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Take the Route to Effective Instruction: Evidence-Based Practices in Math Education for Students with Learning Disabilities

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TAKE THE ROUTE TO EFFECTIVE INSTRUCTION: EVIDENCE-BASED PRACTICES IN MATH EDUCATION FOR STUDENTS WITH LEARNING DISABILITIES

Math is a critical component in school curriculum, success in the workplace, and activities of daily living (Hudson & Miller, 2006). Students with learning disabilities (LD) struggle in mathematics (Bryant, Bryant, & Hammill, 2000), and teachers struggle to provide evidence-based practices in math due to a general lack of research in teaching mathematics to students with LD. When compared to reading disabilities, research in math assessment and instruction is in its infancy. Between 1966 and 1975, the ratio of research studies conducted on reading disability (RD) versus mathematical learning disability (MLD) was 100:1. Although the ratio in these same respective areas improved between 1996 and 2005 to 14:1, math research continues to lag behind when compared to research in reading (Gersten, Clarke, & Mazzocco, 2007).

A fundamental understanding of mathematic concepts is essential to foster quality educational and vocational success of individuals with LD in rural areas. In contrast to their suburban and urban counterparts, special educators in rural areas have less access to resources, funding, and human resources and consequently at a disadvantage for providing high quality differentiated instruction to meet the unique needs of their students (Hammer et al., 2005). A meta-analysis, which provides a systematic and quantitative analysis of research literature, can provide rural educators with a synthesis of research effects and thus a good starting point for developing a portfolio of research- and evidence-based practice in mathematics instruction for students with LD. Gersten et al. (2009) provided such a meta-analysis of mathematics instructional interventions for students with LD.

In their meta-analysis of mathematics instructional interventions for students with LD, Gersten et al. (2009) grouped research into areas of effective practices. Four of the categories of effective practice - explicit instruction, visual representations, heuristics, student verbalizations - are discussed in the sections that follow. Please see Table 1 for a content analysis of research studies published in visual representations and heuristics since publication of the Gersten et al. (2009) meta-analysis.

Explicit Instruction

Explicit instruction is an effective, direct, and skill-based method of instruction that has been verified as an evidence-based practice for teaching individuals with high-incidence disabilities (Archer & Hughes, 2011). Explicit Instruction provides a format from which a wide range of skills can be taught from one-step addition and subtraction (Lee, 1992) to complex algebraic equations (Witzel, Mercer, & Miller, 2003). The National Mathematics Advisory Panel

(2008) endorses the use of explicit instruction for students with LD in teaching computation, word problem-solving and generalizing skills to new situations.

Explicit instruction incorporates a sequence of incremental steps within a lesson. Instruction begins with an advance organizer which contains the following components: gain student attention, state the goal of the lesson, discuss the relevance of the lesson, and review prerequisite skills. The body of an explicit teaching lesson includes three processes: modeling, guided practice, and independent practice. Instruction concludes with a brief review of concepts and skills that have been covered and a preview of the next day's performance objective (Archer & Hughes, 2011). Instructional components that enhance mathematics instruction for students with disabilities, including visual representations by teachers and students, the use of heuristics, and student verbalizations of mathematic activity, can be effectively incorporated into an explicit instruction lesson.

Visual Representation

The use of visual representation for problem solving has often been cited as one of the most successful instructional approaches for students with LD (e.g., Baker, 1992; Krwaec, Huwag, Montague, Kressler, & de Alaba, 2015; van Garderen, 2006). Moreover, the use of visual representations to help students find solutions to math problems has been used by teachers for many years (Gersten et al., 2009). In the meta-analysis conducted by Gersten et al. (2009), 20 studies were sub-classified and examined based on the following four categories: (a) teacher use of visual representation as an instructional approach, (b) teacher instruction using visual presentation with subsequent, mandatory student use of the approach, (c) mandatory student use of the same visual while solving problems, and (d) use of visual representation with sequencing strategy and/or range of examples.

Gersten et al. (2009) described these 20 studies as diverse, complex approaches that included the use of visual representation in isolation (e.g., use of a graphic organizer; Owen & Fuchs, 2002) or in combination with other approaches (e.g., visual cues in combination with explicit instruction; Lee, 1992). Overall results indicated that effect sizes were larger for studies that examined the use of visual representation in combination with other instructional approaches. For example, Xin, Jitendra, and Deatline-Buchman (2005), had two study conditions that incorporated the use of visuals. The first study group incorporated the use of a visual alone, in contrast to the experimental group, presented with a visual representation in combination with an instructional approach (e.g., explicit schema-base strategy) that was more specific and based on the understanding of how experts solve mathematical problems. When using the explicit, schema-based strategy, students are first required to identify the type of problem (i.e., "proportion," or "multiplicative compare") and then asked to use a diagram linked to that specific problem type in order to create a visual representation of the critical information and procedures necessary to find the solution. Finally, students translate the diagram into a math sentence and proceed to the final stage of solving for the solution. Results of the Xin et al, study indicated that the experimental group significantly outperformed the control group on immediate and delayed posttests as well as the transfer test. Studies using the visual representations have also been used in conjunction with such strategies as mnemonics (e.g., Manalo, Bunnell, & Stillman, 2000) and explicit instruction (e.g., Jitendra, et al., 1998; Marzola, 1987; Owen & Fuchs, 2002; Ross & Braden, 1991).

Following the meta-analysis of Gersten et al. (2009) three studies have been identified as examining the use of visual representation to help students with LD to solve mathematical problems. The study by Van Garderen, (2006) has been identified, but not included in Gersten et al., with two studies (e.g., Krawec, 2014; Zhang, Ding, Segall, Mo, 2012) taking place following the review in 2009. Van Garderen, (2006) and Zhang et al. (2012) both focused on the singular approaches of visual imagery and visual-chunking representation, respectively. Both studies yielded positive results with the use of visual representation positively correlating with higher mathematical word-problem performance. In the study by Krawec et al. (2013), a combination approach was used in which effects of visual representation in combination with paraphrasing accuracy were determined to be beneficial for students who were identified as low achievers (LA) and having LD in math. Moreover, results also indicated that students with LD approached problem solving in an oversimplified manner, expressing substantially less relevant information to the problem through paraphrasing and requiring significantly more pictorial representations than their average achieving (AA) same age peers. The results of this study are similar to those in previous research (e.g., Butler, Miller, Crehan, Babbitt, & Pierce, 2003; Hegarty & Kozhevnikov, 1999; van Garderen & Montague, 2003); which indicated that students with LD often need more pictorial representation than their peers, underscoring a need for more explicit instruction in their development of schematic representation of word problems.

Heuristics

Heuristics are generic problem-solving strategies used to organize and process information (Gersten, et al., 2009; Van Luit & Naglieri, 1997). Students with LD or math difficulty experience considerable difficulty in mathematics problem-solving (Cawley, Parmar, Foley, Salmon, & Roy, 2001) and are noted to have minimized working memory capacity, inattention, and slow processing speed (Fuchs & Fuchs, 2002) which are thought to impede the problem-solving process, higher order reasoning (Maccini & Ruhl, 2001), and comprehension (Learner, 2000). Heuristics are tools that can be explicitly taught to students with LD to help them organize and retain procedural frameworks for solving problems (Gersten et al., 2009).

Four studies included in Gersten's et al. (2009) meta-analysis examined the use of heuristics. Heuristic interventions included components of explicit instruction (Woodward, 2006; Woodward, Monore, & Baxter, 2001), visual representation (Woodward, 2006), and student verbalization (Van Luit & Naglieri, 1997; Hutchinson, 1993). For example, Woodward (2006) compared an integrated strategy instruction in multiplication and timed assessment of declarative knowledge to timed practice drills alone. Students with LD in the integrated strategy group outperformed students in a control with LD in the control group.

Research following the Gersten et al., (2009) meta-analysis has echoed the success of heuristic strategies for students with LD. Researchers have examined the use of *SolveIt!* a seven step heuristic strategy in which students *Read* for understanding, *Paraphrase* by retelling in their own words, *Visualize* through a picture or diagram, *Hypothesize* by creating a plan to solve the problem, *Estimate* an answer, *Compute* the arithmetic, and *Check* for accuracy (Krawec et al., 2013; Montague, 2003; Alter, 2010). Results indicated that students in experimental groups using *SolveIt!* answered more problems correctly, maintained skills over time, and used more strategies to solve problems. Iseman and Naglieri (2011) conducted another study that demonstrated the positive effects of heuristics on the learning performance of students with LD.

Iseman and Naglieri developed a procedure to support students with LD completing mathematics problems on worksheets. The procedure cued participants to: 1) establish a goal (*e.g.*, percent correct, complete assignment), 2) find a starting place, 3) develop an overall plan, 4) define specific strategies, and 5) identify patterns in worksheets. Results from these studies indicate that students with learning disability increase achievement in mathematics through instruction in procedural strategies.

Student Verbalization of Mathematical Reasoning

In mathematics instruction, student verbalization often involves a student's oral verbalization, sometimes called "think-aloud," of the cognitive process required to solve a problem or the student's verbalization of metacognitive knowledge, experience, and skills (Rosenzweig, Krawec, & Montague, 2011). The cognitive process of verbalization involves steps for solving a specific problem type, and includes behaviors such as reading and paraphrasing a problem, developing a plan for solving a problem, computing specific steps for solving the problem, and checking to ensure that all steps have been completed and computations are correct (Hutchinson, 1993; Rosenzweig et al., 2011). Verbalization of the metacognitive process involves a student's self-regulation as they complete problem solving, and includes oral statements related to self-correction, self-instruction, self-monitoring, and self-questioning (Rosenzweig, et al., 2011; Ross & Braden, 1991).

Task-relevant student verbalization has been positively correlated with persistence in problem solving and successful task completion in mathematics (Ostad & Sorenson, 2007). Montague and Applegate (1993) noted that while there was no difference in the amount of verbalizations among students with LD and their average achieving and gifted counterparts on one-step word problems, students with LD had fewer verbalizations than their higher achieving peers on more challenging two- and three-step problems. In an analysis of the type of verbalizations iterated during problem solving, Rosenzweig and colleagues (2011) reported that students with LD had fewer productive metacognitive verbalizations, such as self-correction, self-direction, self-questioning, and more non-productive verbalizations related to affect and problem difficulty.

The student verbalization studies reviewed by Gersten, et al. (2009) included overt verbalization of both cognitive and metacognitive processes. The following summaries of three studies reflect the variety of student verbalizations reported in the literature as having a positive effect on the performance outcomes of students with LD. Marzola (1987) provided students with prompt cards depicting the specific cognitive steps needed to solve addition and subtraction problems. After a teacher model, students orally verbalized the problem-solving process with one problem and then covertly verbalized or whispered the remaining problems. Students in the oral verbalization group outperformed students in the control group who were not instructed to verbalize and received only immediate feedback on their performance. In another study (Hutchinson, 1993), following direct instruction on three types of word problems, researchers provided students with cognitive self-questions on prompt cards. Students were instructed to think aloud, and they were provided with prompts and received corrective and reinforcing feedback as they verbalized and completed the process on the cue card. Students in the experimental verbalization group outperformed the direct instruction control group on a post-test and 6-week maintenance probe. In a third study reported by Schunk and Cox (1986), students were instructed to freely verbalize the process they used to solve subtraction problems that

required regrouping. In this study, students in the experimental verbalization groups outperformed students who were not instructed to verbalize their thought processes.

Conclusion

The ability to solve word problems in the field of mathematics has long been recognized as an essential component of math competency. Moreover, problem representation and the verbalization of steps toward a solution are essential to successful problem solving. Meta-cognitive differences have frequently been observed in students with LD, who were more likely to experience difficulties on word problems in their same age peers (Krawec et al., 2013). The present literature review provided an overview of results and implications from studies examining the effects of interventions that addressed each of the four categories of effective practice (e.g., explicit instruction, visual representations, heuristics, and student verbalizations) as noted in the meta-analysis conducted by Gersten et al. (2009). Practitioners and researchers can use Gersten's meta-analysis to identify strengths and weaknesses of identified studies as well as areas of inquiry in which a paucity of research exists and additional research is needed.

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Table 1

Research Studies found following the Gersten et al., (2009) Meta-analysis

Reference	Participants	Setting	Study Design	Dependent Variable (Math Skill)	Independent Variable (Instructional Approach)	Results
Visual Representations						
Krawec (2014)	<i>n</i> = 84; Grade 8	Inclusive, general education	Experimental group design	Problem Solving	Visual representation paired with paraphrasing and problem solving accuracy	<i>Effect size</i> = 1.05; visual representation accounted for greater significant variance for students with LD, with paraphrasing identified as an area of struggler for students who were LD and LA in math
Van Garderen (2006)	<i>n</i> = 66; Grade 6	Inclusive, general education	Experimental group design	Problem solving	Visual representation using spatial/schematic visualization and visual imagery	<i>Tukey's post hoc</i> ($\eta^2 = .58$); The use of visual and schematic imagery on assessments indicated students with LD relied more on pictorial images than schematic in comparison to students identified AA or G.
Hueristics						
Lee Swanson, Moran, Lussier, & Fung (2014)	N= 82, Grade 3, students with LD	Inclusion, general education	Experimental Group Design	Word problem solving	Explicit instruction and paraphrasing strategy for math word problems	Students who paraphrased all parts of the word problem yielded high results from students with higher working memory
Krawec, Huang, Montague,	N=77, Grade 7 and	Inclusion pre-algebra	Group Experimental	Word Problem Solving	<i>SolveIt!</i> Strategy using read,	Students in the treatment group used more strategies

Kressler, & dSe Alba (2012)	8, students with LD		Design		paraphrase, visualize, hypothesize, estimate, compute, and check the answer	to solve problems
Alter (2010)	N= 4, Grade 4 and 5, students with EBD	Alternative school	Multiple Baseline	Word Problem Solving	Token economy and <i>Solveit!</i> Strategy	On-task behavior and problems answered correctly increased
Iseman & Naglieri (2011)	N= 29, Grade 5-8, students with ADHD	Private, specialized school	Group Experimental	Procedural	Structured planning facilitation which included goals, starting place, overall plan, specific strategies, and noticing patterns in worksheets	<i>Effect size = 0.85</i> ; Students in the experimental group scored more problems correctly on worksheets and the WIAT II numerical operations subtest

Note. LD = learning disability; LA= low achieving; AA= Average achieving; G= Gifted