle with making decisions, application, and problem-solving. I would not think PBL is a better and easier instruction to use than DI.

With PBL, teachers should have clear structures for students with ASD. Teachers should carefully plan and give specific instructions when they face errors. I would pre-teach students expected errors so students can prepare for uncertainty. Instructions should be broken down into smaller steps than instructions to neurotypical students. I believe these additional instructions minimize students' confusion and provide support in order to cover their deficits of executive functioning. I may use PBL for older students who are mentally matured and have abilities to control their emotions when they face challenging tasks. I will also see if students are risk-takers or challenge avoiders to avoid unnecessarily emotional outbursts or problem behaviors.

Summary

Education has trends (Göransson et al., 2016) and teachers and schools follow the trends. However, we, as special education teachers, should not forget that the Individuals with Disabilities Education Act (IDEA) and the No Child Left Behind Act of 2001 (NCLB) require us to instruct students by using effective methods, which have been researched for effectiveness (Rockwell et al., 2011). More importantly, teachers should keep in mind that the purpose of special education is meeting individual students' needs. In other words, teachers have to critically evaluate if the outcomes of innovative instruction match with their student's needs and goals, rather than the name of instructions. How can we decide effective instructions?

If the innovative instruction can meet students' needs with accommodations and modifications, then it would be a great instruction for students to build application skills and learn to analyze and solve problems such as ones that exist in their everyday life. However, if innovative or traditional instruction does not meet their needs, then teachers should choose different instructional ways, which will meet students' needs. As long as teachers focus on students' needs, instead of educational trends and names, students benefit from the instructions.

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